# Chapter 9

# Energy-Efficient Comfort Conditioning Equipment

| Recommendations | First Cost | % Potential Savings | |
|---|---|---|---|
| | | Cooling | Heating |
| 1. Choose air conditioners with SEERs of 12 or higher with sensible heat fractions (SHF) less than 0.8; consider multispeed compressors. | M | 20-40 | — |
| 2. Properly size the air conditioner. | R | 0-10 | — |
| 3. Shade the compressor/condensing unit. | N | 0-5 | — |
| 4. Choose the best heating system for your location. | S/M | | 0-60 |
| 5. Use a multispeed blower to maintain comfort. | S | — | — |
| 6. Locate air handler and duct system in conditioned space. | S/M | 10-15 | 10-15 |
| 7. Install and seal the air handler and duct system properly. | S | 10-25 | 10-25 |
| 8. Create zoned HVAC system. | M | 0-15 | 0-15 |
| 9. Choose an appropriate thermostat and thermostat location. | S | 0-5 | 0-5 |
| 10. Install timers on kitchen and bath exhaust fans. | S | 5 | — |
| 11. Install ceiling fans. | M | 5-30 | — |
| 12. Install whole house fans. | S/M | 5-15 | — |
| 13. Seal fan penetrations. | N | 0-5 | 0-5 |
| Maximum Combined Total | H | 65 | 60 |

Cost Codes:
R = reduced
N = negligible
S = small ($<$\$0.25/ft$^2$ of floor area)
M = medium ($>$\$0.25 and $<$\$1.00/ft$^2$ of floor area)
H = high ($>$\$1.00/ft$^2$ of floor area)

# Marketing Comfort Conditioning Equipment

"Come on in – it's 20 degrees cooler inside!"

Not too many years ago, banners worded like this were commonly used outside movie theaters to entice people to come in. Many people chose to spend summer afternoons in theaters for the air-conditioned comfort as much as for the featured movies.

Times have changed greatly, and air conditioning is now a part of just about every Floridian's lifestyle. And because energy use for home cooling ranges from 25% of the annual energy bill in North Florida to nearly 50% in the southern part of the state, an efficient system can significantly lower a home owner's utility bills. An efficient air conditioning system is a major selling point in marketing Florida homes.

To promote energy-efficient equipment selected for your homes, you need to explain to your clients how much they will save on their power bills. Prepare a sheet with a definition of SEER (see p. 9-3), and list the values for the units you have chosen.

Next, show your clients how much money an efficient unit will save them. The following chart shows dollar savings associated with installing efficient units (assuming a 3 ton air conditioner, 2100 annual cooling hours, and an energy cost of $0.09 per kwh).

| New SEER | Existing SEER 10.0 | 10.5 | 11.0 | 11.5 | 12.0 | 12.5 | 13.0 | 13.5 | 14.0 | 14.5 | 15.0 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 15.0 | 227 | 194 | 165 | 138 | 113 | 91 | 70 | 50 | 32 | 16 | 0 |
| 14.5 | 211 | 179 | 149 | 122 | 98 | 75 | 54 | 35 | 17 | 0 | |
| 14.0 | 194 | 162 | 133 | 106 | 81 | 58 | 37 | 18 | 0 | | |
| 13.5 | 176 | 144 | 115 | 88 | 63 | 40 | 19 | 0 | | | |
| 13.0 | 157 | 125 | 95 | 68 | 44 | 21 | 0 | | | | |
| 12.5 | 136 | 104 | 74 | 47 | 23 | 0 | | | | | |
| 12.0 | 113 | 81 | 52 | 25 | 0 | | | | | | |
| 11.5 | 89 | 56 | 27 | 0 | | | | | | | |
| 11.0 | 62 | 29 | 0 | | | | | | | | |
| 10.5 | 32 | 0 | | | | | | | | | |
| 10.0 | 0 | | | | | | | | | | |

**Compare SEER values along top of chart with SEER values at left to find annual energy savings in dollars by using units with higher SEERS. For example, choosing a unit with SEER = 13 instead of 10 would save $157/year (savings are for a 3 ton A/C, 2100 annual cooling hours at $0.09 per kwh).**

An important part of marketing efficient cooling and heating equipment is assuring the home buyer that the equipment has been sized properly. Too large a system will do a poor job of dehumidifying the home and will cost more to purchase and operate. Too small a system will not do an adequate cooling job. Show the home buyers the actual calculations or other guidelines you have used to determine the best system size.

Explain to your clients that because you will be properly locating and sealing the air handler and ductwork, they will save up to 25% on their cooling and heating bills over typical new construction.

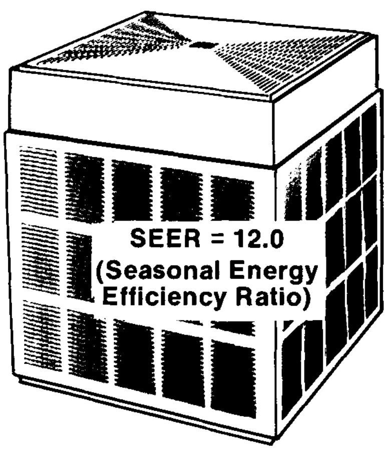
The best way to market fans is to use the most effective and attractive products in your office, model homes, or other areas where you meet with clients. Give clients who may be unfamiliar with whole house, exhaust, and ceiling fans the opportunity to appreciate how effective they are by demonstrating their use.

Ceiling fans increase comfort by making people feel cooler. They can be effective when ventilating or air conditioning. If you do not install ceiling fans in all the major rooms, at least consider pre-wiring rooms for them. Making it easier for home owners to add fans at a later time is a strong selling point in marketing your houses. Point out to prospective buyers that they should be able to install their own ceiling fans fairly easily, but that putting in the wiring after the house is built can be tricky and, if done by an electrician, expensive.

## 1. Select efficient air conditioners

While all the energy-conserving strategies discussed in this book affect both comfort and electricity consumption, selection of an efficient air conditioner with the right characteristics is the number one factor in reducing cooling bills.

Air conditioners are rated by their Seasonal Energy Efficiency Ratio (SEER). The higher the SEER rating of the unit, the greater the efficiency. A minimum SEER of 10.0 for central air conditioners is required by the National Appliance Efficiency Standard which went into effect in January of 1992. A unit rated at SEER 12, for example (the minimum we recommend for today's Florida homes), will be 20% more efficient than one rated at SEER 10.




**Choose efficient air conditioners that have SEERs of 12 or greater.**

You can obtain a copy of the latest ratings of energy-efficient cooling and heating equipment from the Air-Conditioning Refrigeration Institute (see "For further information" at the end of this chapter).

Keep in mind that the SEER rating tells you nothing about the unit's dehumidification ability. This is expressed by its sensible heat fraction (SHF); **the lower the SHF, the better the dehumidification ability**. The suggested maximum SHF is 0.80. Units with a higher rating may not adequately dehumidify some Florida homes, allowing mildew to grow and causing physical discomfort. Some air conditioners with high SEERs have high SHFs, so there is a trade-off between cooling efficiency and dehumidification. Compare manufacturers' engineering data to determine the SHF. Make sure to check the data for the combination of compressor *and evaporator* unit you will be using. The air flow rate is also important. Faster flow rates reduce air conditioner run times but also increase the SHF. Multispeed blowers are a good solution (see Section 5 of this chapter). **In general, search for units with an SEER of 12 or greater and SHF less than 0.80.**

**Key Concepts for Heating/Cooling Systems**

**SEER** - Seasonal Energy Efficiency Ratio - The seasonal weighted performance of an air conditioner based on the cooling accomplished (in Btu's of energy) divided by the electricity consumed (in kW).

$$SEER = \frac{\text{Btu cooling provided}}{\text{kW consumed}}$$

**SHF** - Sensible Heat Fraction is the fraction of a given cooling system's total capacity that is being used to remove sensible heat. One minus the SHF is the fraction that is used to remove moisture (latent heat).

**CFM** - Cubic Feet per Minute - This abbreviation is used to describe the rate of air flow for a given system.

**COP** - The Coefficient of Performance gives the energy output/energy input ratio for a given system at a given operating point.

**HSPF** - Heating Season Performance Factor - Rating used to describe the seasonal performance of heat pump heating systems.

**AFUE** - Annual Fuel Utilization Efficiency - Rating used to describe the efficiencies of gas units.

There are computer programs and calculations that can help you decide on the best combination of SEER and SHF for the home you are building. Check with your local utility company or air-conditioning suppliers for assistance in selecting programs and sizing guidelines.

**Multispeed compressors.** Some manufacturers have released air-conditioning units with two-speed or multispeed compressors. Depending on the operating conditions, a two-speed unit will run in either an efficient low-speed mode or a more powerful high-speed mode. A multispeed or variable-speed unit will change to any one of a number of speeds based on the operating conditions. These units can be sized to meet a peak party load without sacrificing energy savings and moisture removal during most of the cooling season. The overall efficiency of these units can be compared by their SEER rating. Using multispeed blowers with multispeed compressors will provide significant flexibility.

**Sensible Heat Fraction (SHF)** — To determine an air conditioner's dehumidification ability you have to find the sensible heat fraction for the compressor, evaporator and air flow rate you expect to use. Ask your dealer for the *manufacturer's engineering data.* Some manufacturers give the SHF value (which is always between 0 and 1) as shown below (0.71). Others give the sensible capacity as shown at right. Divide the sensible capacity at standard conditions (95 outdoor dry bulb, 67 indoor wet bulb, 80 indoor dry bulb) by the total capacity. For the example at right the SHF is 17.3/22.8 = 0.76. The lower the SHF, the more moisture the air conditioner will remove.

