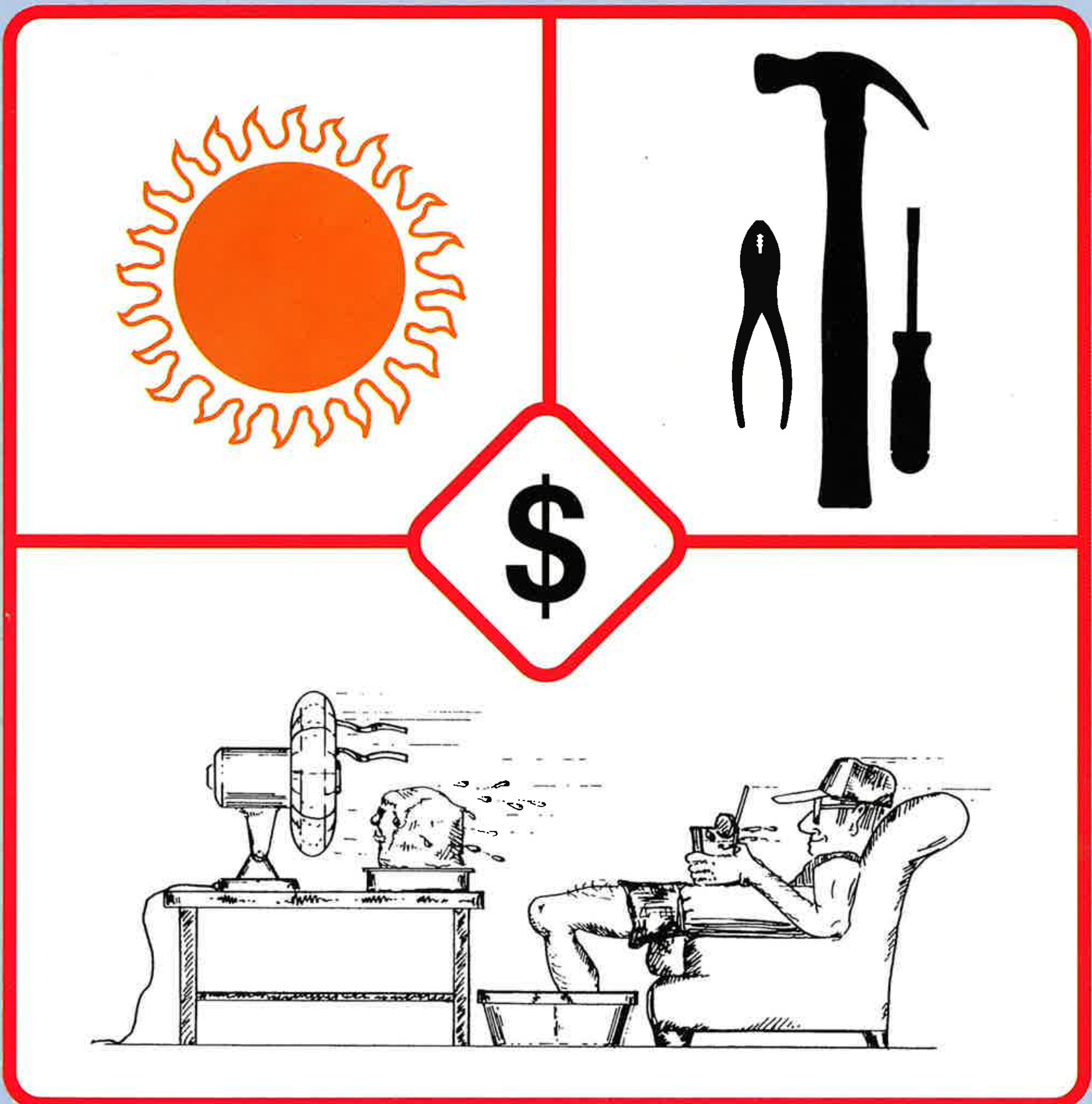
Your HOME COOLING ENERGY GUIDE



Publisher's Cataloging in Publication

Krigger, John T.
Your home cooling energy guide / John T. Krigger
p. cm.
Includes bibliographical references and index.
ISBN 1-880120-04-6

1. Dwellings -- Air conditioning -- Handbooks, manuals, etc. 2. Dwellings -- Energy conservation -- Handbooks, manuals, etc. I. Title.

TH7688.H6K5 1992 644'.5
QB192-1300

Your Home Cooling Energy Guide

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Sponsored By:

Southwestern Power Administration

United States Department of Energy

Saturn Resource Management, Helena, Montana 1991

Acknowledgements

Sponsors:

Southwestern Power Administration, Tulsa, OK
D.O.E. Weatherization Assistance Program, Washington, DC
Don and Ann Krigger, San Diego, CA

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ISBN 1-880120-04-6

This book was edited and produced by:
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Printing: Comstock Graphics and Century Lithographers
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Introduction

More than 50 million American homes have mechanical air conditioning, representing more than 50% of all homes. About 75% of new homes have central air conditioning installed during construction. Air conditioning now costs American consumers about 10 billion dollars per year in energy costs.

If you want to reduce your dependence on mechanical air conditioning, lower your cooling energy bills, and, at the same time be more comfortable in your home during hot weather, then this book is for you. Even if you don't use mechanical air conditioning, you can learn more about low-cost cooling strategies for your home. Your best defense against high cooling costs is to educate yourself about home cooling. Knowing more about cooling can help you to reduce cooling costs and keep them low by maintaining your air conditioning equipment, using low-cost cooling strategies, and purchasing cooling products and services wisely.

In Section 1, *Your Home Cooling Energy Guide* introduces comfort and cooling principles to help you understand what makes you feel cooler in hot weather. Information on **Reducing Heat Gain, Cooling With Ventilation**, and using **Mechanical Cooling Systems** is in Sections 2, 3, and 4 respectively.

The text is illustrated with many drawings to clarify technical details and procedures. An extensive glossary is included to provide a quick reference to unfamiliar terms. The annotated bibliography includes the principle references used in developing this book as well as suggestions for further reading. The index will help you pinpoint information on specific topics. Other appendixes provide cost information, cooling strategies for various U. S. climates, and a checklist of cooling options.

Throughout this guide the author has tried to be as specific as possible given the availability of research and the variations among homes, climates, and cooling products. When a number or percent is used, either it represents the author's best estimate based on research or a specific reference is cited. The instructions for using various cooling strategies are not step-by-step instructions because of variations between different products and equipment. Refer to manufacturer's instructions, owner's manuals, and parts and service manuals for step-by-step instructions for installation and operation of cooling products.

High cooling costs are often the result of preventable energy waste relating to failure to use simple methods of reducing heat build-up in the home and the lack of maintenance of mechanical air conditioning systems. **The Problems and Solutions table on page vi outlines the chief sources of cooling energy waste and proposes action to reduce that waste.** This table lists potential solutions to problems and the sections of the book that discuss those areas.

NOTE: Additional copies of this guide can be ordered on the postage paid reply form at the back of the book. We plan to reprint this guide periodically and would like your opinion on how we can improve it and make it more useful for you. Please send us your comments or suggestions on the form at the back of the book.

Problems and Solutions in Home Cooling

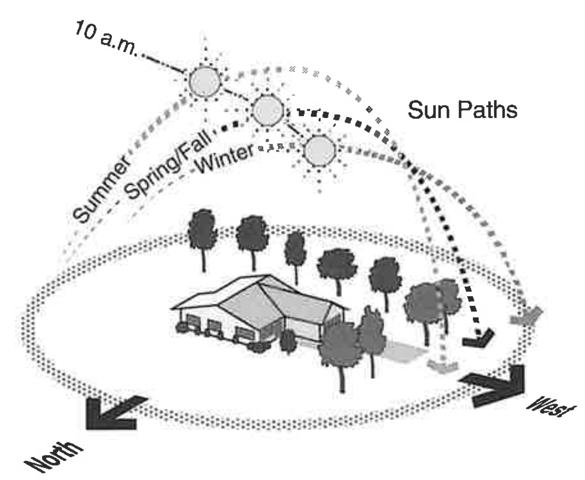
The cooling problems discussed in the book are listed here with page numbers and section where you can find information. We define a problem as a weakness that will cause cooling costs to be higher than necessary. Does your home have any of these problems?

Problem	Suggested Solution	Section & Page #s
Lack of shade	Use all cost-effective shading options including plants, and exterior or interior window shading	2.4.4 to 2.4.7 p. 14–21
Lack of air circulation within the home	Employ ceiling fans and oscillating fans to increase air speed	3.1 and 3.6 p. 23, 31
Failure to use ventilation where it is appropriate	Use ventilation whenever outdoor temperature and humidity permit; employ fans to optimize ventilation	3.1 to 3.5 p. 23–31
Excessive air leakage	Seal air leaks, after measurements of leakage are performed	2.3 p. 8-10
Dark wall and roof color	Lighten roof and wall color to bright white or the lightest acceptable alternative	2.4.1 p. 11-12
Inadequate maintenance of air conditioners or evaporative coolers	Perform necessary maintenance procedures	4.4 to 4.4.5 p. 50–56
Leaky ductwork in central air conditioning system	Seal leaks in ductwork yourself or hire a technician to do it	4.5.2 p. 57,58
Incorrect refrigerant charge and/or low air flow	Hire a qualified technician to measure charge and airflow and to take appropriate action	4.4.5 p. 54
Ductwork runs in unconditioned area	Insulate ductwork yourself or hire technician to insulate ducts	4.5.3 p. 58–60

1.1 Introduction

This section introduces basic cooling principles related to heat, humidity, comfort, and climate. Learning these principles enables you to apply the specific information found in Sections 2, 3, and 4. You can make practical improvements to reduce cooling costs and increase comfort levels during hot weather.

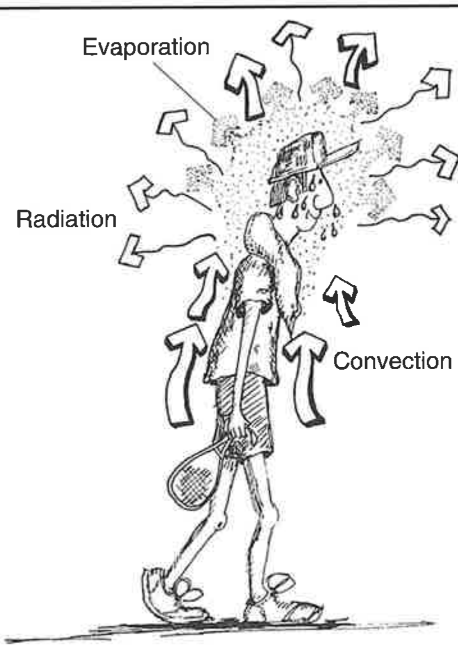
The sun heats the earth, atmosphere, and your home with its rays. In summer, the earth tilts more toward the sun—therefore, the sun rises higher in the sky and stays there longer than in the other seasons (*see figure* **1-1**). The summer abundance of solar energy causes heat to accumulate in your home.



1-1 Sun Trajectories *- Winter weather is cool because the sun's rays come from the south at a low, less direct angle. Summer weather is warmer because the sun is higher in the sky, and its rays strike the earth more directly.*

1.2 Cooling Your Body

Your body constantly produces and releases heat to remain at 98.6°F. Many factors combine to create a feeling of comfort. Air temperature and humidity are the most important. Air movement, sunshine, clothing, activity level, and the temperature of the surfaces around you also influence how comfortable you feel.



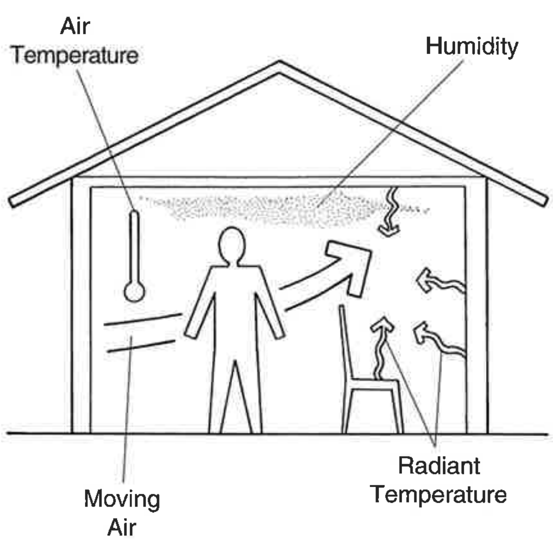
1-2 Cooling Your Body *- Your body cools itself through convection, evaporation, and radiation.*

Body heat is released in three ways: convection, evaporation, and radiation (*see figure* **1-2**). When the air temperature is less than skin temperature (about 92°F), the air absorbs heat from the skin and rises, taking the heat away. This is called convection. As the warmed air rises, cooler air moves in and absorbs more heat from the skin, and the process continues.The faster the air movement, the faster it carries heat away.

Sweating is a very important way to release body heat. Perspiration evaporates and takes excess body heat with it into the air. The rate at which perspiration evaporates from our skin depends on the relative humidity of the air. The less humid the air around us, the more we can cool our bodies by sweating. Humid air reduces evaporation and carries more heat than dry air at the same temperature, which makes it more difficult for our bodies to stay cool. Moving air increases the evaporation of sweat.

In calm air above 92°F with 100 percent relative humidity, the body has great difficulty releasing its excess heat into the environment and can overheat (*see Appendix E, Heat Ailments*). At a comfortable temperature of 75°F with 50 percent relative humidity, the body releases about 20 percent of its excess heat by evaporation and then releases the remainder by convection and radiation. However, when the air temperature rises to 90°F with 50 percent relative humidity, evaporation is responsible for 80 percent of the heat loss from your body.

Your body radiates heat to surrounding objects and objects radiate heat toward you. Heat rays form at the surface of your skin and fly off through the air until they strike another solid object, which either absorbs or reflects the rays. In the same way, heat rays from other objects strike us and we can absorb them to heat our bodies. A block of ice feels cold to us, even at a distance, because we radiate heat to the ice, but it radiates almost none back. A roaring fire feels hot because it radiates more heat than we do.



1-3 What Determines Comfort? *- Comfort is determined by four interrelated factors: air temperature, humidity, radiant temperature, and air movement.*

The temperature of the walls, ceiling, and other objects in our homes (called "radiant temperature") determines if we can cool our bodies by radiation or if our hot surroundings will, instead, heat us. Cooling by radiation can account for up to 50 percent of the body's heat loss under optimum radiant temperatures.

The tolerance of different individuals to heat and humidity varies widely. Healthy people who work or exercise outdoors, regardless of temperature, usually have the best resistance to heat. Reducing caloric intake, wearing loose, lightweight clothing, and exposing plenty of skin indoors helps the body feel comfortable in the heat.

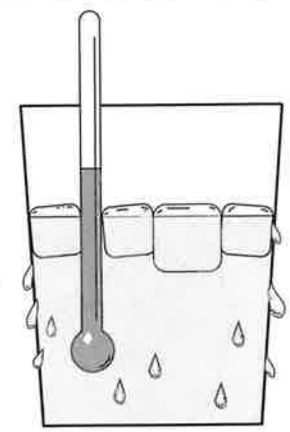
1.3 Elements of a Comfortable Environment

Air temperature, humidity, air movement, and the temperature of the surfaces around us all influence comfort (*see figure* **1-3**). Air temperature and humidity determine how much heat the air can hold. The higher the air temperature and the higher the humidity, the more heat the air can store. The more heat the air contains, the more difficult it is for the human body to release heat. Therefore, it is harder for our bodies to stay cool in a hot, humid climate than in a hot, dry climate.

Moving air always makes you feel cooler because it carries heat away from the skin and increases the evaporation of sweat. Circulating air inside your home is the key element to staying comfortable during hot weather. Rapidly moving air works well by itself, and can be combined with air conditioners, evaporative coolers, and whole-house fans to further improve comfort.

Ventilating with outdoor air carries heat away from the home and reduces air conditioning costs whenever the outdoor air temperature and humidity are comfortable.

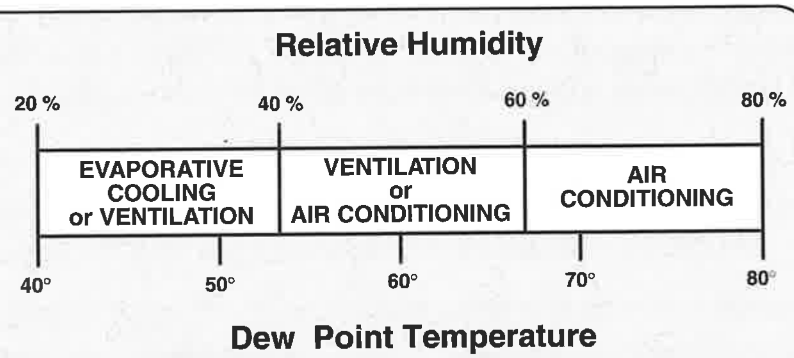
High outdoor temperatures and absorbed sunlight heat the walls and ceilings of a home. These surfaces then become radiant heaters and the air temperature in the home rises. The higher the indoor air temperature and relative humidity, the more discomfort and desire for mechanical cooling.



1-4 Dew Point *- Fill a beverage glass with warm water. Then slowly add ice. When condensation begins to appear, the temperature of the glass has reached the dew point of the air.*

Humidity is very important to comfort. Humidity is measured by either relative humidity or dew point. Dew point is the highest temperature of an object on which water from the surrounding air will condense (change from a gas to a liquid). Dew point is the temperature in a mixture of air and water vapor at which condensation begins (*see figure* **1-4**).

Figure **1-5** demonstrates how humidity affects your choice of a cooling strategy during hot weather. At low relative humidity and low dew point, evaporative cooling and ventilation are good cooling methods. Ventilation works well up to about 70 percent relative humidity (or a dew point in the high 60°s). People want air conditioning during hot weather to achieve modern standards of comfort when the dew point is above 68°F or when the relative humidity is over 70 percent.

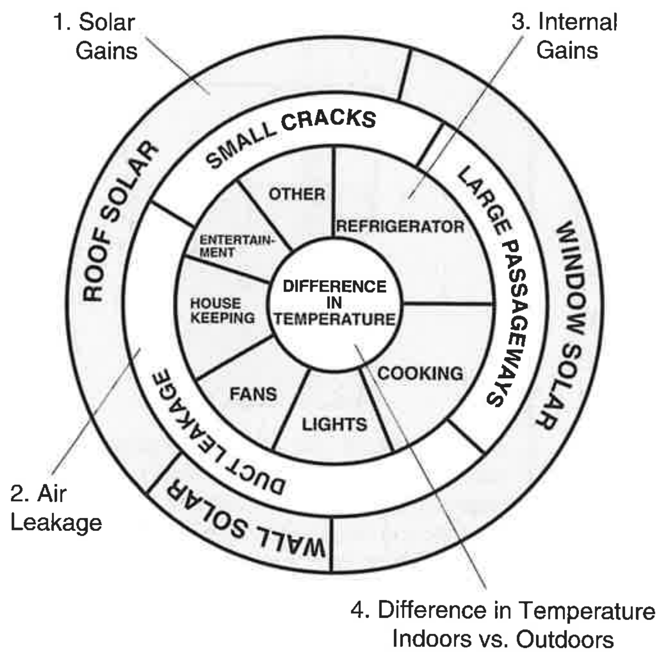


1-5 Humidity and Cooling Methods *- In hot, dry weather, evaporative coolers reduce the temperature of the air by adding moisture. In warm and moderately humid weather, ventilation can effectively remove solar gains and internal gains to cool the home. In hot and humid weather, air conditioning is required for modern standards of indoor comfort.*

At 100 percent relative humidity, the air is saturated and can hold no more moisture. At 70 percent relative humidity or above, the air feels either hot and sticky, or cold and clammy, and is not comfortable to most people.

1.4 Heat Gain, Climate, and Cost

Absorbed sunlight, heat generated inside the home, high humidity, high outdoor temperatures, and air leakage make homes uncomfortably hot and necessitate using various cooling strategies. Solar gain through windows accounts for 15 to 20 percent of



1-6 Heat Gains *- Unwanted heat comes from four sources as shown here. The amount of area on the circle that a source occupies is proportional to the amount of heat it adds to an average home.*

cooling costs. Solar gain through the roof and walls accounts for another 20 to 30 percent. Air leakage varies widely and accounts for 5 to 30 percent of the cooling costs, depending on the amount of air leakage, the outdoor temperature, and relative humidity. Another 15 to 25 percent of the cost comes from internal gains caused by bathing, cooking, and operating electric appliances. Heat conduction through the walls and roof due to temperature differences between indoor air and outdoor air is a modest 5 to 15 percent of cooling costs (*see figure* **1-6**).

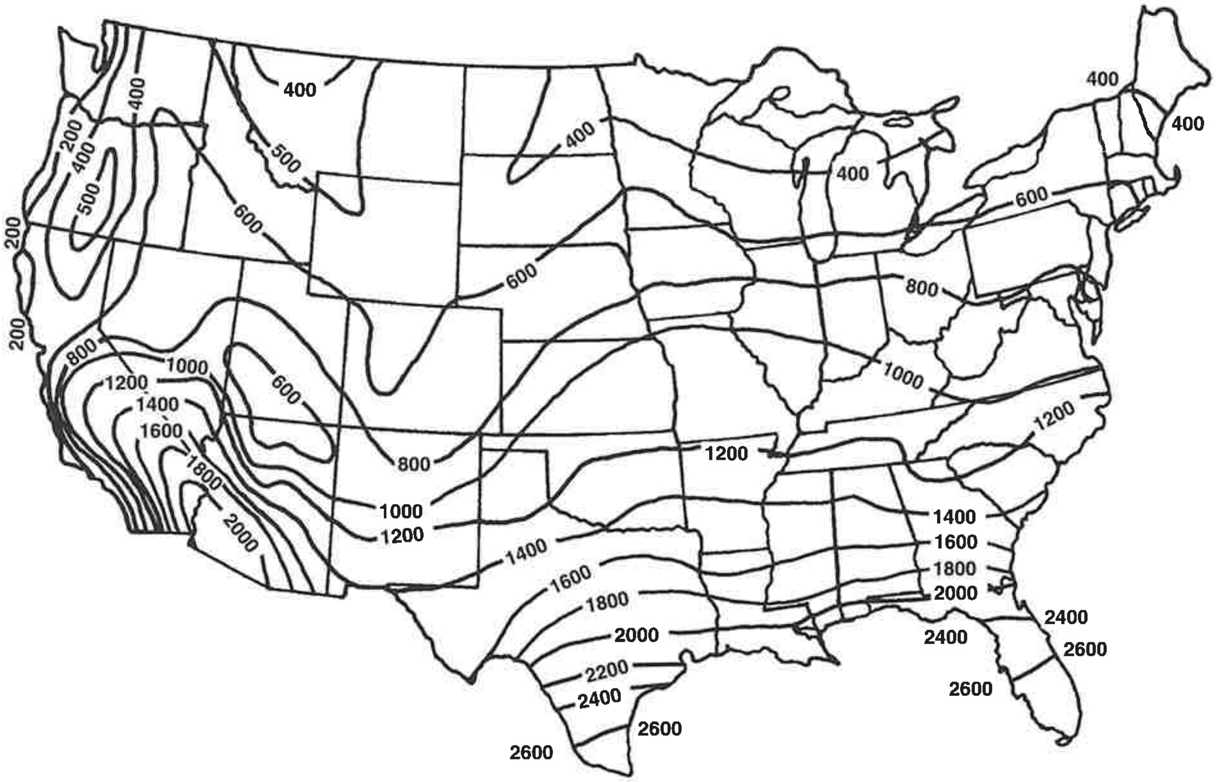
The most cost-effective cooling strategies are those which prevent heat from building up in your home. These strategies include: shading windows, roofs and walls; using light-colored roofs and walls; removing hot air with fans; and circulating indoor air with fans, creating a wind-chill effect. Shade is the most important cooling strategy in a hot, sunny climate.