Compressor unit, evaporator unit, CFM rating

| O.D. D.B. | I.D. W.B. | TOTAL CAP. | SENS. CAP. AT ENTERING D.B. TEMP. 72 | 76 | 80 |
|---|---|---|---|---|---|
| 85 | 59 | 20.9 | 18.1 | 21.1 | 22.1 |
| | 63 | 22.5 | 14.9 | 18.1 | 21.3 |
| | 67 | 24.1 | 11.4 | 14.6 | 17.8 |
| | 71 | 25.8 | 7.8 | 11.1 | 14.3 |
| 95 | 59 | 19.7 | 17.6 | 20.1 | 21.1 |
| | 63 | 21.2 | 14.4 | 17.6 | 20.8 |
| | 67 | 22.8 | 10.9 | 14.1 | 17.3 |
| | 71 | 24.4 | 7.4 | 10.6 | 13.8 |
| 105 | 59 | 18.4 | 17.0 | 19.0 | 19.9 |
| | 63 | 19.8 | 13.8 | 17.0 | 19.9 |
| | 67 | 21.3 | 10.3 | 13.6 | 16.8 |
| | 71 | 22.8 | 6.8 | 10.0 | 13.2 |

Compressor unit, evaporator unit

| Enter. Wet Bulb (°F) | Total Air Vol. (cfm) | Outdoor Air Temperature Entering Condenser Coil (°F): 85 — Total Cool Cap. (Btuh) | Comp. Motor Watts Input | Sensible To Total Ratio (S/T) Dry Bulb (°F) 76 | 80 | 84 | 95 — Total Cool Cap. (Btuh) | Comp. Motor Watts Input | Sensible To Total Ratio (S/T) Dry Bulb (°F) 76 | 80 | 84 | 105 — Total Cool Cap. (Btuh) | Comp. Motor Watts Input | Sensible To Total Ratio (S/T) Dry Bulb (°F) 76 | 80 | 84 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 63 | 1000 | 36,300 | 2850 | .70 | .80 | .90 | 34,000 | 3000 | .72 | .83 | .93 | 31,800 | 3160 | .74 | .85 | .96 |
| | 1250 | 37,900 | 2890 | .75 | .86 | .97 | 35,400 | 3050 | .77 | .89 | 1.00 | 33,200 | 3210 | .80 | .93 | 1.00 |
| | 1500 | 39,100 | 2920 | .79 | .92 | 1.00 | 36,400 | 3080 | .82 | .95 | 1.00 | 34,400 | 3260 | .85 | .99 | 1.00 |
| 67 | 1000 | 39,300 | 2930 | .55 | .65 | .74 | 36,800 | 3090 | .56 | .66 | .76 | 34,400 | 3260 | .58 | .68 | .79 |
| | 1250 | 40,600 | 2970 | .58 | .69 | .80 | 38,000 | 3140 | .60 | .71 | .83 | 35,500 | 3300 | .61 | .74 | .86 |
| | 1500 | 41,600 | 3000 | .61 | .73 | .85 | 38,900 | 3160 | .63 | .76 | .89 | 36,300 | 3330 | .64 | .79 | .92 |
| 71 | 1000 | 42,200 | 3010 | .42 | .51 | .60 | 39,700 | 3190 | .43 | .52 | .61 | 37,200 | 3360 | .43 | .53 | .63 |
| | 1250 | 43,700 | 3050 | .43 | .54 | .64 | 40,900 | 3230 | .44 | .55 | .66 | 30,300 | 3400 | .45 | .56 | .68 |
| | 1500 | 44,600 | 3080 | .45 | .56 | .68 | 41,800 | 3250 | .45 | .58 | .70 | 39,000 | 3430 | .46 | .60 | .73 |

## Basic Air Conditioning System Components and Terms

ADS - Air Distribution System- All indoor components of a heating/cooling system including the air handler, plenums, and supply and return ducts.

AIR HANDLER - Indoor component of a heating/cooling system comprised of a rectangular metal enclosure which houses the blower, evaporator, and in many cases a heater.

BLOWER - Fan mounted within the air handler used to drive air across the evaporator and through the air distribution system.

COMPRESSOR - Central outdoor component of a cooling system used to compress and drive refrigerant through the system.

CONDENSER - Heat exchanger which condenses hot, gaseous refrigerant, typically transferring the heat to the surrounding air.

DUCT - A passageway through which air moves, typically made of metal, fiberglass board with sheathing, or flexible tubing.

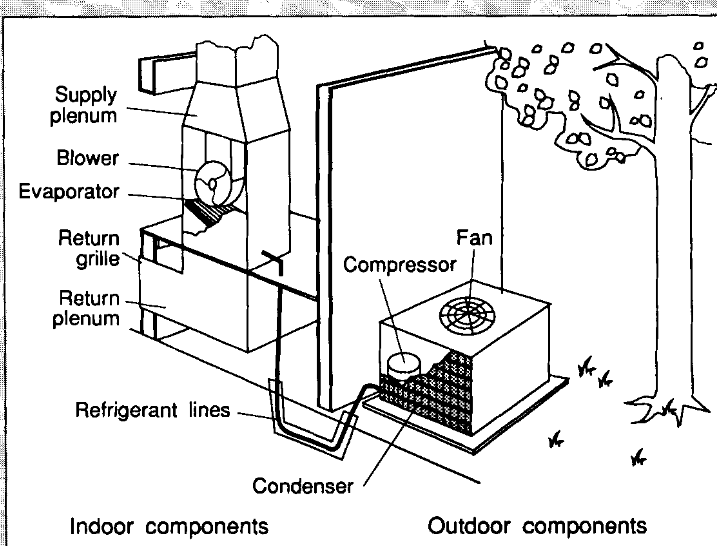
EVAPORATOR - Heat exchanger which vaporizes cold liquid refrigerant, typically absorbing heat from the surrounding air.

PLENUM - Enclosure on either side of the air handler through which air moves. Supply plenums are areas in which air is deposited before entering the supply ducts; return plenums are areas in which air is collected before entering the air handler.

RETURN AIR - House air drawn back to the air handler to be conditioned. The air is drawn either through open areas of the house (i.e. hallways) or through separate return ducts.

SUPPLY AIR - Conditioned air distributed throughout the house through supply ducts.

TONNAGE - Measure of the amount of cooling an air conditioner or heat pump is capable of; 1 ton = 12,000 Btu per hour.

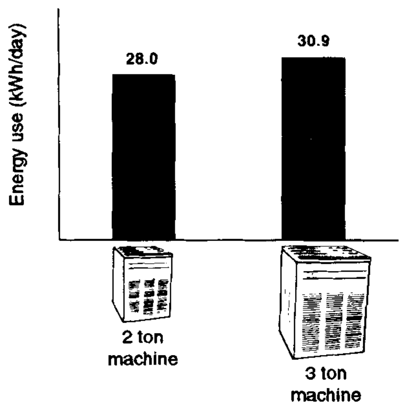



**Air conditioning system components (heat pump in cooling mode).**

## 2. Properly size the air conditioner

Accurate sizing is an important part of obtaining the most energy-efficient air conditioner. Systems should be sized to meet peak heating and cooling requirements. Peak heating generally is needed during early morning hours in winter; peak cooling is needed during the afternoon in summer.

Air conditioners are sized by the "ton." One ton is equal to 12,000 Btu of cooling per hour. When choosing the systems for your houses, keep in mind that bigger is not necessarily better. In fact, oversizing a residential air conditioner by 50% has been estimated to cause a 10% increase in energy use.




Source: FSEC analysis, unpublished, 1990

**50% oversizing of a residential air conditioning system causes 10% increase in energy consumption**

In the past, many builders have relied on general rules-of-thumb in sizing systems. Some builders have roughly estimated the needed size, then installed a slightly larger unit to make sure it was adequate. But as houses become more energy-efficient, with less air infiltration and more energy-conserving features, these old guidelines grow obsolete.

Air conditioning sizing should never be based merely on an estimate. Sizing methods are available from professional organizations such as ASHRAE and the Air Conditioning Contractors of American (ACCA). The most popular method is the ACCA's "Manual J" load calculation (required by FHA and VA). All these methods find home cooling and heating loads based on the area, orientation, and insulation of walls, windows, and doors and the area and type of ceiling and floor. They also account for load due to infiltration, people, and appliances. Many utilities will assist you in making the calculations.

**System Charging**

Air conditioner efficiencies are greatly affected by the state of refrigerant charge. A system that is undercharged by 10% may have a drop in efficiency of 20%. Over-charging can lead to refrigerant and oil flooding – causing over-heating of bearings and motor, and slugging or a reduced system life.

Unfortunately, system charging is not always done correctly, mainly because it can be time-consuming, taking a trained technician close to an hour. A device has recently been introduced that should lead to more accurate charging. The device, called an accumulator charger, is installed in the suction line external to the condensing unit and provides a visual means of charging systems. Results from field tests in Texas indicated the device does keep the system properly charged, and reduces maintenance calls.

The few minutes spent calculating the numbers and sizing the air conditioner to match may result in:

- Saving hundreds of dollars on initial cost of the system and ducting.
- Better air conditioner run time resulting in better humidity control, making it unnecessary for home owners to set thermostats lower to remove moisture.

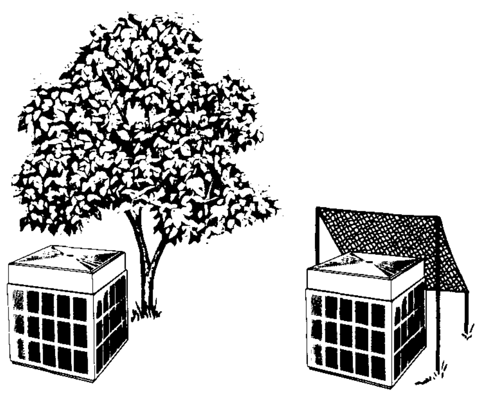
The disadvantages of not over-sizing are:

- The house will not cool down as fast when the system is first turned on.
- The unit may have trouble meeting the load for a large party held during a summer afternoon, requiring home owners to precool before the party begins.

The best compromise would be to use a multispeed blower, a multispeed compressor, or preferably both (see sections 1 and 5).

## 3. Shade the compressor/ condensing unit

Shading the compressor unit helps keep the condensing coil inside cooler and running more efficiently. One way to shade the unit is to install it on the north side of the house, in an area where it will receive little direct solar radiation in the summer. Avoid unshaded locations on the west side of the house because the sun will strike the unit when it needs to work the most in the late afternoon and evening. The condensor can also be effectively shaded with a shade tree, but be sure not to block airflow to and from the unit. Another shading method is to use a screen similar to the sun screens used for windows. Support the screen as shown below.