Internal gains are a big factor in all cooling efforts, but are more of a problem in humid climates. The extra humidity added by showers and cooking must often be removed by the air conditioner.

Table **1-A** shows the number of watts of electric power drawn by the mechanical cooling devices discussed in this guide, and their hourly cost of operation. As you can see, the most expensive cooling method is air conditioning. The more you reduce heat gain and use low cost

Cooling Device	Watts	Cost/Hour
Central Air Conditioning	2000-5000	16¢-52¢
Room Air Conditioner	500-3000	4¢-24¢
Evaporative Cooler	400-1800	3¢-15¢
Whole-House Fan	300-600	2¢-5¢
Circulating/Exhaust Fan	25-200	0.2¢-1.6¢

Table 1-A - Wattage and Hourly Cost for Cooling Devices *- The ranges of watts and cost represent the different sizes of the cooling devices. The hourly cost assumes 8¢ per kilowatt-hour.*



1-7 ***Cooling Hours Map*** *- This map shows the number of hours per year when the temperature and humidity outdoors are uncomfortably high, leading to a build-up of heat indoors. (Courtesy of The Air Conditioning and Refrigeration Institute)*

alternatives to air conditioning, the lower your cooling costs will be.

Flaws in the original installation and neglect of routine maintenance are common air conditioning problems. These problems can waste 30 percent or more of the electricity used for cooling. Your summer thermostat setting determines cooling costs. The thermostat setting can make a difference of 2 to 4 percent of your total cooling costs per degree.

The differences between cooling costs in different parts of the United States relate to the relative humidity, the amount of sunshine, and the average outdoor temperature. Solar heat gain is a more important factor in sunny climates than in wetter, cloudier climates. Air leakage is more important in humid climates than it is in drier climates. In climates that are both humid and very sunny, minimize cooling costs by employing all the shading strategies and by making sure your home is reasonably airtight.

The Air Conditioning and Refrigeration Institute (ARI) estimates the average number of hours that people use air conditioners to maintain comfort in different U. S. climates. Figure **1-7** shows the continental United States with these "cooling hours" shown as lines on the map. ARI publishes a method for estimating cooling costs: multiply the number of cooling hours by the number of watts drawn by the air conditioner; then multiply by the cost per kilowatt hour.

Hours x Watts x $/kWh = Cost

Use Table **1-A** with figure **1-7** to roughly estimate the yearly costs of the cooling devices discussed in this guide. Appendix D, Regional Cooling Solutions, discusses the differences in strategies for different climatic regions of the country.

1.5 Cooling Cost and Investment in Energy Savings

You can figure your monthly or yearly cooling costs by estimating how much extra electricity you buy when turning on your air conditioner. Table **1-B** demonstrates home electricity costs and illustrates how to record your cooling costs. First, estimate the basic monthly cost of operating lights and appliances (from energy bills for months using no electric heating or cooling). Subtract that lighting and appliance cost from each cooling month's electricity cost. This figure provides the monthly air conditioning cost (last column in the example). Total all the monthly air conditioning costs.

Month	kwh	$ Electrical		$ Appliance		$ Cooling
April	275	22	-	22	=	$ 0
May	1188	95	-	22	=	73
June	2075	166	-	22	=	144
July	2650	212	-	22	=	190
Aug.	1938	155	-	22	=	133
Sept.	1226	98	-	22	=	76
Oct.	700	56	-	22	=	34
Nov.	274	22	-	22	=	0
Total Cooling Costs						**$650**

***Table 1-B** - Shows monthly kilowatt hour consumption and cost for an example discussed in the text. The cost of appliance use is subtracted from each monthly total to get monthly cooling costs which are added together to arrive at total yearly cooling cost. You can make a table like this one to determine the yearly cooling cost for your home.*

This yearly cooling cost allows you to estimate possible yearly savings from various cooling energy saving measures. For example, if a group of improvements will save 20 percent, and you spend $650 a year for air conditioning, then you will save 20% x $650 = $130 each year.

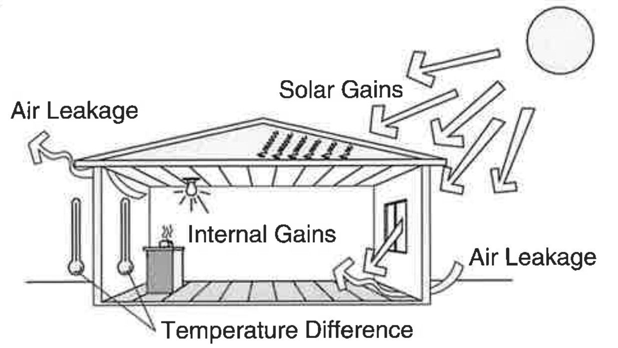
If you made an investment of $520 in improvements and they will save $130 per year, your initial investment will be repaid completely in 4 years ($520 ÷ $130/year). If you think of it like an investment in stocks or bonds: dividing the $130 yearly savings by the larger initial investment figure of $520 gives you annual return on investment of 25 percent ($130 ÷ $520). A very good investment!

$ Initial Investment ÷ $ Yearly Savings = Payback Period (years)

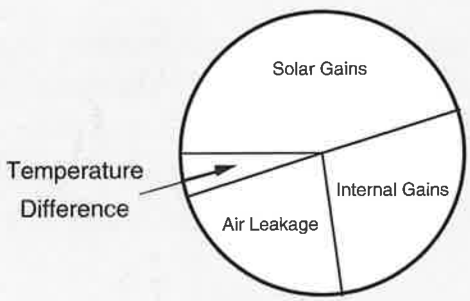
$ Yearly Savings ÷ $ Investment = Yearly Return (%)

2.1 Introduction

Heat gain is unwanted heat that accumulates indoors causing a comfort problem (*see figure* **2-1**). Heat driven through the walls and roof by high outdoor temperatures accounts for less than 10 percent of the heat that accumulates in your home. Solar gains, air leakage, and internal gains comprise 90 percent or more. Solar gains through the windows, roof, and walls are the biggest source of unwanted heat—50 percent or more of the total heat gains. Internal heat gains are generated inside the home by people, lights, and appliances. Air leakage is outdoor air that leaks into a home, and indoor air that leaks out. Table **2-A** shows the types of heat gains as a percent of the total heat gains. Note that air leakage and internal gains provide both humidity and heat.



***2-1 Heat Gains** - Heat accumulates in a home four ways: solar gains, internal gains, air leakage, and temperature difference.*



Percent of Total Heat Gain from the Major Sources of Unwanted Heat

Solar Gains - Windows	20 - 30%
Solar Gains - Roof	10 - 20%
Solar Gains - Walls	5 - 10%
Internal Gains - Heat	15 - 25%
Internal Gains - Humidity	5 - 15%
Air Leakage - Heat	5 - 20%
Air Leakage - Humidity	5 - 25%
Temperature Difference Between Indoors and Outdoors	5 - 10%

Table 2-A

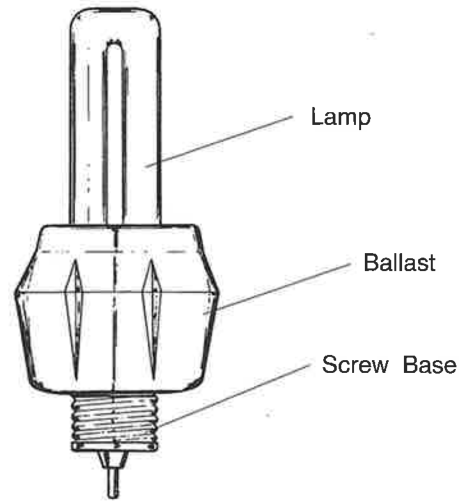
2.2 Reducing Internal Gains

Internal gains come from indoor activities. Internal gains are divided into two categories: internal heat and internal humidity. The primary sources of internal heat are appliances and lights. The refrigerator and the water heater are major heat sources; the washer, dryer, and stove each add both heat and humidity.

If possible, you should isolate the water heater, washer, and dryer from the cooled living space to prevent them from heating and humidifying your home (*see figure* **2-3**). Seal all air leaks between the living areas and the utility areas where they are located. (Remember that the dryer needs a supply of air, and gas appliances need a source of combustion air from outdoors.)

Reduce heat and humidity during hot weather by washing clothes in cold water, drying clothes outdoors, cooking in a microwave, and barbecuing outdoors.

Fluorescent lighting provides the same light levels as standard home lamps for about 25 percent of the energy cost and heat production. The new compact fluorescent bulbs screw into a standard light socket and save money on both lighting and cooling (*see figure* **2-2**). These new light bulbs are appropriate for fixtures that are used at least 3 hours a day. (Some fixtures will not accept compact fluorescent bulbs because they are slightly bigger than standard light bulbs.)



2-2 Compact Fluorescent Bulbs *- These new bulbs provide the same amount of light as common incandescent bulbs, for 25 percent the cost and heat production. A variety of decorative or practical globes are available to cover the bulb.*

Efficient lights and appliances are worth the extra initial cost (which may be substantial). They are less expensive to operate, and they release less unwanted heat indoors. The American Council For An Energy Efficient Economy lists the most efficient appliances in their annual guide, *The Consumer Guide to Home Energy Savings* (see Bibliography). Energy-efficient refrigerators are a particularly good investment since they represent such a large percentage of total energy consumption by appliances. Most major appliances carry Energy Guide Labels that provide an estimate of yearly operating costs for comparison shopping.

2.3 Reducing Air Leakage

Normal air leakage doubles when a central air conditioning unit turns on. This is caused by pressure and suction created in the air conditioner and the ductwork. Joints in ductwork are often the most important sources of air leaks in a home.

Windows and doors are not the major source of air leakage in most homes. Large hidden leaks generally account for far more air leakage than do doors and windows. Areas such as ducts, plumbing penetrations, exhaust fans, electrical service boxes, fireplaces, and chimneys are usually the main culprits. Figure **2-3** shows where to look for air leaks in your home. (*See Section 4.5.2, Sealing Leaky Ducts.*)

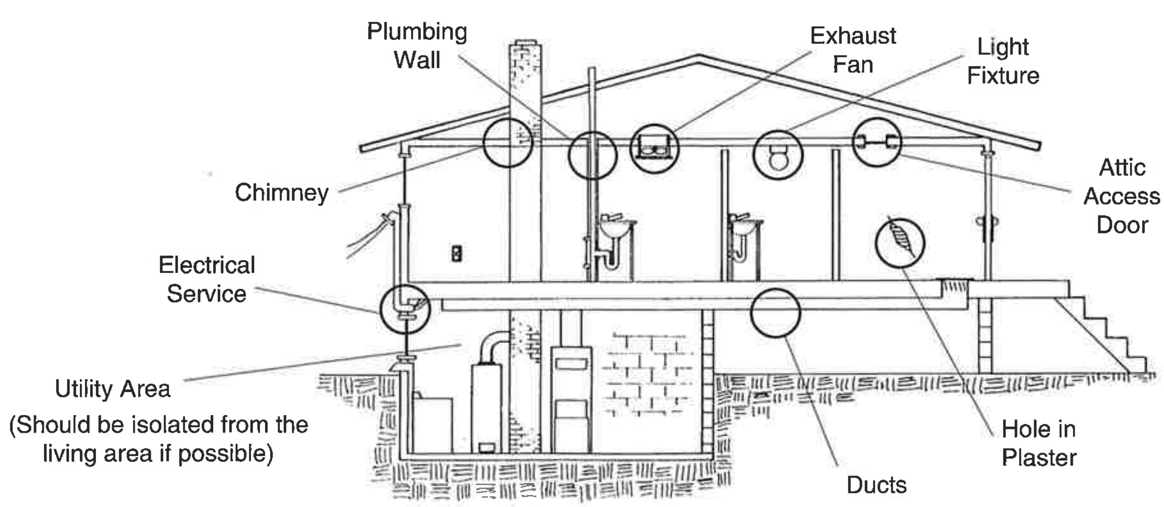
Heat gains from air leaks are more expensive in humid climates than in drier climates. An air conditioner must remove humidity from the air to provide comfort, and this drying process takes a lot of energy. Air leakage accounts for 10 to 30 percent of the cooling load, depending on the size and number of the leaks and the relative humidity of the air entering the home.