**A tree or screen can be used to shade the compressor.**

## 4. Choose the best heating system

Even though cooling is a greater concern of Florida home owners, annual heating costs still account for 18% of the total energy used to condition homes. The most common heating systems in Florida are electric strip, natural gas, oil and heat pumps.

**Electric resistance or strip heat.** First used in the state because of its low initial cost, electric resistance heating is more expensive to operate than alternative systems. It has a Coefficient of Performance (COP) of 1.0. The more efficient heat pumps, by comparison, typically have a COP of 2.0 to 3.5. Although most new homes with this type of heating use an air handler equipped with an electric resistance heater, baseboard heaters located in each room of the house are preferred. They offer the benefits of zoning and no duct losses.

**Natural gas furnaces.** Generally costing only one-third as much to operate as electric resistance heating, these systems offer benefits to home owners throughout the state. Gas units will cost about as much to operate as heat pumps, but offer two distinct advantages over heat pumps:

- Their efficiency does not decrease with colder weather.
- They have reduced maintenance costs (heat pumps require proper charging).

Look for sealed combustion systems which draw combustion air directly from and exhaust flue gases directly to the outdoors. These units are generally more efficient than non-sealed units and greatly reduce the possibility of dangerous combustion gases getting into the house through back-drafting or leaks.

Recent technological developments have resulted in substantial increases in furnace efficiency. The AFUE (Annual Fuel Utilization Efficiency) rating can be used to compare the efficiency of different models. Typical AFUE ratings for presently available furnaces and boilers are 0.78 to 0.85, meaning that 78 to 85% of the combustion heat is used effectively. The most efficient units achieve ratings of 0.90 or higher. Condensing furnaces that have an AFUE rating of 0.90 or greater need no chimney. Plastic pipe is adequate, thereby reducing the net cost of a high-efficiency unit. Typical annual heating bills for gas furnaces are shown below.

**Annual Cost of Gas Heating***

| AREA | AFUE 0.80 | AFUE 0.93 |
|---|---|---|
| North Florida | $117 | $102 |
| Central Florida | 83 | 72 |
| South Florida | 25 | 22 |

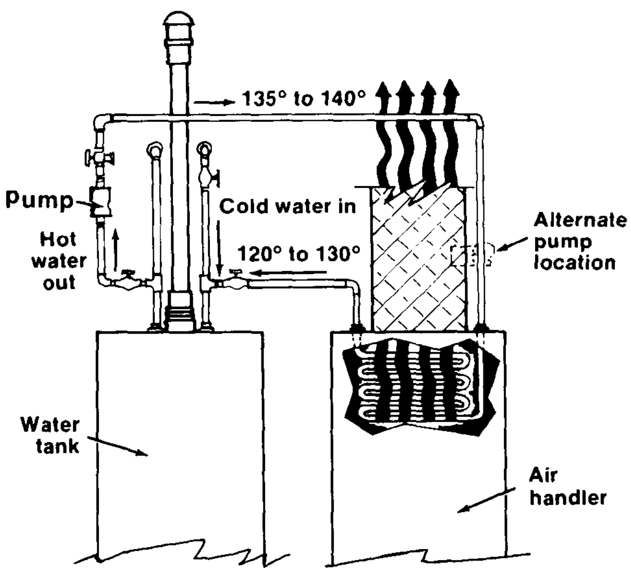
* Gas priced at $0.60/therm.
Table source: City of Tallahassee Energy Services.

Highly efficient units cost only a few hundred dollars more than standard systems, and can repay the investment where heating requirements are significant. **Choose a system with electronic ignition to eliminate the need for a pilot light and its continuous use of gas.**

If you decide on natural gas, also consider using it for heating water, cooking, drying clothes, and fueling a barbecue grill.

**Hydronic gas systems.** An excellent method of providing gas space heating is the use of a hydronic forced-air gas system. The system takes water heated by a gas water heater and circulates it through a coil in the air handler. It offers the following advantages over a conventional gas furnace:

- There is only one source of combustion.
- The air handler can be located in the conditioned space.
- There is less heat loss.




**Forced-air hydronic systems use hot water to supply heat.**

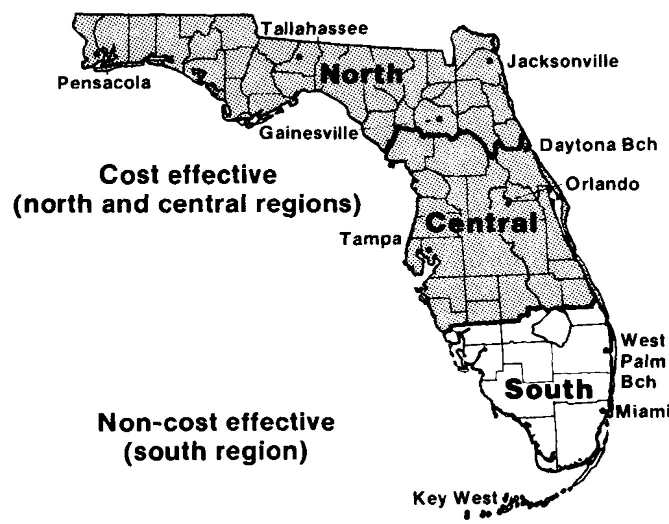
A number of manufacturers of these systems offer matched components (air handler and water heater). Consult with a gas utility representative or a dealer for sizing guidelines.

**LP or propane.** With propane systems you get the benefits of gas heating where natural gas is not available. Propane gas is readily available and is recommended over electric resistance heating, but may cost more to operate than a heat pump.

**Oil heat.** Oil furnaces were installed in many Florida homes 15 to 30 years ago. They are rarely used these days. Fuel oil prices fluctuate more than other heat sources. During times of oil surplus (the 1980s), oil heating can be the least expensive form of heating. If you do install an oil heater, you need an above-ground location for the 100- to 200-gallon oil tank. Burying tanks underground is no longer recommended due to the difficulty in detecting leaks and the environmental contamination associated with leaking underground tanks.

**Heat pumps.** Another option growing in popularity is to combine air conditioning and heating with an electric heat pump. A heat pump is basically an air conditioner that can be run in reverse in the winter to heat by switching the use of the evaporator and condenser coils. Naturally, a heat pump will cost more than an air conditioner alone so its cost effectiveness is dependent on the amount of heating required in the winter. A heat pump is generally an energy efficient choice in central and northern Florida, especially if it is to be used in the place of electric resistance heating.

The efficiency of a heat pump is measured by a units Heating Season Performance Factor (HSPF). Heat pump HSPFs generally average 7.0 to 9.0. An HSPF of 9.4 or higher is possible.




**In North and Central Florida heat pumps are a cost-effective choice for electric space heating.**

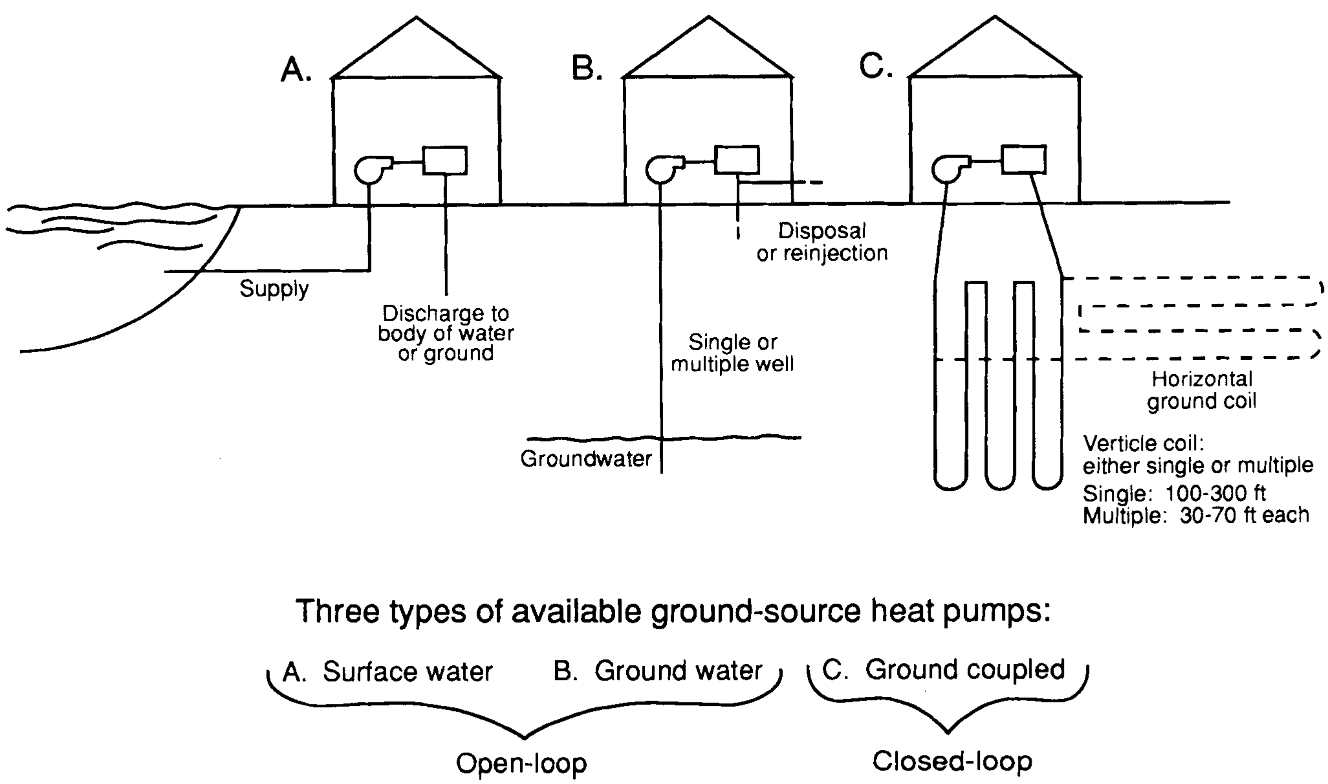
There are two main types of heat pumps, air-to-air and ground-source. Both operate on the same principle but use different cooling and heating sources.