Blower door testing is a practical and effective technique for measuring and locating air leakage in homes (*see figure* **2-4**). Blower door testing determines how much air leakage a home has. If you decide to seal air leaks, the blower door locates specific areas in the home that require sealing. **Blower door testing is the only really accurate way to determine whether or not you need to seal air leaks.**

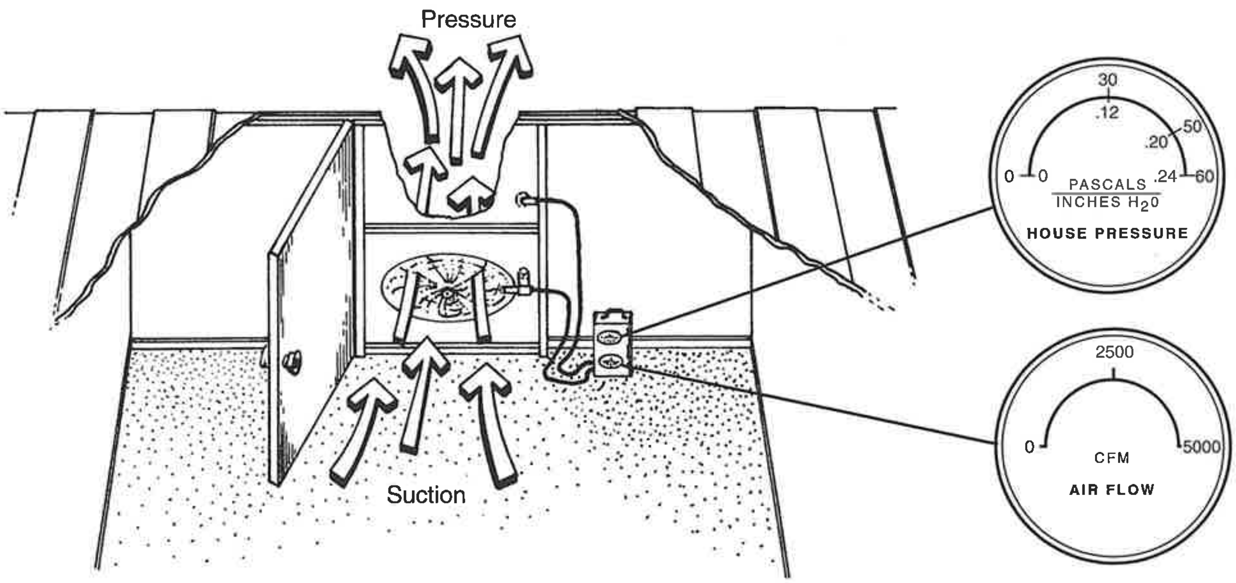
The blower door is a large fan positioned in a sealed doorway. It sucks air through the holes and cracks in the house, and measures the air flow rate. The greater the air flow and the leakier the home, the more beneficial sealing will be. You can seal a leak temporarily or permanently and then measure the reduction in air flow through the blower door. Residential energy service companies and publicly funded weatherization programs are the most likely organizations to contact for blower door testing.

Sealing air leaks is fairly simple for persons who are handy with tools and don't mind working in crawl spaces and attics where many of the large leaks are located. Damaged and incomplete areas on the interior and exterior shell should be patched with appropriate materials. For instance, patch plywood with plywood, drywall with drywall, and so forth. Caulk major cracks between materials if they are an obvious energy problem. Stuff large open cavities with fiberglass insulation inside a plastic bag. Patch odd-shaped holes in floors and ceilings around chimneys, pipes, and other penetrations with aluminum flashing or any kind of easy-to-cut sheeting, fastened with staples, nails, or screws, and caulked at the seams.

The Environmental Protection Agency (EPA) states that a home should exchange approximately one-third of its indoor air for outdoor air each hour, to maintain good air quality. When a home is tighter than this recommendation, the air may become



***2-3 Air Leakage Sites** - Openings and penetrations in the floor and ceiling are often the primary air leaks in a home. Ventilated attics and basements are pathways for outdoor air to come in, and indoor air to flow out.*

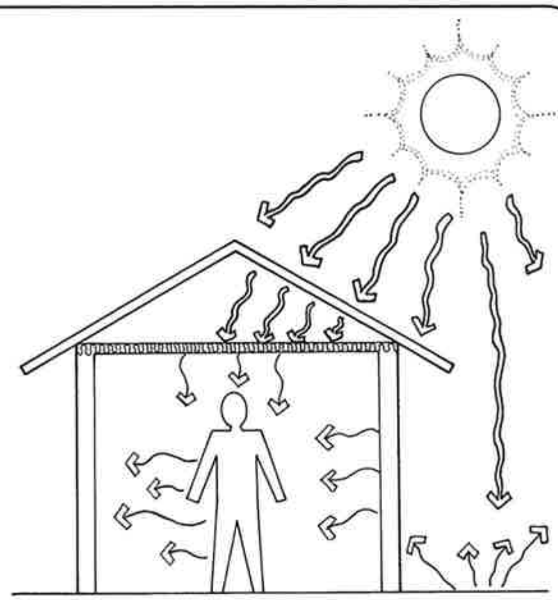


***2-4 Blower Door Testing** - Blower doors estimate air leakage by measuring how much airflow is required to produce a specific difference in air pressure indoors and outdoors.*

concentrated with pollutants generated indoors. Many modern homes have low air leakage rates that are near the EPA guideline already. However, most homes have an air change rate between 0.4 and 1.4 air changes each hour. A rate greater than one-third air change per hour indicates that the cooling costs can be reduced by air tightening without creating a health problem.

2.4 Reducing Solar Gains

Heat from the sun shining through windows and on building surfaces (called solar gains) is the major source of unwanted heat (*see figure 2-5*). The most effective way to reduce solar heat gain is to stop the sun's rays before they enter the building by reflecting the rays or blocking them with shading devices. Reflectivity is the ability of shiny materials or light-colored materials to reflect solar heat away from the home. Shading means putting a solid object between the sun and parts of the building, to absorb or reflect the solar heat. Shade trees, vines on trellises, sun screens, and awnings provide



***2-5 Radiant Heat Flow** - Heat rays fly through space until they strike a solid object. People absorb radiant heat from their surroundings, and radiate heat back to their surroundings.*

effective shading to windows by reflecting solar heat or absorbing the heat outside the home. Shades, draperies, and blinds can be effective shade-givers too, but they must be closed, blocking daylight and the view through the window.

2.4.1 Roof and Wall Reflectivity

Roof color affects cooling costs. Reflective, light-colored roofs save 10 to 20 percent on cooling costs compared to darker roofs.

Dull, dark-colored surfaces absorb more than 90 percent of the solar energy that falls on them, while bright white surfaces absorb only about 20 percent. The Florida Solar Energy Center measured a significant difference in cooling requirements between reflective and non-reflective roofs and walls. Mississippi Power Company and the Rohm and Haas Company found that white roofs saved 16.8 percent of summer cooling costs over darker roofs.

Common asphalt and fiberglass shingle colors, even white, absorb 70 to 95 percent of the solar heat that strikes the shingles. However, one standard roof coating is very reflective and absorbs less than 30 percent of the solar heat. This bright white latex rubber coating can be applied over many common roofing materials such as asphalt shingles, fiberglass shingles, tar paper, metal, and some other roofing materials. For most surfaces a primer is required under this latex coating. The latex coating sheds dust when sprayed with a garden hose during cool weather.

Another reflective coating is the

Percent of Solar Heat Absorbed by Common Wall Surfaces

Paint	
White	15-25%
Flesh/Cream	40-45%
Light Gray	45-50%
Medium Gray-Blue	65-70%
Tan/Brown	70-75%
Medium Brown	75-80%
Brick	
Light-Colored	35-50%
Light Red	50-60%
Burnt Red	65-70%

Table 2-B

(Based on information from the Florida Solar Energy Center)

Percent of Solar Heat Absorbed by Common Roof Surfaces

Asphalt Shingle Roofs	
Dark	85-95%
Medium	80-85%
Light	70-75%
Pebble/Gravel Built-Up Roofs	
Dark	80-90%
Medium	60-80%
Light	45-60%
Tile Roofs	
Dark	80-90%
Medium	70-80%
Light	35-50%
Wood Shingle Roof	
Old Cedar Shake	75-85%
New Cedar Shake	65-75%
Rubber Roofs and Roof Coatings	
White Rubber Roofing	25-30%
White Latex Coating	15-30%
Asphalt/Aluminum	35-55%

Table 2-C

(Based on information from the Florida Solar Energy Center and others) asphalt-based roof coating containing glass fibers and aluminium particles. The quality of this silver-colored asphalt coating varies according to the amount of aluminum particles in the mix. This roof coating is compatible with most asphalt and metal roofing materials. Stir the material thoroughly during installation because the aluminum particles and fibers sink to the bottom of the can. The percentage of solar heat absorbed by the asphalt and aluminum coating increases as it ages and as dust collects on its tacky surface. See Table **2-C** for the percentage of solar heat absorbed by various roofing materials.

Wall color, although not as important as roof color, is an important energy-saving measure, especially for south, east, and west walls. Keep wall color as light and bright as possible, both for energy use and for longevity of the siding material. Table **2-B** shows that white paint absorbs very little solar heat. The percent of absorbed heat increases quickly with the addition of pigment. To minimize cooling costs, use a paint color as close to white as you can tolerate.

2.4.2 Radiant Barriers

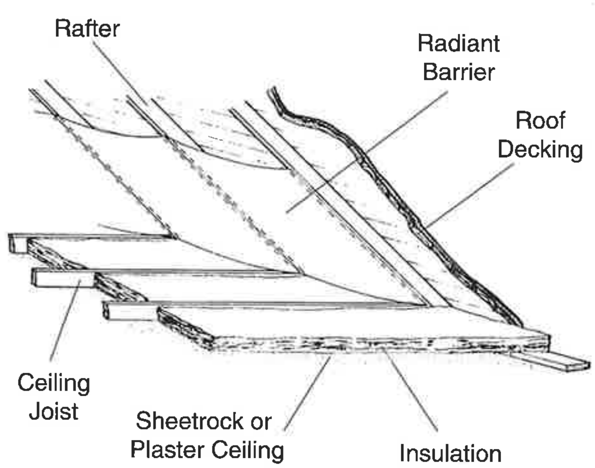
A radiant barrier blocks radiant heat transfer between the roof and the ceiling of a home. The radiant barrier is a sheet of aluminum foil with air spaces on one or both sides.

A radiant barrier cuts air conditioning costs by blocking most of the heat flow that radiates from the roof downward into the attic insulation. In the spring and fall, radiant barriers may allow you to cool with ventilation and air circulation instead of with air conditioning. Radiant barriers can make porches and garages more comfortable, too.

An aluminum foil radiant barrier can block up to 95 percent of the heat radiated down from the roof, and save 2 to 10 percent of total cooling costs. **Insulation is a better investment than radiant barriers wherever the climate demands both heating and cooling.** Homes with dark-colored roofs will benefit most from radiant barriers.

Radiant barriers should be installed on the bottom of the rafters or the top cord of the roof truss as shown in figure **2-6**. Don't install the radiant barrier horizontally directly over the ceiling insulation because the shiny surface facing the roof will collect dust, reducing its effectiveness. If the radiant barrier is installed horizontally, it could also cause moisture problems.

Install a radiant barrier on a cool,



***2-6 Radiant Barriers** - Radiant barriers reduce cooling costs in hot, sunny climates. Attach the radiant barrier to the bottom of the rafters as shown here, or to the side of the rafters.*

cloudy day. Use plywood walk boards or wood planks over the ceiling joists for support. Installation is quicker and easier when working with a partner. **Caution:** *If you must walk around the attic without walk boards, be sure to walk on the ceiling joists and do not step between them, or you may fall through the ceiling.*

Staple the foil to the bottom of the rafter (*as shown in figure* **2-6**) or to the side of the rafter. Don't worry about small tears or about getting the material airtight. Staples should be spaced closely, 2 or 3 inches apart, to prevent air circulation in the attic from eventually loosening or detaching the radiant barrier. A thin bead of construction adhesive applied by a caulking gun to the rafters makes the installation permanent.

Install radiant barriers on the interior side of gable walls and attics above attached garages, to maximize the benefit of radiant barriers. When building new homes, contractors often staple the radiant barrier to the underside of the roof decking, or drape the radiant barrier over the trusses from the top, before nailing the decking onto the roof trusses.

Researchers at Oak Ridge National Laboratory found radiant barriers to be a good investment in hot, sunny locations like Miami, Phoenix, Orlando, and Las Vegas, if installed in an attic with R-11 insulation at a cost of between 20¢ and 35¢ per square foot. However, if the attic has R-19 insulation or greater, radiant barriers are not a very good investment.

2.4.3 The Importance of Insulation

Attic insulation saves money on mechanical cooling and keeps homes comfortable. Insulation reduces the conduction of heat from the hot attic through the ceiling and into the home (*see figure* **2-5**).

The resistance of various thicknesses and types of insulation to heat flow is measured by the R-value (*see Table* **2-D**). The greater the R-value, the more slowly heat conducts through the insulation.

Insulate a new home to a minimum of R-19. The extra value of R-30 insulation is certainly worth the cost. Be sure to consider heating costs, too, in determining insulation levels. You should be able to install R-19 in your attic for between 40¢ and 55¢ per square foot.

Adding R-19 to an existing insulation level of R-11 makes good economic sense in all but the hottest climates. Adding another R-19 to an existing insulation level of R-19 makes sense for the northern half of the U.S.

Roof color is also important when determining the need for more attic insulation. Attics under darker-colored roofs need more insulation because they are hotter.

R-Values of Common Attic Insulation Materials Per Inch of Thickness

Fiberglass Batts	2.9-3.1
Fiberglass Blowing Wool	2.9-3.2
Mineral (Rock) Blowing Wool	2.5-3.0
Cellulose Blowing Insulation	3.2-3.5
Vermiculite	2.1
Polystyrene Beads	2.3

Table 2-D

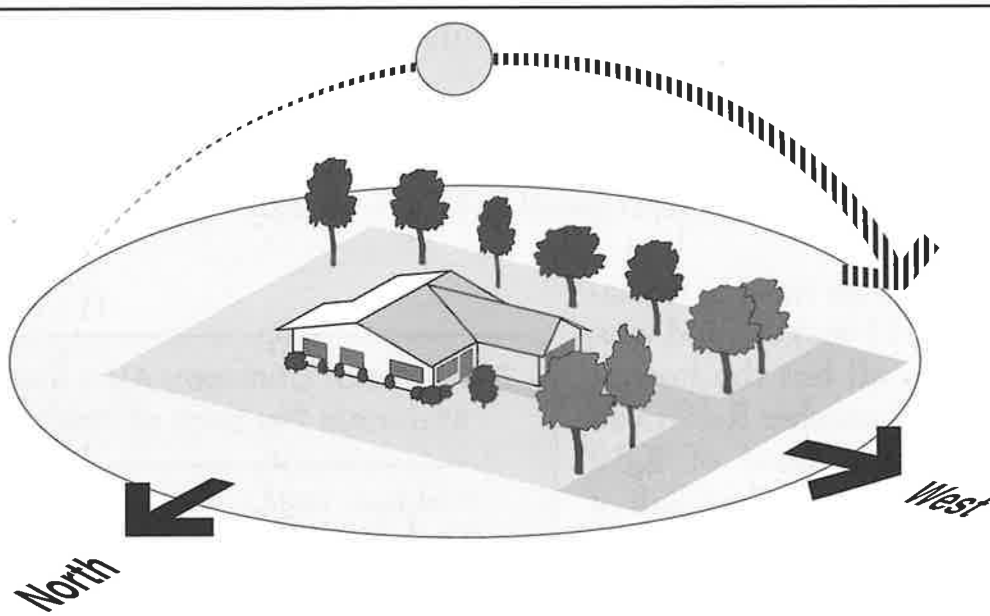
Wall insulation is not as important as attic insulation because the outdoors is not as hot as an attic in the summer. Floor insulation is not an important consideration for cooling energy savings.

2.4.4 Shade Trees, Vines, and Trellises

Planting trees and shrubs is an important way to reduce heat gain. Trees shade the roof, walls, and the ground around the home (*see figure* 2-7). Air drawn into the house from shaded areas is cooler. **Shade trees are probably the best long term investment available to reduce cooling costs.** A well-planned landscaping program for an unshaded home should save from 20 to 40 percent of air conditioning costs and return a homeowner's investment in less than 8 years, according to researchers at Florida International University.

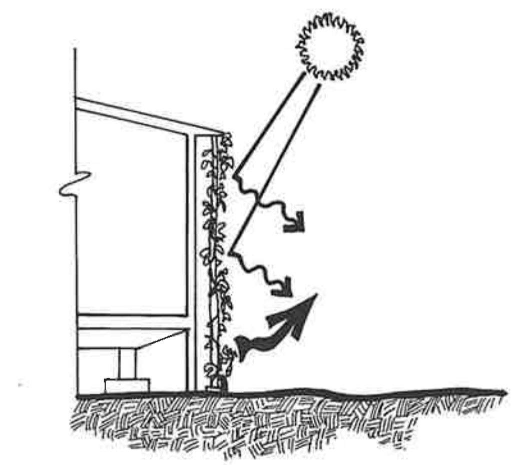
2-7 Natural Cooling With Vegetation *- Reduce paved areas and plant shade trees, shrubs, and vines to cool the south and west sides of the home.*

Deciduous trees planted to the south, east, and west (*see figure* 2-8) of your home will shade the walls, roof, and windows during the cooling season. The most important priorities for shade are the west wall



2-8 Plot Plan for Tree Planting *- Plan the location of shade trees to shade the south and west windows and walls. Trees will shade the roof, too, as they mature. Trees on the south should be closer to the house and taller than trees on the west.*

and west-facing windows. A tree that shades the walls and roof in the afternoon can reduce the wall and roof temperature by 15° to 30°F. Shading the outdoor unit of the air conditioner can increase the efficiency by 5 to 10 percent (*see figure* **2-10**).

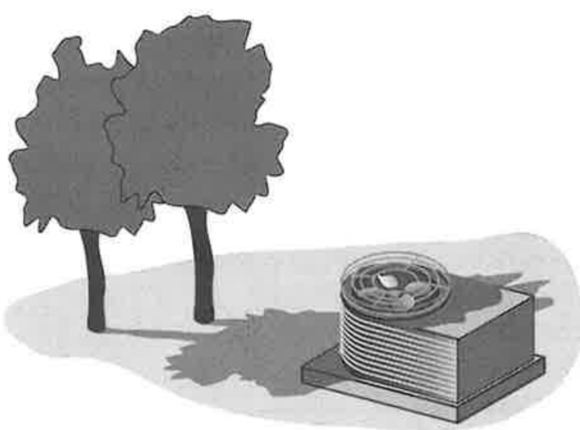


2-9 Plants and Vines Used for Sunscreen *- A lattice and vines are effective for shading a wall.*

Plant hardy, fast-growing trees or larger specimens of medium- to fast-growing trees. A six to eight foot deciduous tree planted near the home will shade windows the first year and, depending on the species and the home, will shade the roof in five to ten years.

Watering and fertilizing trees will maximize growth, health, and foliage. Drip irrigation is the most efficient way to water trees. Roots of trees planted close to a house could disrupt foundations or underground pipes. Trees with brittle branches must be planted at least fifteen feet away so that falling branches do not hit the house during a storm. Proper planting is vital for the tree's survival and growth

Think about the mature size and shape of the trees you plant. Plant trees on the south that have a spreading canopy to shade the roof within 7 years of planting. Trees on the west can be shorter and rounder to block the heat rays coming from a lower angle. Find out how much watering and other maintenance the tree requires before you choose. See Appendix F for more information on selecting and planting trees.



2-10 Shading the Condenser *- Planting trees to shade the condenser unit will increase the efficiency of the air conditioning system.*

Shrubs, especially taller varieties, can also optimize landscaping by shading the walls and the ground adjacent to the home. Shrubs also absorb reflected heat from sidewalks and driveways before it hits the house. Find out how large the mature shrub will be so you can plant it close to the house while still allowing a foot or so breathing space between the full-grown shrub and the wall of the home.

Vines and trellises are good sun blocks and they allow cooling breezes to flow through them. Form a screen with lattice (*see figure* **2-9**), a trellis with climbing vines, or a planter box with trailing plants. Many vines provide shade in the first growing season. Plant either annual vines, climbing plants such as runner beans, sweet peas, or morning glories, or perennials such as wisteria and clematis. Full-grown vines can be quite heavy and may need a strong support structure. This structure should be built with sturdy weatherproof materials.

For information on what plants and trees grow well in your area, contact your county extension agent or local nurseries. Landscape architects can help you plan your landscape. Nurseries and landscape contractors usually offer design and planning assistance.

2.4.5 Window Films and Interior Window Treatments

Metallized, plastic window films like those used to tint automotive windows can save substantial amounts of cooling energy when applied to existing glass. Shiny metal flakes or metal vapors deposited on a plastic film reflect the solar radiation back outdoors. Metallized films reflect 50 to 75 percent of the solar heat hitting a window (*see Table 2-E*).

Reflective window films installed on the interior side of the glass repel solar heat and reduce glare and fading through single-pane glass in south-, east-, and west-facing windows.

Special all-season metallized films, sometimes called Low-E films, also reflect heat energy from inside the home back outside. These films are more cost-effective than films that merely reflect solar heat, in all but the hottest, sunniest climates. Low-E films transmit more visible light and look clearer than reflective films from indoors.