By far the most widely used, the air-to-air heat pump uses outside air flowing across the outdoor coil as its heating and cooling source. As a result, the capacity of the system is dependent on the outdoor air temperature. In the winter, as the outdoor temperatures decrease, the system capacity and energy efficiency decrease as well. At some point the system is not able to deliver enough heat to maintain home comfort and an auxiliary heat source such as an electric strip must be used in conjunction with the heat pump.

A ground-source heat pump is either directly or indirectly connected to the ground and/or water table which the system uses to exchange heat. These systems benefit from the fact that Florida's ground water temperatures stay fairly constant throughout the year, mostly eliminating the problem of decreased performance during outdoor air temperature extremes. Cost effectiveness of the ground-source systems is dependent on many factors including location, soil type, water table height, and type of system chosen.

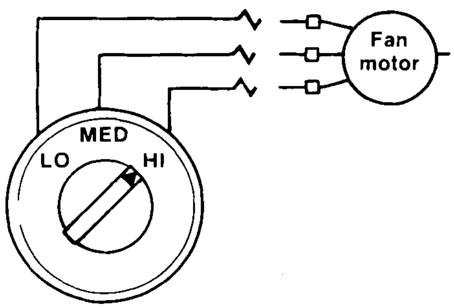
The figure below shows the types of ground-source heat pumps available today. The open-loop system circulates water from either a body of water or the water table, discharging it back to its source or other point. Water disposal is strictly regulated however, so the appropriate authorities must be contacted before installing this type of system. A closed-loop heat pump circulates a working fluid through long buried pipe using the earth as a heat source and heat sink. The pipe can be buried either horizontally or vertically. Using a closed loop eliminates the need for supply water and water discharge.

One problem sometimes encountered by heat pump owners is discomfort from semi-warm air (80°-90°F) blowing out of the ducts (oil or gas furnaces generate much hotter air). This inadequacy can be partly remedied by having well-insulated, well-sealed ductwork so that the air does not cool down en route from the air handler to the room. The cooling effect can also be reduced by using a multispeed blower set at a low speed (see next section) and installing diffusers at the grilles to control the direction of the air flow.



## 5. Use a multispeed blower

Select an air handler unit with a multispeed blower and connect it in a manner that permits the home owner to change its speed. The unit will perform most efficiently if the blower is on high speed, but will remove more moisture from the air on a lower speed. This mode can be used during humid nights or to remove moisture from typically wet areas such as a room with a jacuzzi or a large number of plants. Any qualified HVAC installer or electrician should be able to install a simple switch the home owner can control. At least one manufacturer offers a blower hooked up to a humidistat to perform this function automatically.



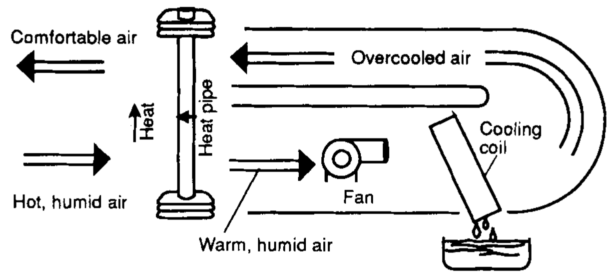

**Use multispeed blowers that home owners can control with a switch.**

One alternative to a multispeed blower for removing moisture is a heat pipe (offered by at least one air conditioning manufacturer). The heat pipe performs the function of a heat exchanger, precooling return air with cool supply air. The compressor thus uses more of its cooling capability to dehumidify. Remember though, a heat pipe should only be considered where higher than usual moisture loads are anticipated. Even though heat pipes are very efficient, their use will increase energy consumption.

Discourage the home buyer's use of a separate dehumidifier for humidity control. Unless custom built to expel the compressor heat outdoors, dehumidifiers introduce heat into the house which must be removed by the air conditioner, causing extra power usage.

## 6. Locate air handler and duct system in conditioned space

Florida home designs usually show space for the air handler and ducts in unconditioned



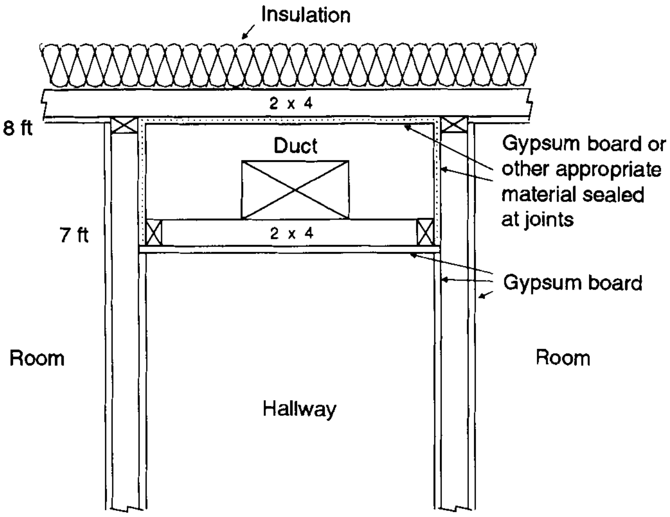

**A heat pipe precools return air with overcooled supply air to provide more moisture removal.**

space. But because duct systems tend to leak air, they can be a major source of infiltration and energy loss and should be installed in conditioned areas instead. Especially try to avoid attic and crawl space locations for the air handler because service and maintenance is difficult in these areas and any condensate problems in an attic could damage the ceiling. A **properly** installed air handler and ductwork system in conditioned areas can reduce total heating and cooling energy use by up to 25% in new homes. The main task you face is finding the needed area.

**Locating the air handler.** You should design your home to locate the air handler in conditioned space. If your design has not provided this space consider using a corner of a bedroom closet adjacent to a hallway. See the house plan examples in Chapter 4 for ideas.

**Locating the ducts.** While aesthetics must be considered, it is still possible to locate ducts in the conditioned space. Exposed, insulated ductwork has become popular in many restaurants and some residences, but most home owners will probably prefer to conceal ductwork by covering it with drywall. Keep in mind that you will gain a significant energy code credit by locating ductwork within conditioned areas. You will still want to insulate all ducts. In some home designs, you can install ductwork above 7-foot hallways. The space above the kitchen cabinets can also be used to conceal ductwork. Ducts can be run along the perimeter of a room, or across the center of a great room with a high ceiling to suggest separate living and dining functions.

Multistory houses make it easy to place all ductwork in conditioned spaces by using well-sealed ductwork between floors. You can eliminate the duct in the attic and use grilles in the floor or wall spaces to supply air to the

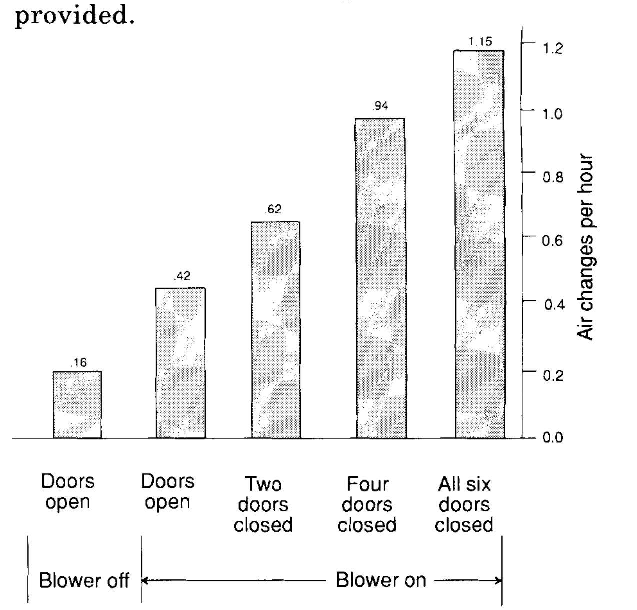



**Isolate ductwork from unconditioned space with a continuous air and heat barrier.**

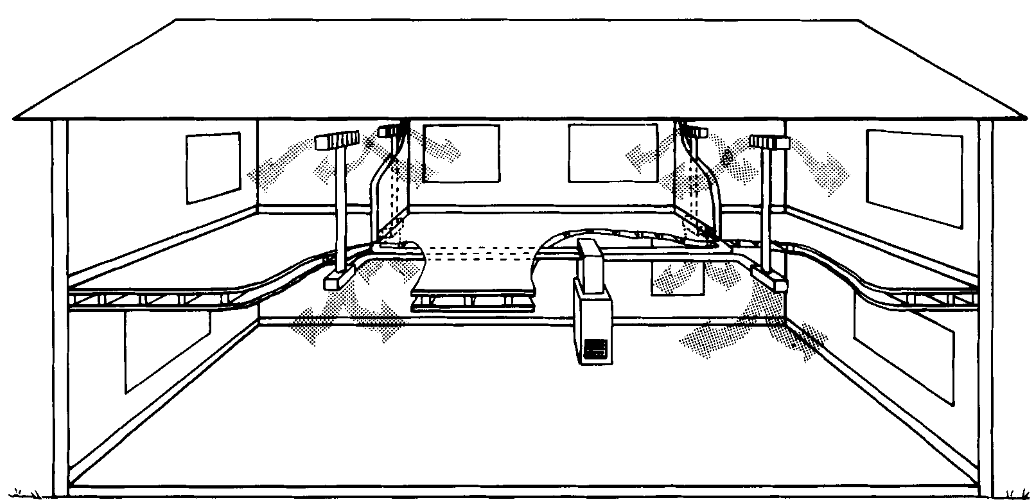
second floor. Typically, about half of the total duct length will be eliminated, saving on installation costs.

Still, the best solution from an energy standpoint is to use "exposed" ducts in conditioned space, which guarantees that any losses go to conditioned areas. Ducts installed in conditioned spaces behind drywall need to be properly isolated from unconditioned areas or significant losses may result, defeating the purpose of the installation. This is especially true because once the drywall is sealed and painted, leaks may go unnoticed and be difficult and expensive to repair (see Section 7 on sealing the duct system).