Window films (both all-season and reflective) come in different types for different climates. In sunny southern climates, use a film that stops most of the solar heat and glare. In more northern climates, use a film that lets more light and heat into the home. **Caution:** *Do not use reflective metallized window films on the inside of double-paned glass because it may lead to glass breakage.*

Installing window films is a moderately difficult do-it-yourself project. The films designed for do-it-yourselfers have a protective layer to remove and may be

Percent of Solar Heat Blocked by Various Window Shading Devices

Treatments for Single-Pane Glass (Includes a single pane of clear glass)

Sun Screen (indoors)	20-30%
Colored Venetian Blind	25-40%
Draperies (light colored)	40-55%
Opaque Rolling Shade (dark)	45-50%
White Venetian Blind	45-50%
Window Films	40-75%
Light-Transmitting Rolling Shade	60-70%
Sun Screen (outdoors)	65-75%
Opaque Rolling Shade (white)	75-80%
Aluminum Louvered Sun Screen	80-85%
Awnings	50-90%

Table 2-E Solar Heat Blocked - *The table above shows the approximate percentage of solar heat blocked by different types of glass and shading devices. There is no universally accepted test for measuring the percentage of window shading.*

installed for $1 or less per square foot. Insist on a warranty for materials. Expect to pay $2 to $5 per square foot for professional, guaranteed installation.

Modern window films have a scratch resistant coating and can be cleaned with soapy water and a soft cloth. Lower-quality window films may become cloudy or deteriorate due to intense sunlight, harsh cleaning fluids, or abrasion from rough towels.

Window films are probably the best shading method for sliding glass doors in unshaded areas. Window films also work well on outwardly opening windows which are unsuitable for exterior sun screens. However, removable sun screens are better than window films if you want solar heating during the winter.

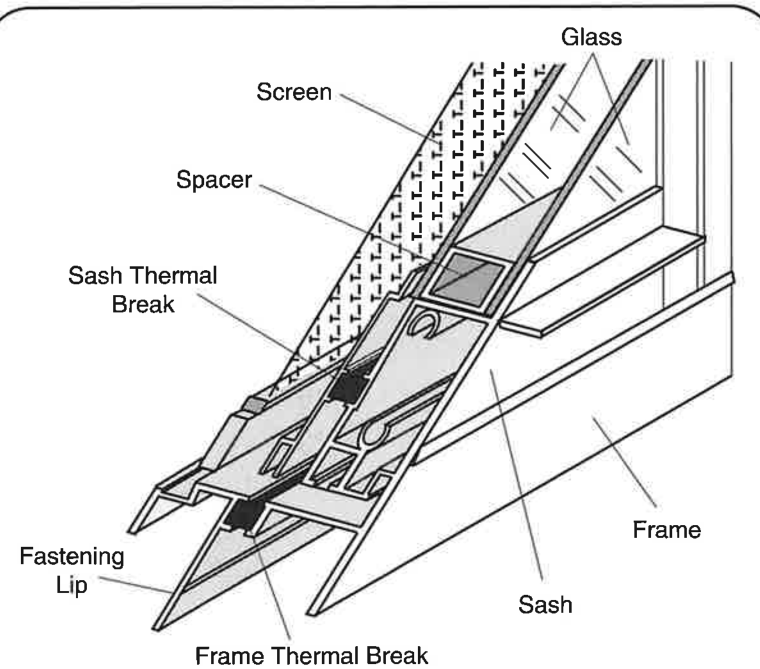
Interior shades, blinds, and draperies are effective at shading if they have a reflective white surface facing the outdoors. The white surface reflects direct sunlight and heat radiating from the warm glass.

Opaque rolling shades with a white outer surface block up to 80 percent of the solar heat which strikes the window. White venetian blinds and draperies with white linings also reflect heat well (*see Table* **2-E**). The disadvantage of shades and draperies is that they must be closed to be effective. Blinds block 30 to 50 percent of the solar heat when partially open.

2.4.6 Windows

If you plan to replace the windows in your home there are a variety of options for specialty glass designed to reduce cooling costs. In very hot, sunny climates where heating costs are not significant, single-pane glass with a reflective coating may be a good option. Reflective glass looks like a mirror from the outside and will color the outdoors gray or bronze when looking from the inside. This tinted, reflective glass blocks much of the visible light from the sun in addition to the heat rays. Some people object to the tint and low levels of visible light transmitted by reflective glass.

Newer types of coated, reflective glass transmit most of the visible light while blocking most of the heat rays. These so-called "Low-E" or selective coatings for new windows are installed on one or another of the interior glass surfaces of a



***2-11 Double-Pane Window** - High-performance glass with special coatings to reflect heat is packaged in modern double-pane windows.*

double-pane window—depending on whether heating or cooling is the primary energy concern (*see figure* **2-11**). The standard Low-E glass double-pane, designed primarily to reduce heat loss in the heating season, also significantly reduces heat gain during the cooling season. Low-E double-pane glass performs very well at saving heating and cooling energy in most areas of the country. And, some of these new coatings are specially designed for southern climates. These hot-climate Low-E coatings are designed to block more solar radiation than the standard Low-E windows while transmitting more visible light than tinted, reflective glass (*see Table* **2-F**). They also help reduce heat loss through the windows during the heating season.

Solar and Visible Transmittance for New Window Glass

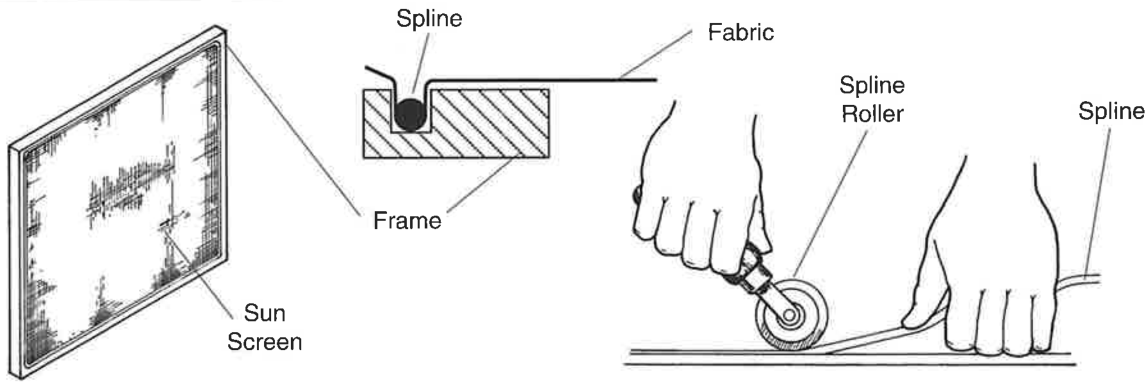
Glass Type	Solar Transmittance	Visible Transmittance
Single-Pane	85-90%	90%
Single-Pane Reflective	25-30%	30%
Double-Pane	70-80%	80%
Double-Pane Low-E (standard)	55-65%	75%
Double-Pane Low-E (hot climate)	45-50%	50%

***Table 2-F** shows the approximate solar and visible transmittances of two types of single-pane glass and three types of double-pane glass.*

Low-E windows have R-values that range from 2.5 to 3.5 depending on the coating and whether air or argon (which insulates better than air) fills the space between the panes. In contrast, single-pane glass is about R-1 and double-pane glass is about R-2. The R-value is more important in the heating season than the cooling season, but windows with higher R-values save significant cooling energy, too. Most new windows have low air leakage rates—so, the leakage rate is not a very important characteristic for comparison shopping.

Replacing your windows is an expensive way of reducing your cooling costs compared to the other window options discussed in this guide. However, new windows can give you a variety of other benefits: reducing solar gain to a minimum, transmitting visible light, preserving the view, and enhancing the value and appearance of your home. If you plan to replace your windows, then the newer glass products for windows are very cost-effective compared to standard glass. In choosing glass for your new windows, look at the following performance factors:

- Total Solar Transmittance - The percentage of total solar radiation tranmitted by a window.
- Visible Transmittance - The percentage of visible light transmitted by a window.
- R-Value - The resistance of a window to the conduction of heat through the window.
- Shading Coefficient - A decimal number like .55 which compares the



***2-12 Sun Screens** - Sun screen fabric is stretched onto a metal frame and held in place by a plastic spline inserted in a track.*

transmittance of a window assembly with clear glass which has a shading coefficient of 1.00. A window with a shading coefficient of .55 would transmit 55% of the solar energy of single-pane glass.

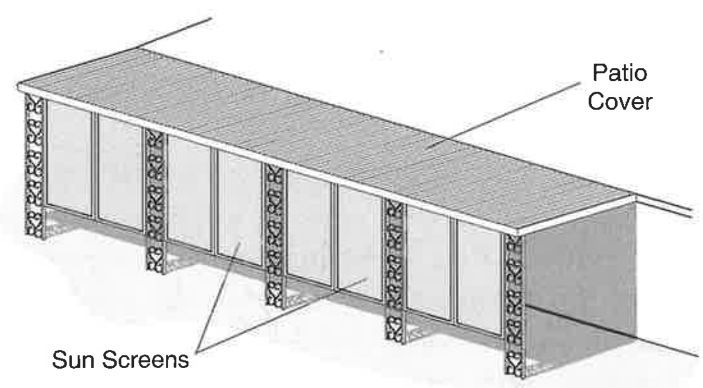
2.4.7 Sun Screens

Sun screens are constructed like insect screens. The sun screening is stretched onto an aluminum frame and held in place by a plastic spline pushed into a track (*see figure* **2-12**). **Sun screens are often the least expensive window shading option which still allows a view.** You can remove them during the winter to let solar heat in.

Sun screens, like window films, are a good substitute for awnings when headroom or price prevents the use of awnings. They don't work on outward-opening jalousie and casement windows because exterior sun screens would prevent the window from opening. Putting the screen inside allows solar heat to penetrate the home (*see Table* **2-E**). Sun screen walls installed outdoors shade patios from the sun in hot climates (*see figure* **2-13**).

The fabric used on sun screens is designed to absorb and/or reflect 65 to 70 percent of the solar heat before it enters the home. Sun screen fabric is available in a variety of colors.

A different type of sun screen, made of aluminum with tiny louvers, blocks out about 85 percent of the solar heat. Expect to pay



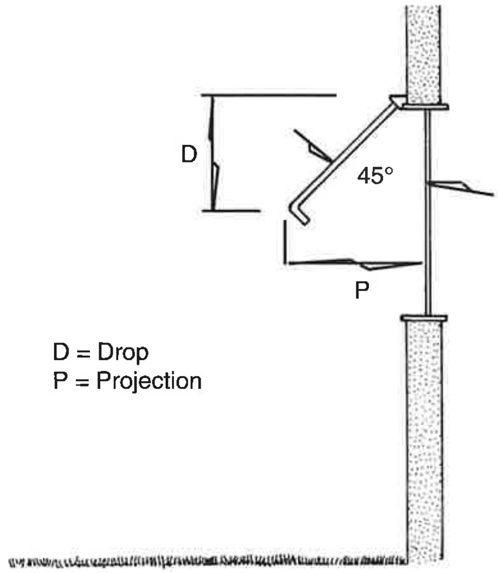
***2-13 Shaded Patio** - An aluminum patio cover and a wall of large sun screens shade west windows and the patio area.*

from $2 to $4 per square foot for professionally-installed sun screens. The aluminum-louvered sun screens are $5 to $6 per square foot.

Sun screens are not easy do-it-yourself projects. Kits are available but your final product probably won't last as long as a professionally-built sun screen.

2.4.8 Awnings

Awnings are usually more expensive than window films and sun screens. However, they are very effective at shading because they intercept the solar heat before it gets to the window. Awnings are popular in hot, sunny climates. Custom-made canvas and aluminum awnings can be fairly expensive and are not as cost-effective as shade trees, window films, and sun screens. However, some awning companies sell do-it-yourself awnings that are only slightly more expensive than sun screens and window films (*see figure* **2-15**).