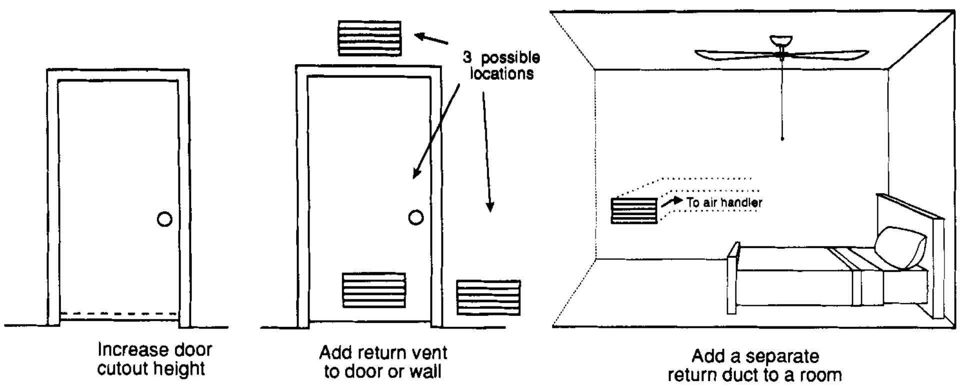
**Providing a return system.** A properly designed duct system will also include provisions to assure ample return air. Many builders use a "free air return system" in which the rooms and hallways of the house serve as the return duct. Not having to use a separate return duct gives an immediate savings during construction and is preferred to extra returns in which ducts run through attic space. Oftentimes, however, adequate provisions for the return air are not made. The following graph shows the significant increase in infiltration (the unintentional movement of outdoor air into the house) that closing interior doors can cause if an ample return is not provided.




**Closing interior doors can significantly increase air infiltration.**



**Place ducts between floors in two-story homes.**




**Provide adequate air return capacity for when doors are closed.**

Infiltration is increased because air supplied to rooms cannot easily return so it exits though cracks in windows, walls, floors and ceilings. At the same time, the room containing the return is not receiving air from the other rooms so it pulls air in from the attic or outdoors. There can be a significant energy penalty because of this infiltration. Adequate return air can be provided in a number of ways:

- Door cutaway heights can be increased.
- Grilles can be put in the door or a wall of the room.
- A separate return can be installed in rooms in which the door is often kept closed (i.e., a master suite) if grilles to a common area or hallway are not desired.

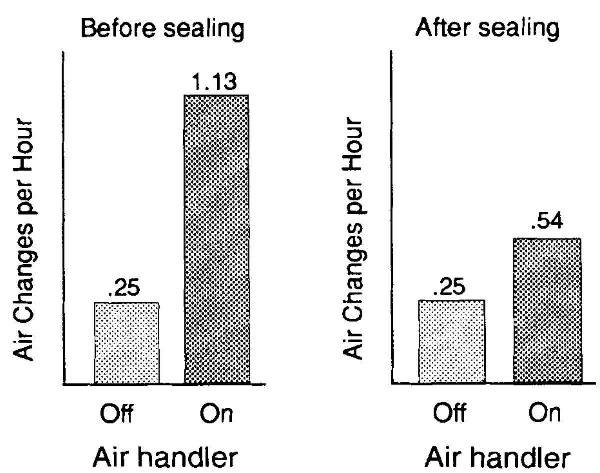
No matter which solution is chosen, it is important that the work is properly sealed (see next section).

If a door cutaway, door grille or wall grille is used, the area of the air passageway should be at least two times the total supply duct area. If a separate return duct is used, its area should be at least the same as that of the supply duct terminating in the room.

Finally, note that return plenum pressures are also influenced by the size of the grille and filter used in them. If the grille/filter area is too small, higher plenum pressures will result causing increased losses through any leaks, so the grille and filter should be oversized whenever possible.

## 7. Install and seal the air handler and duct system properly

Proper duct system installation and sealing can greatly reduce energy use. As mentioned earlier, duct system losses account for about 25% of heating and cooling loads in Florida homes. This is because although air handler and duct system leak area is usually a small part of the total leak area of a house (estimated to be 10-15%), pressures are much greater in these systems. As a result, the leaks greatly increase house infiltration, commonly by as much as 100 to over 400%. The graph below shows the results of a study done on 25 homes to find the effects of duct system leaks on house infiltration.




**Sealing the duct system can dramatically decrease house infiltration.**

**Types of ducts.** Three basic types of ducts are used in Florida homes: rigid fiberglass ductboard, round metal duct, and flexible plastic duct. Each offers different benefits.

Fiberglass ductboard produces a relatively quiet system than can have very low air leakage if correctly sealed. However, it costs more than the other types of ducting, and a high degree of skill is needed to properly install it, especially in making the L-shaped turns to decrease pressure losses. Labor costs can be reduced by using machine-fabricated segments.

The smoothness of round metal ductwork minimizes air pressure loss and allows the use of smaller diameter duct. Because the surface is galvanized and zinc-coated, mildew or fungus cannot grow inside. It is important that the joints be tightly sealed during installation to prevent leaks. This type of system is more expensive to install than flexible plastic duct.

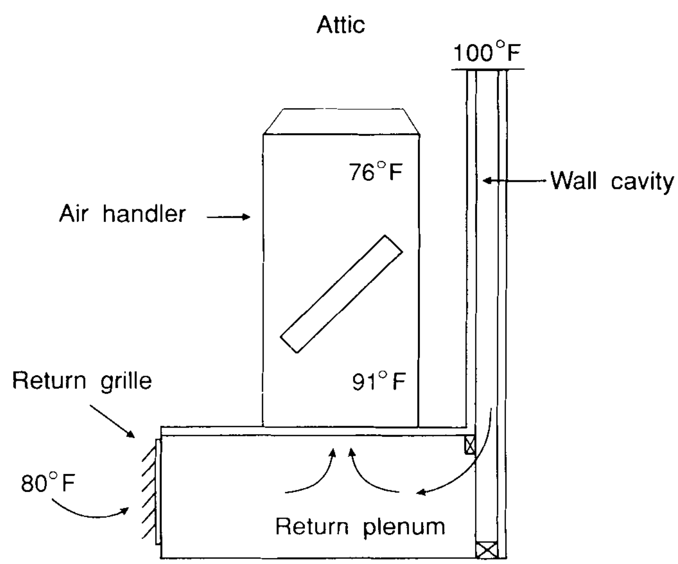
Commonly called flex-duct, flexible plastic duct is pre-constructed with two thin plastic sleeves separated by fiberglass insulation. It can be made fairly airtight if care is taken to overcome its tendency to leak at joints. The material is susceptible to damage from inadequate support, abrasion, and ozone generated by the air-handler fan motor. However, its low cost and ease of installation have made it popular with many builders.

Because ducts carry all of the air-conditioned and heated air through the house but have fairly low R-values, you may wish to add more insulation to whichever system you choose. Insulation wraps are available for metal ducts, higher-insulation ductboard can be used if the fiberglass type is selected, and a mound of blown insulation can cover any type of rigid duct which is supported near the attic floor.

It shows that sealing the ducts caused a 52% reduction in house infiltration when the air handler was on. This reduction corresponded to an 18% cooling energy savings.

In order for duct systems to work efficiently, it is necessary to achieve a continuous air barrier – an uninterrupted partition between air in the duct and the air surrounding it. Almost all commonly used duct materials are themselves effective air barriers. The problem is that because of seams, connections and terminations, the whole system is not usually continuous. Making a system continuous requires a good understanding of how and where duct systems leak and proper sealing methods.

**Sealing the air handler/plenums.** Fifty percent of all duct leakage is through the return plenum. Although having the air handler in conditioned space can help reduce plenum leaks, it does not guarantee a leak-free return system. In actual test cases of indoor mounted air handlers, return air leaks were found to be causing reductions in air conditioner capacity of up to 75%. In many cases, the leaks caused much of the return air to be pulled in from the attic or outdoors.

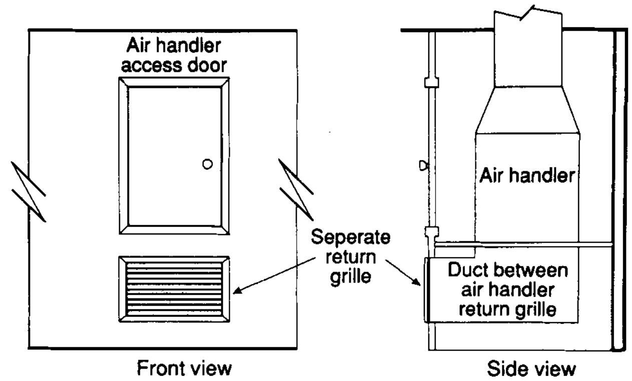



**A common problem: The air conditioner must cool 91°F air instead of 80°F air because of leaks from the attic.**

In one house, leaks from the attic were so severe that the air conditioner was not able to cool the house during daytime hours.

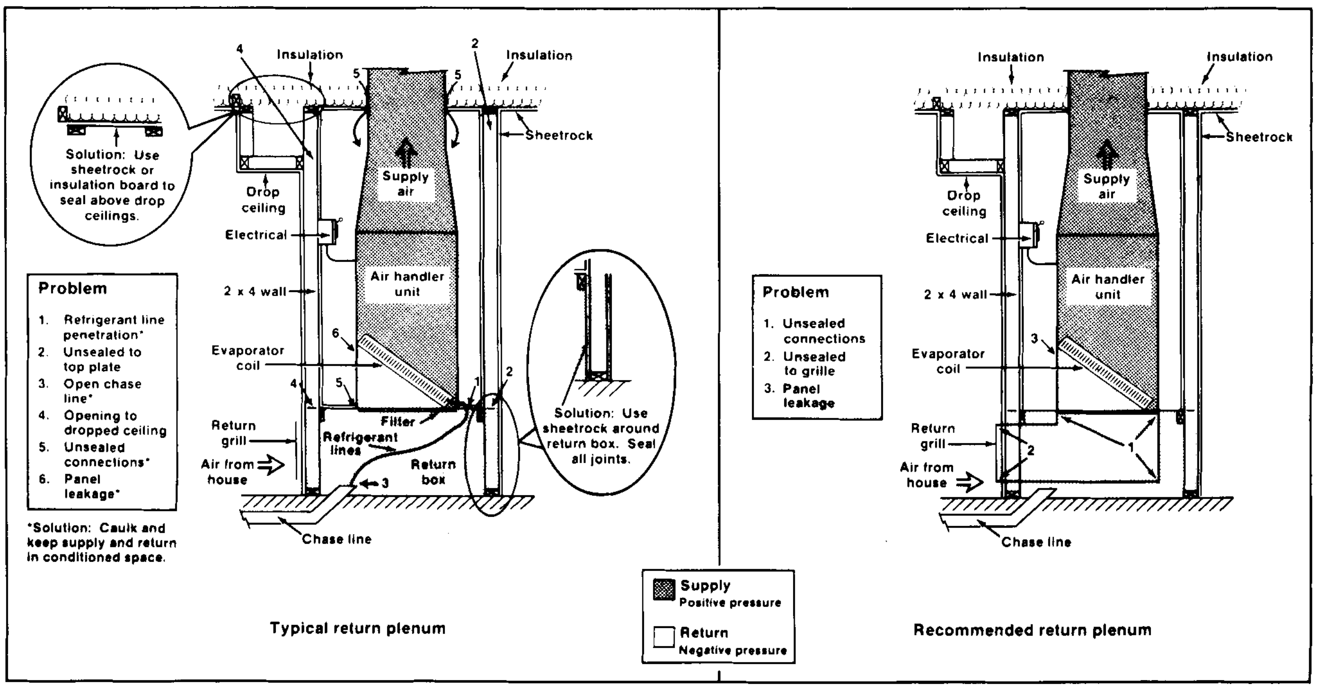
The figure below shows common air handler system leak sites. It is important to consider all these potential sites and prevent any leaks through them. Return boxes or platforms especially tend to be a major source of leaks because appearance is not important in them and so in many cases they are not fully finished and sealed. To eliminate these leaks, use sealed ducts between the grille and air handler instead. The location of the air filter can also affect return leaks. If, for example, a dirty filter is located at the grille, air flow through the return grill will be restricted and pressure inside the duct to the air handler will increase, causing increased air flow through any leaks.

A louvered door return system in which the whole air handler closet is used as the return is not recommended. Because of the large closet area involved with this type of return, there is also a large potential for leakage. Use a cut solid door for air handler access with a separate sealed return duct to the air handler.




**Use a solid door for air handler access and a separate sealed return duct from the air handler to a grille below.**

**Sealing the duct system.** No matter if the ducts are located in conditioned or unconditioned space, it is important to properly seal them. Duct leaks are most common at connections with plenums, junction boxes, boots, and registers.




**Typical leakage points in air handler systems. (Based on illustration by Natural Florida Retrofit, Inc.)**

## Combustion Safety and Air Quality

In order to properly install an air handler and ductwork, it is important to first of all understand all the possible impacts the equipment and its installation may have. The use of an air handler and duct system will affect house pressures, infiltration, and air quality. Duct systems work at high pressure (10 to 100 pascals) compared with pressures a house normally experiences (averaging less than 1 pascal) from wind or thermal stack. If these systems are not designed and sealed properly they can pressurize or depressurize rooms and leak, possibly causing:

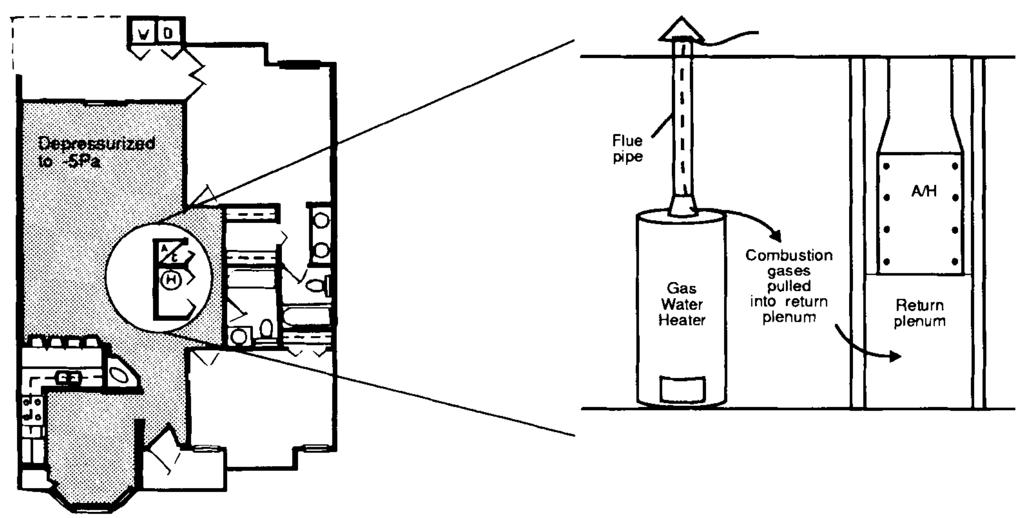
1) Backdrafting and flame-roll-out in combustion appliances if depressurization goes below -3 pascals and -12.5 pascals respectively. Backdrafting can lead to lethal levels of carbon monoxide and flame roll out can cause house fires.
2) Reduced air quality because of pollutants such as insulation from the attic or harmful vapors from chemicals stored in the garage being pulled into the air distribution system.

For example, closing interior doors in a house with insufficient return capacity may depressurize a room in which a gas water heater is located, causing the heater to backdraft and leak carbon monoxide into the house. Also note that use of an exhaust fan (clothes dryer, kitchen or bath fan, etc.) when the air handler is on can further depressurize rooms in which they are used, possibly increasing the effects listed above.

Understanding house systems interaction is the key to preventing the potential problems listed above. Achieving this understanding requires training and the proper use of diagnostic equipment, which is highly recommended but beyond the scope of this manual. In general, try to follow these guidelines:

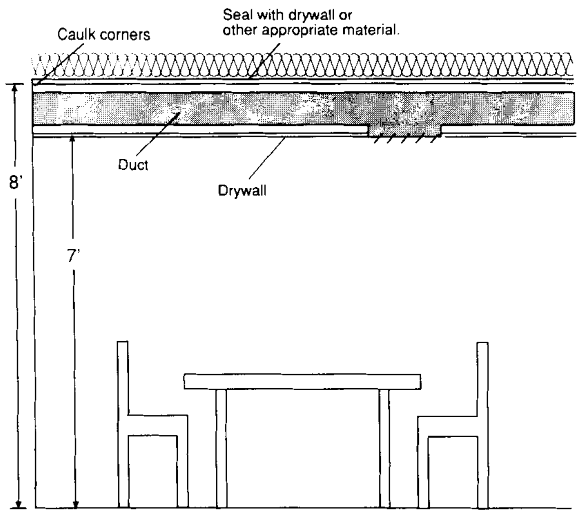
- Assure a continuous air barrier on return and supply ducts using non-toxic sealing materials.
- Allow for adequate return air flow in the house - even when interior doors are closed.
- Provide a storage area for toxic household products away from the air handler, preferably outside of the house.
- When selecting combustion appliances, choose units with sealed air intake and exhaust and install vents properly.

Research findings and instruction on duct system diagnostics are available through a Florida Solar Energy Center training program entitled "Duct Doctoring" (see "For Further Information" at the end of this chapter).




**Closing bedroom and bathroom doors with the air handler on may depressurize the main body of the house, and subsequently cause backdrafting of the gas water heater.**

Be sure to seal each joint and any other area you are not certain is airtight. Also, if ducts are located in conditioned space behind drywall, it is important that this space is completely sealed. Especially be sure to seal above 7-ft drop ceilings at the 8-ft level to preclude losses to the attic or outdoors through leaks between wall cavities or joists. For the same reason, seal along the edges and in the corners of any wall or floor cavities that ducts are run through. Seal all duct joints before the insulation materials are applied.




**Seal and insulate well at the 8 ft. level above ducts in conditioned space.**

**Proper sealing materials.** Fabric imbedded mastic, not duct tape, is recommended for all sealing. Mastic is preferred because of its mechanical strength and ability to fill gaps and retain its adhesion to surfaces. Although high quality tape can be an effective sealant if applied properly, its long term durability is questionable; experience has shown that tape seals fail much more frequently than fabric and mastic seals.

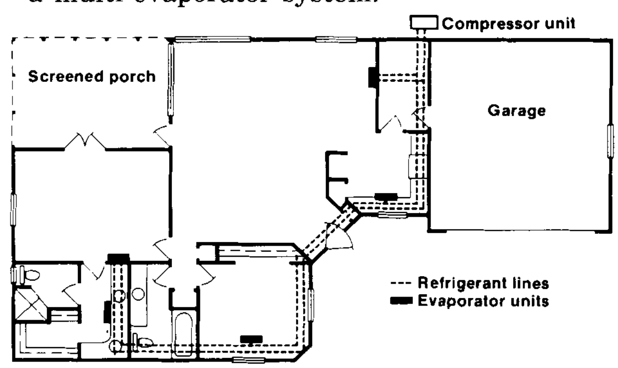
Note that the fiberglass in ductboard is not an air barrier and should not be used in making seals. Always seal to the foil liner when using this material.

## 8. Create separate zones

Home owners can save on air-conditioning and heating costs by only cooling or heating part of the house at any given time. To accomplish this, part of the home must be separated from the rest with a door or doors that close tightly. In some designs, you may want to consider providing one area that is naturally ventilated, instead of air conditioned, and heated only by a local space heater. The rest of the home can be conventionally cooled and heated and used as a retreat during the times of year when temperatures reach extremes.

Usually, however, home owners will want the option of air conditioning the entire house. To achieve the energy saving advantages of zoning, one of the following is then required:

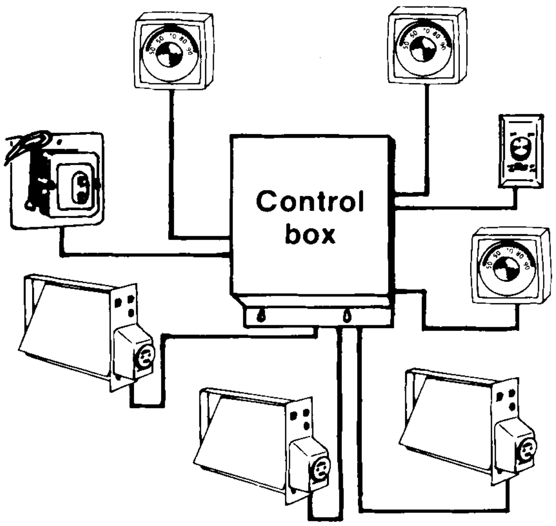
- more than one heating/cooling system
- a multizone control system
- a manually controlled damper
- a multi-evaporator system.