***2-14 Awning Parameters** - The drop of the awning determines how much shade it gives. East and west windows need more drop than south windows to provide the same amount of shade. 45° is a pleasing angle to the eye for mounting an awning. Make sure the awning doesn't project into the path of foot traffic unless its lowest point is at least 6 feet 8 inches from the ground.*

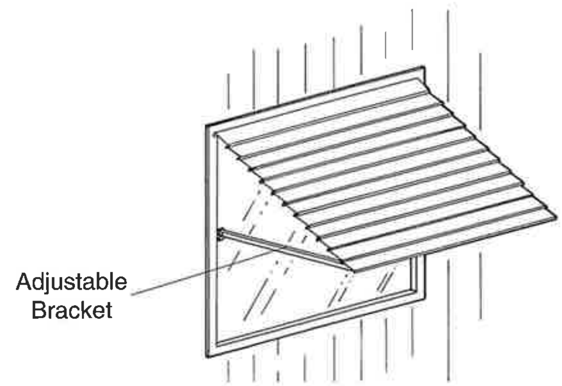
The three most important considerations in selecting and designing awnings are: the amount of shade desired, the importance of maintaining the view out of the window, and the appearance of the awning.

The amount of shade that an awning will produce is most closely related to the distance that the awning drops down over the window. This distance is referred to as the "drop" of the awning (*see figure* **2-14**). Awnings on the south side block solar radiation coming from higher in the sky. They need a drop measuring 45 to 60 percent of the window height. Awnings on the east and west should have a drop of 60 to 75 percent to block solar radiation coming from lower in the sky.

Awnings with sides in addition to a top provide the most effective shade on south facing windows. Do-it-yourself awnings usually do not have sides but this can be partially compensated for by making the awning wider than the window. The greater the drop of the awning the more the view is reduced, so you may have to compromise between shade and view.

Awnings with slats rather than a solid surface (*see figure* **2-16**) will allow some limited viewing through the top of the window. A patio cover can shade large windows that are grouped together in one area of a home (*see figure* **2-13**).

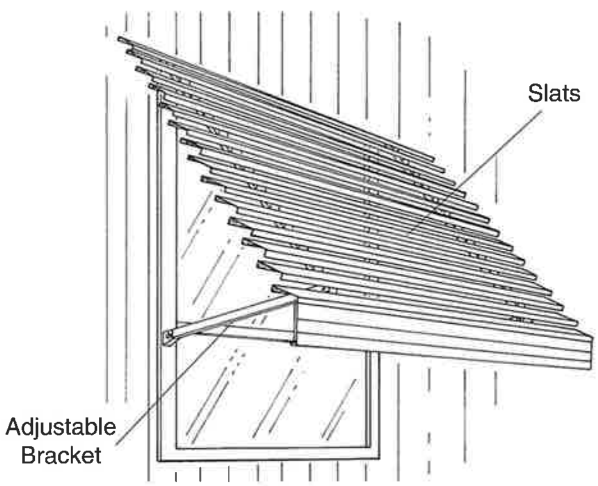
Canvas and other fabric awnings are more attractive than metal awnings. But they are also more expensive and slightly less effective because they absorb more solar heat. Fabric awnings are more difficult to maintain and have a shorter life span than metal awnings.



2-15 Aluminum Awnings *- Awnings like this are sold as do-it-yourself kits. They include adjustable mounting brackets and fasteners.*

Consider these factors when locating awnings: the direction your windows face, how much wall space your windows cover, the amount of roof overhang, and the location of natural shade. North-facing windows and windows with good natural shade don't need artificial shading.

It can be difficult to strike a perfect balance among the important factors of shade, view, appearance, and cost in selecting an awning. Awnings for tall narrow windows may need to be considerably wider than the window for a more balanced appearance. Awnings installed at a 45-degree angle seem most attractive (*see figure* **2-14**). If a maximum amount of view is important, use sun screens and window films instead of awnings.



2-16 Slatted Awning *- The slatted construction of this do-it-yourself awning allows limited viewing through the top of the window between the slats.*

Local building codes may have restrictions on materials, construction, or installation of awnings, particularly in areas where hurricanes or earthquakes are possible. Maintain headroom above driveways and sidewalks for safety. Check with your local building department before purchasing or installing awnings.

Notes:

3.1 Introduction

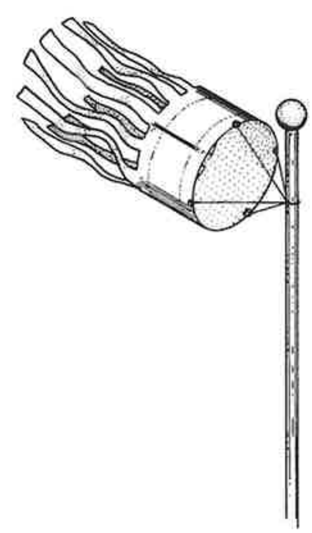
Ventilation brings fresh air into your home and can save up to 50 percent on cooling costs.

Ventilating works when the temperature inside is higher than the temperature outside. You can replace hot, stale, indoor air with cooler, fresh air from outdoors. (Solar gains and internal gains make indoor temperatures higher than the temperature outdoors; *see Section 2.2 Reducing Internal Gains, and Section 2.4 Reducing Solar Gains.*)

Several factors affect ventilation. Shade cools the air surrounding the house and reduces the accumulation of solar heat indoors. The more shade you have, the more ventilation can substitute for air conditioning.

Another factor is calm air versus moving air. Constantly moving air in the house feels cooler than calm air at the same temperature. Use ceiling fans and oscillating fans to maintain air movement in your home throughout the cooling season (*see Section 3.6, Indoor Air Circulation*).

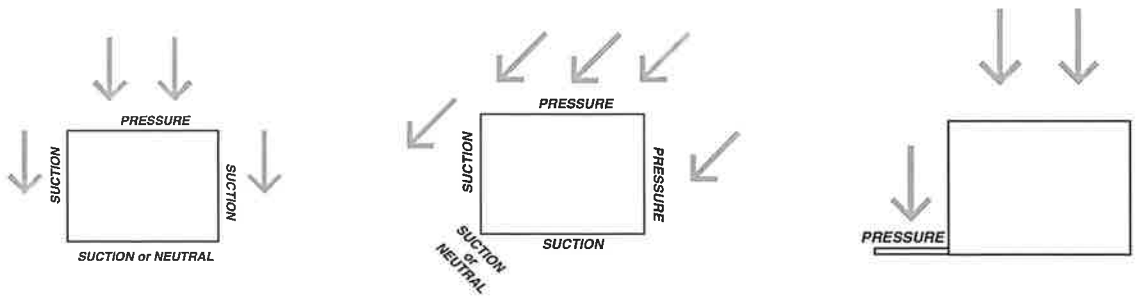
A third factor affecting ventilation is humidity. Ventilating during very hot and humid weather may not be effective if you use air conditioning most of the time. Air conditioners remove moisture from the air; opening the house to ventilate each day replenishes the indoor humidity. Air conditioning costs could actually be increased as much as 20 percent as the air conditioner works to remove the moisture every day. Outdoor air temperature should drop below 70°F before ventilating during humid weather.



***3-1 Wind Sock** - Natural ventilation takes advantage of prevailing winds. Wind socks show the direction of the breezes around your home.*

Florida Solar Energy Center researchers found that when apartments were ventilated at night during very humid weather, the water removed by the air conditioner increased from about 7 liters to about 26 liters a day.

Most people are uncomfortable when the relative humidity of the air is above 70 percent, or when the dew point is above 68°F. The dew point is the maximum temperature of a surface (like a glass) on which water from the air will condense. (*See Section 1.3, Elements of a Comfortable Environment.*)



***3-2 Natural Ventilation** - Wind creates areas of pressure and suction around a home depending on the direction of the wind. Air flows in on the pressurized windward side. Air flows out due to suction on the leeward side. Solid objects can dam the wind and create a pressurized area.*

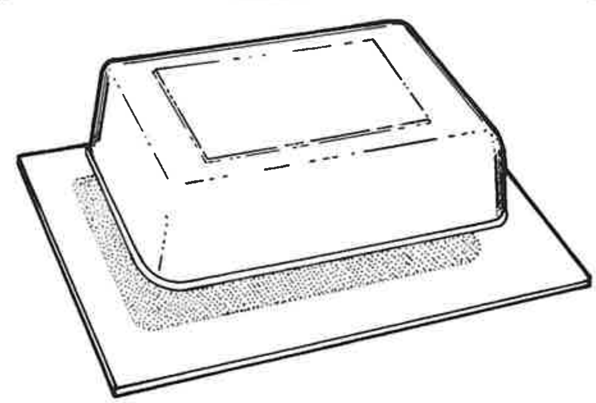
3.2 Natural Ventilation

Natural ventilation maintains indoor temperatures close to outdoor temperatures, and helps remove heat from the home. You should ventilate during the coolest parts of the day and night, and close the windows during the hottest periods.

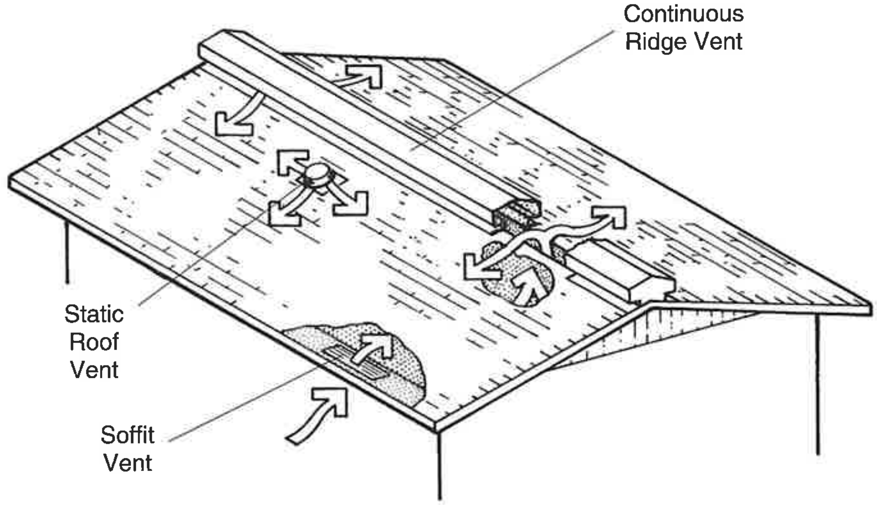
A little wind allows you to ventilate successfully without fans until outdoor temperatures rise above 85° F. Wind creates areas of pressure and suction around the house. It will take some testing to determine which windows to open to maximize the benefits of natural ventilation. The windows near pressurized outdoor areas will be the cool air inlets, and windows near suction areas will be the warm air outlets.

Wind socks or wind vanes help determine the wind direction when deciding what combination of windows to open for maximum air flow (*see figure* **3-1**). Walls facing the wind are pressurized, and walls facing away from the wind are under suction or neutral pressure. Wind blowing parallel to a wall of the house generally creates strong suction at the window. Fences, thick hedgerows, or other buildings near the home can dam the wind and create a pressurized area, or channel the wind along a wall and create suction. Figure 3-2 shows areas of wind-caused pressure and suction around a home.

Inlets and outlets located directly opposite each other cool only those areas in the direct path of the air flow. More of your home will be cooled if the air must take a longer path between the inlet and outlet. Use smaller window openings for the inlets and larger openings for the outlets. This increases air speed and improves the cooling effect. Remember that air from shaded out-



***3-3 Static Roof Vent** - This type of roof vent ventilates isolated sections of an attic. It is most effective combined with soffit and/or ridge vents.*



***3-4 Effective Attic Ventilation** - The most effective way to ventilate an attic without fans is to place the intake vents low, in the soffit; and place the exhaust venting high, in a continuous ridge vent.*

door areas is cooler and enhances natural ventilation.