**A multi-evaporator system sends refrigerant to individual room conditioning units, eliminating ductwork.**

When using separate systems, one is usually chosen for the living, dining, kitchen and den areas and another for the bedrooms. In split floor plans, the master bedroom suite may be combined with the living areas and the other bedrooms can be conditioned by a separate system. With separate systems it should be easier to keep duct runs short and to place the ducts in conditioned space. Accurately size the units for each zone. Typically, a rather small (1 1/4- to 1 1/2-ton) air conditioner or heat pump can be used for the bedroom zone. For some zones, available central systems may not be small enough, so room units may be more appropriate.

Another alternative is to use one system but control the airflow to different parts of the house at different times, either manually or through a thermostat in each zone. A typical system consists of a unit with one compressor and dampers (a multizone control system) or refrigerant valves with no duct work (a multi-evaporator system) to control conditioning in specific zones.




**An automatic multizone control system has a controller, plus thermostats and dampers for each zone.**

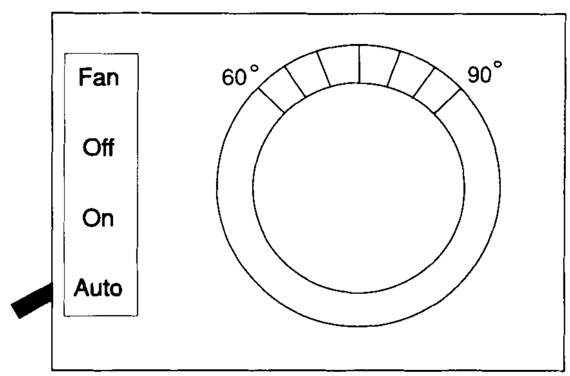
In two-story homes with ductwork placed between floors, a single system can be easy to control and less expensive than two separate heating/cooling systems. It can also be a solution to the distribution problem of rising hot air keeping the upstairs too hot and the downstairs too cold. Through the use of either a motorized or manual damper, the air flow can be directed upstairs in summer and downstairs in winter, or changed everyday, directed upstairs at night when people go to bed and downstairs in the morning.

A simplified method of creating some of the benefits of a multizone system is to use a hi-lo return. It makes use of the fact that hot air rises by providing two returns: one high (on a second story) and one low (first story). In summer, you seal off the high return and open the low return. The coolest air from the house will be conditioned and then redistributed. In winter, seal the low return and take warm air from the second-story through the high return. With this system, it is very important that the return ducts be in conditioned spaces.

## 9. Choose an appropriate thermostat and thermostat location

Install the thermostat on an interior partition wall away from direct sunlight to ensure the most accurate reading. It is also important to locate the thermostat away from fireplaces, ovens, or other home features which could affect the unit's temperature-sensing ability. Do not place it where it will receive air directly from a duct outlet, causing the unit to cycle too frequently. Install it where the home owner can easily read the numbers and make adjustments when needed.

Make sure the differential has been set according to manufacturer's recommendations, and instruct the residents to set the thermostat to "auto," not "fan on". Leaving the fan on typically increases energy use by 10% and relative humidity levels by 5-10%, decreasing comfort. With a heat pump, a two-stage thermostat is required by the Florida energy code to control the use of the electric strip element. Otherwise, the electric strip may run too often, reducing the overall efficiency of the system.




**Setting thermostats to "auto" instead of "fan on" will save energy and increase comfort.**

The two main types of thermostats used to control home cooling and heating today are the conventional, bimetallic thermostat and the electronic or programmable thermostat.

The conventional thermostat utilizes a bimetallic element which rotates as the air temperature changes, opening and closing a mercury switch. An anticipator is commonly used with conventional thermostats. It consists of a resistive heating element which artificially causes the air conditioner to start sooner than it otherwise would. As a result, temperature swings are decreased and comfort is improved, but at the price of decreased overall air conditioner efficiency due to an increased cycling rate.

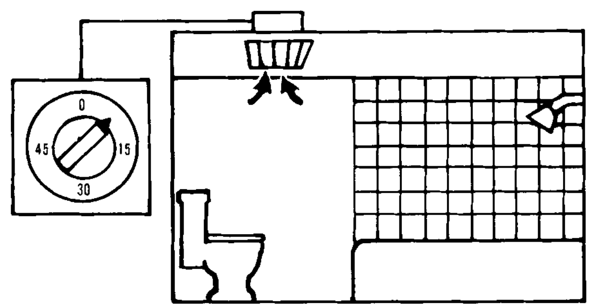
A programmable or electronic thermostat uses electronic logic to activate a relay when temperatures go above or below given setpoints. One of the main benefits of a programmable thermostat is that it can be programmed to cool or heat the house to given temperatures at selected times. For example, during the summer the home owner may wish to set the temperature to be 76°F at 6:30 a.m. when the occupants awaken, and then increase to 83°F at 8:00 a.m. when they leave for the day, etc. While a standard thermostat can be adjusted manually to the desired settings, its shortcomings are obvious when the residents forget to make the changes. However, many home buyers may not want to learn how to program thermostats so this device is best left as an option.

Most programmable thermostats do not have anticipators, but control system cycling using a deadband (the temperature difference between turn-on and turn-off), which should be user adjustable. Those programmable thermostats that have small deadbands (plus or minus 1°F) or contain anticipaters will provide greater comfort for occupants.

## 10. Use kitchen and bath exhaust fans

Fans should be installed in kitchens and bathrooms to exhaust moisture to the outdoors. For ease of use, and energy efficiency, observe the following guidelines:

- Use a timer control switch on the bathroom vent fan. After a bath or shower, the fan should continue running long enough to remove excess moisture from the bathroom and should shut off by itself. Fans left on for long periods of time will cause unwanted air infiltration and use unnecessary electricity.
- Use fans which have vent dampers so air will not infiltrate when not in use.
- Choose quiet fans that have ratings (given in most suppliers' catalogs) of 3 sones or less, so occupants are not deterred from using them.
- Install exhaust fans properly:
  - Exhaust air to the outdoors.
  - If possible, do not have bends in the exhaust duct; take it straight out of a wall or up into the attic and out the roof. Do not run flexible duct over and around trusses as a trap may form and collect condensation.
  - Do not exhaust bath or kitchen fans to the attic; moisture may accumulate, causing mold growth or damage to insulation or the ceiling.
  - Seal tightly around the exhaust duct penetration through the ceiling.



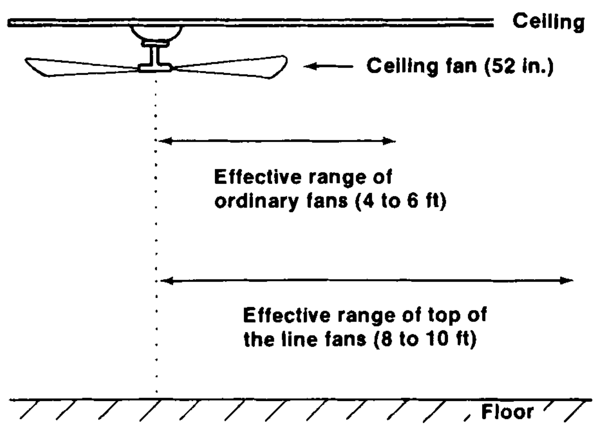

**Use time controls on bath exhaust fans.**

## 11. Install ceiling fans

In general, a ceiling fan should produce enough air movement so the occupants will be comfortable at a temperature of 82°F and 80% relative humidity. The average ceiling or portable oscillating fan will allow the home owner to raise the thermostat by about 4°F without any decrease in human comfort. This could result in significant savings, since each degree the thermostat is raised above 78°F will save about 7 to 8% on electric cooling costs.

**Fans do not cool rooms; they cool people** by creating air movement across the skin, so ceiling fans are most beneficial if installed in rooms where people spend the most time. Since the fans take up no floor space, they can be installed in just about any room (providing there is at least 7 feet between the fan blades and the floor for safety). As a rule, the larger the fan, the greater the air movement and also the quieter it is for a given flow rate.

Fan quality and blade size will make a difference in the comfort people feel at varying distances from the fan. Unfortunately, there are no objective tests presently used to establish standards of quality. Generally, the more expensive fans tend to be most effective. The illustration below shows the difference quality can make in the effective range of the fan.




**Quality can make a difference in the effective range of ceiling fans.**

As for blade size, you can figure that a top-of-the-line 52-inch fan will be effective 8 to 10 feet from the fan's center, while a smaller fan will cool people within 4 to 6 feet. In a bedroom, with the fan directly over the bed, a 36-inch fan may be adequate. In the family and living areas, consider installing a 48- to 56-inch fan, and use two if the room is longer than 18 feet.

Fan Guidelines

| Largest room dimension | Minimum fan diameter |
|---|---|
| 12 feet or less | 36 inches |
| 12 - 16 feet | 48 inches |
| 16 - 17.5 feet | 52 inches |
| 17.5 - 18.5 feet | 56 inches |
| 18.5 feet or more | Two fans |

Research shows that using a downrod to lower the fan 8 to 10 inches from the ceiling will give much better air movement for cooling people in the room. **Fans too close to the ceiling, such as most "ceiling huggers," will not provide adequate breeze.**

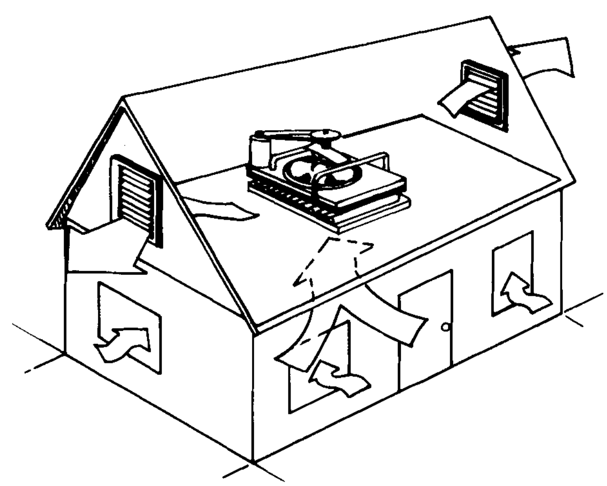
When wiring and installing ceiling fans, be especially careful to tightly seal the attic penetrations. These openings can otherwise be a major source of air infiltration.

Fans allow the home owner to save about one-fourth to one-third on cooling costs and still stay comfortable when the outside temperature rises. Fans also help to extend the "swing" seasons, those nice months in spring and fall when it's not hot enough for air conditioning but it's warm enough that the air movement feels good. Although a ceiling fan may help limit air stratification, its use in the winter may not be beneficial because of the cooling effect caused by the increase in air movement.

Ceiling fans should be controlled just as lights are. When leaving a room, shut off the fan. The fan motor consumes electricity and adds heat to the room.

## 12. Whole-house fans

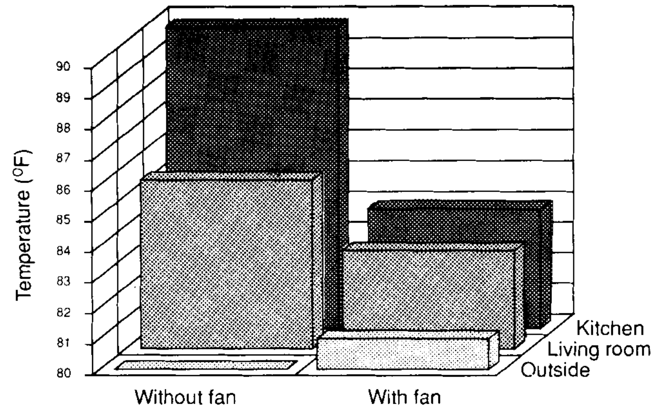
In most cases, natural ventilation alone will not take full advantage of the cooling potential of outdoor air. Whole-house fans increase natural ventilation by drawing outdoor air through the house and expelling it back outside through the attic.



**Whole-house fans effectively increase natural ventilation.**

They can be effective in decreasing air conditioner use by both venting heat built-up in the house structure and furnishings and causing evaporative cooling by increasing air movement (as does a ceiling fan). In addition, because the air is expelled through the attic, attic temperatures are lowered. If the outside air temperature and humidity remain low enough, a whole-house fan can be used without the air conditioner to keep the house comfortable throughout the day. Research comparing natural and whole-house fan ventilation showed use of a fan to lower room temperatures by up to 5°F.

In many cases, however, the fans are mainly used in the evening hours when outdoor temperatures are lower than indoor temperatures to augment air conditioner use during the day. Research done in Gainesville showed a whole-house fan reduced air-conditioning energy use by 22 to 44%. Note that the fans are used in the place of air-conditioning; a whole house fan and air conditioner should never be on at the same time.




**Whole-house fans can keep homes cooler.**

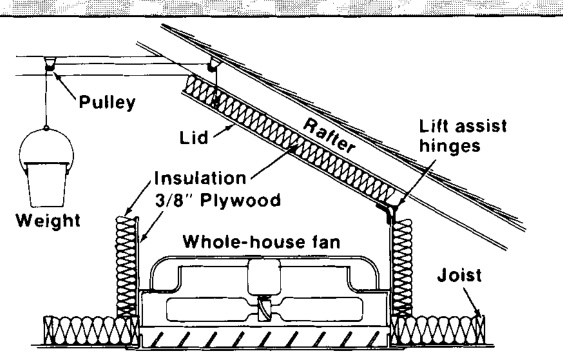
Whole-house fans can provide 20 or more air changes of the home's air per hour, or 0.33 air changes per minute. To accurately size the fan,

**An Automatic Fan Cover**
(from *Rodale's New Shelter*, June, 1984.)

In summer, a whole-house fan can cut your air-conditioning bills by as much as 20%. You can use the fan to ventilate your home with large volumes of cool night air or create a breeze on a hot, still day.

But at other times, the fan actually can cost you, because its large, ceiling mounting hole is usually covered with sievelike louvers. Whenever the fan isn't running, your expensively heated or air-conditioned air bleeds away into the attic.

One solution is to make or buy an insulated cover for the fan, but most require manual opening and closing every time you want to use the fan. Florida resident Kurt Voss devised a solution to that problem – a self-opening and closing, insulated cover for the fan.




A design for an automatic whole house fan cover.

The cover – actually a lid to an insulated box – is attached to counter-weights that work in much the same way as those in double-hung windows. Because the weights are just a few ounces lighter than the lid, the lightest air pressure from the whole-house fan can open the lid.

Voss designed the insulated box to fit around his whole-house fan and under the attic rafters. He insulated the plywood box in sections so he could get it up into the attic. Once the box was assembled in the attic, he attached two pulleys to the rafters with screw eyes, then added to a weight bag until the force of the whole-house fan lifted the insulated box lid easily.

"The insulated box saves energy in summer and winter," Voss says. "It works by itself."

use a cubic-feet-per-minute (CFM) rating that is equal to or greater than the house volume (square footage of floor area x ceiling height in feet) multiplied by 0.33. For example, a home with 1500-square feet of floor area and an 8-foot ceiling has a volume of 12,000-cubic feet. The required rating is thus 12,000 x 0.33, or 3960 CFM. Compare this value to the manufacturer's CFM rating. Most manufacturers would typically rate a 24-inch fan running at high speed to equal or exceed the 3960 CFM given in this example. However, you should **consider installing a larger diameter unit so that the fan will run at a quiet low speed to deliver the required volume of air.**

When you read the manufacturer's CFM rating, be aware that it may be one of two different types. The preferred rating gives the CFM under a static pressure (SP) drop of 0.1 inch of water column. If the CFM rating with the fan does not specify the pressure drop, assume that the manufacturer has used the free-air CFM rating, which gives the maximum possible CFM. Subtract 15% to 20% from the free-air CFM to get the 0.1 inch SP rating. A wall-mounted timer switch (12 hour) should be used to control the fan. Home owners can then elect to have it turn off automatically during the night.

Be sure to include adequate vent openings in the attic to allow hot air to escape. The free-exhaust vent area in the attic should be approximately twice that of the fan area. A total vent cutout area (add all cutout areas for gables, turbine vents, ridge vents, etc.) equal to four times the fan open area should be sufficient. Though soffit and gable vents should do the job, a continuous ridge vent with soffits is preferable (see Chapter 8).

Some owners of whole-house fans have complained about fan noise and the fact that they consume between 300 and 500 watts of electricity. However, they offer an excellent ventilation alternative especially in areas where low wind speeds are prevalent. Since a whole-house fan is more difficult to install once the house has been built, you should emphasize to the prospective buyer the value of having it installed during construction.

## 13. Seal fan penetrations

As discussed in Chapter 8, it is very important to seal penetrations between the house and attic spaces. The energy and comfort benefits of exhaust fans, ceiling fans and whole-house fans will be negated if penetrations are not sealed.

Caulk around exhaust fan casing and seal ceiling fan wire or pole connections with an expandable sealant.

### Summary

Properly sized, efficient air conditioners will keep home owners comfortable and utility costs low. Choosing units with low sensible heat fractions and multi-speed blowers can help remove excess moisture. Heating equipment should also be carefully selected, keeping in mind the heating requirements of the part of the state the equipment is to be used in. Locating and properly installing the air handler and duct work in conditioned space can save 25% of the cooling and heating energy used in the home. Fans are also important in reducing energy use. Kitchen and bath fans with timers should be used to remove moisture at its source. Ceiling fans can increase comfort in lieu of lower thermostat settings, and whole-house fans can be used to reduce the need for air conditioning during several months of the year.

## For further information

Air Conditioning Contractors of America, *Manual J Load Calculation for Residential Winter and Summer Air Conditioning*, 1986.

Air Conditioning Refrigeration Institute, 1815 North Myer Dr., Arlington, VA 22209.

American Society of Heating, Refrigeration and Air Conditioning Engineers, Inc., 1791 Tullie Circle, NE, Atlanta, GA 30329.

Florida Natural Gas Association, P.O. Box 2562, Tampa, FL 33601.

Florida Propane Gas Association, 526 East Park Ave., Tallahassee, FL 32301.

"Central Air Conditioner Impact Upon Infiltration Rates in Florida Homes," James B. Cummings, FSEC-PF-194-90, Passive Proceedings, American Solar Energy Society, 1988.

"Dealing with heat and humidity in Florida homes," Robin Vieira, FSEC-EN-14-86, 1986.

"Duct Doctoring: Diagnosis and Repair of Duct System Leaks," James B. Cummings, et al., Florida Solar Energy Center, 1992.

"Duct Leakage Impacts on Airtightness, Infiltration, and Peak Electrical Demand in Florida Homes," James B. Cummings, et al., FSEC-PF-212-90, 1990.

"Fans to Reduce Cooling Cost in the Southeast," Subrato Chandra, FSEC-EN-13-85, 1985.

"Florida Cooling, the Natural Way," Danny Parker, *Home Energy*, November/December 1991.

"Measuring Thermostat and Air Conditioner Performance in Florida Homes," Hugh I. Henderson, Jr., et al., FSEC-RR-24-91, 1991.

"A Report on a New Device and Method to Extend the Life, Efficiency and Maintainability of Unitary Air Conditioning Compressors and Systems," Richard J. Avery, Jr., Proceedings of the 42nd Meeting of the Mechanical Failures Prevention Group, Gaitherburg, MD, 1987.

"Bathroom Fans by Capacity-to-Noise Ratio," *Energy Design Update*, November 1987.

Certified Home Ventilating Products Directory, Home Ventilating Institute (30 West University Dr., Arlington Heights, IL 60004; 708/394-0150) 1984.

*Consumer Guide to Home Energy Savings*, Alex Wilson, American Council for an Energy Efficient Economy, Washington D.C., 1990.

*Low Energy Cooling*, Donald W. Abrams, Van Nostrand Reinhold Company, New York.

"New Products Home Energy – Heat your house with a water heater?," V. Elaine Gilmore, *Popular Science*, October, 1986.