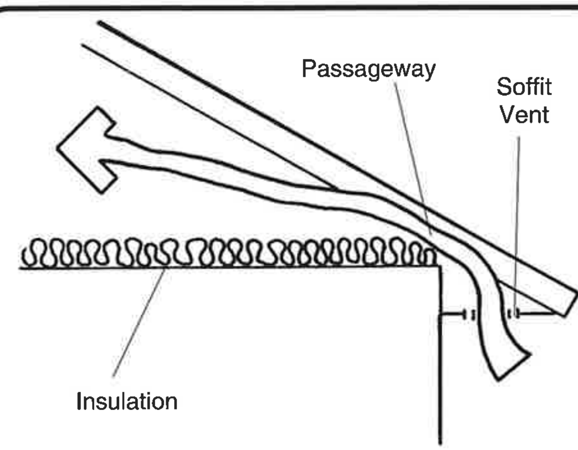
Ventilation in two-story homes can be increased by using the natural buoyancy of hot air. Using windows that are low on the pressurized (windy) side of the home for intakes and high windows on the leeward side for exhaust can enhance ventilation through two-story homes. However, the wind is stronger and less obstructed by objects on the ground at second story windows, so they can be good air intakes, too.

Experiment with different patterns of window venting to move fresh outside air through all the living areas of your home. This may involve leaving some windows closed if they interfere with moving air along a longer path through the house.

When you know how air moves naturally, you can decide how fans might enhance ventilation.

3.3 Attic Ventilation

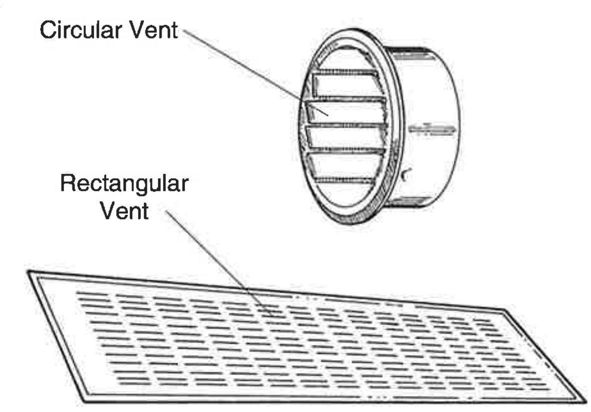
There are two important reasons to ventilate an attic: to eliminate moisture that may accumulate in the insulation and other building materials during the colder months, and to cool the hot attic during the summer months.



***3-5 Air Flow for Soffit Ventilation** - Make sure your insulation does not block the air passage between the soffit and the attic.*

The need for attic ventilation varies with the local climate and the construction of your home. Homes in dry, windy areas will need less attic ventilation than homes in calm, humid areas. Attics under dark-colored roofs need better ventilation than attics under light-colored roofs.

Water condenses out of warm, moist air as the temperature cools. Much of the moisture that accumulates in attics during cold weather comes from the living spaces below, as warm air rises into the attic through unsealed areas (*see Section 2.3, Reducing Air Leakage*). Sealing the leaks in the ceilings is more effective than increasing the attic ventilation.



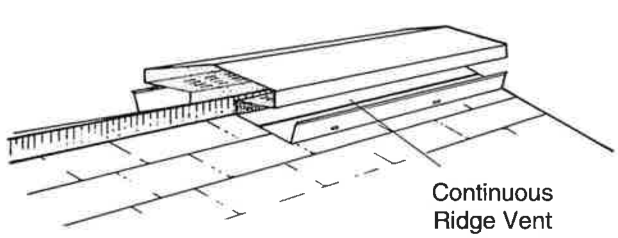
***3-6 Soffit Vents** - Circular vents fit into 2- to 4-inch holes placed close together. Rectangular vents provide more free-vent area and can be spaced farther apart.*

Condensation in summer may be caused by cool air leaking from cooling system ductwork. Attic ventilation is needed in even the driest climates to remove dampness caused by roof leaks or condensation.

Attic ventilation also serves an important cooling function. The outside temperature and the amount of attic insulation determine how much heat flows into the home through the ceiling. The temperature of your ceiling influences both comfort and cooling costs. The greater the airflow through the attic, the cooler the attic and the indoor ceilings will be. **In some cases, effective attic ventilation can save 10 percent or more on cooling costs.**

There are three primary ways to cool your attic: install a reflective roof color (*see Section 2.4.1, Roof and Wall Reflectivity*); use radiant barriers (*see Section 2.4.2, Radiant Barriers*); and provide ample ventilation.

Good attic ventilation allows an even flow of air through all parts of the attic. Most attics do not have an evenly distributed flow because they are vented by a few randomly spaced roof vents. This type of attic venting tends to ventilate some areas and leave other areas unventilated. A better ventilating scheme uses ample soffit vents and a continuous ridge vent (*see figures* 3-4 *and* 3-7). Static vents, as shown in figure 3-3, should be located higher on the leeward side of the roof as exhaust vents, or lower on the windward side of the roof as intakes. The wind provides some pressure and suction to move ventilating air through the attic.



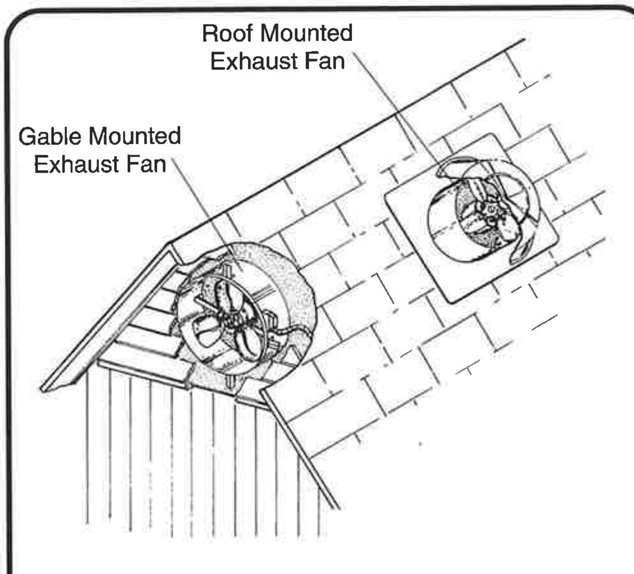
***3-7 Continuous Ridge Vent** - This continuous high vent allows the hottest air to flow out of the attic. Installation: cut the roofing back about 2 inches on each side of the peak. Then cut and remove 1 to 2 inches of roof decking on each side of the peak. Install the ridge vent.*

Attic insulation near the eaves must leave a path for ventilating air that comes through the soffit vents into the attic (*see figure* 3-5). Existing insulation can be packed down at the eaves to facilitate the flow of air through the attic.

To determine your attic ventilation

needs, calculate the square footage of the attic. You will need from 1/2 to 2 square inches of "net free" area per square foot of attic. Cool, dry, windy climates need less ventilation while hot, sunny, humid climates need more. Homes with whole-house fans or evaporative coolers with up-ducts need the most attic ventilation and represent the higher end of the above recommendations (*see Section 4.2.1, Sizing and Selection*).

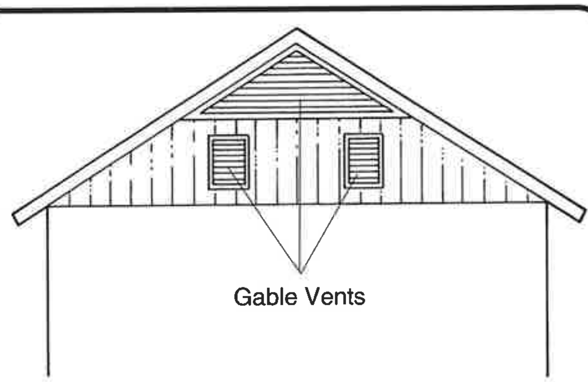
Most vents are marked with their "net free" area. This figure takes into account the resistance offered by screening, louvers, and weather coverings. Installing insect screen on a vent reduces its effective area or net free area in half. Determine the total number of vents needed, and install half of them as lower intake vents and half as higher exhaust vents.



***3-8 Power Attic Ventilator** - Power exhaust fans mounted on the roof or in an attic gable are expensive, but effective, ventilators. Use power ventilators as a last resort when other venting methods won't work.*

Power attic ventilators are exhaust fans controlled by thermostats that turn on at a set temperature between 110°F and 140°F. They are an expensive but effective venting strategy used as a last resort for attics under dark-colored roofs, and for attics with moisture problems.

Place a power attic ventilator near the top of the roof on the leeward side of the house (facing away from the prevailing winds). Or, mount the fan in the leeward gable (*see figure* **3-8**). Provide at least one square foot of net free intake area for every 300 cfm of fan capacity. The American Ventilation Association recommends 1 cfm per square foot of attic floor space. Therefore, if your attic is 1200 square feet, you'll need a 1200 cfm fan, with 4 square feet of net free intake area. Power attic ventilators are rated at between 700 and 2000 cfm.

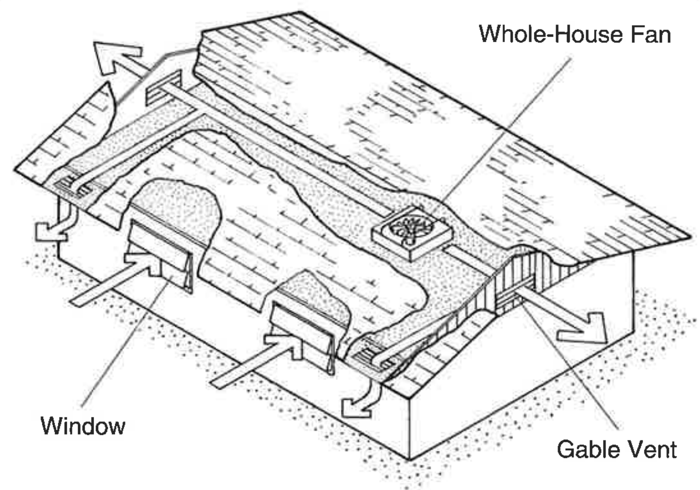


***3-9 Gable Vents** - Large gable vents are useful for releasing exhaust air from whole-house fans and evaporative coolers that use up-ducts. See Sections 3.4 and 4.2.1.*

3.4 The Whole-House Fan

A whole-house fan can substitute for air conditioning during spring, fall, and mild weather (*see figures* **3-10** *and* **3-11**). Whole-house fans combined with ceiling fans and portable fans provide acceptable summer comfort for many families, even in hot weather. They can reduce indoor temperatures 3 to 8 degrees, depending on outdoor temperatures. **You can expect a 15 to 55 percent reduction in air conditioning costs through the prudent use of a whole-house fan.**

The whole-house fan pulls air in from open windows and exhausts it through the attic and roof. It provides good attic ventilation in addition to whole-house ventilation (*see figure* **3-10**). You can regulate cooling by simply closing windows in the unoccupied areas and opening windows wide in occupied areas. Most people cool the bedrooms at night and the living areas during the daytime.



***3-10 Whole-House Fan** - These fans exhaust air through the attic and attic vents, and cooler air flows through open windows.*

Whole-house fans should provide homes with 15 to 40 air changes per hour. The rate of air change depends on your climate and how much you depend on the whole-house fan for cooling. Cooler, shadier areas don't require as much ventilation as warmer, sunnier ones. Homes entirely dependent on whole-house fans require a higher ventilation rate.

Whole-house fans range in diameter from 24 inches to 42 inches, with capacities ranging from 3,000 to 10,000 cubic feet per minute (cfm). The capacity of the fan in cfm is rated for two different conditions: 1) free air; and 2) air constricted by 1 inch of static pressure. The second condition is closer to the actual operating conditions of the fan in a home, and the cfm rating at 1 inch of static pressure may still be 10 to 30 percent higher than the actual volume of air moved by the installed whole-house fan. This means you should probably install a fan with a greater capacity than the sizing recommendations that follow would recommend.

Whole-house fans require 2 to 4 times the normal area of attic vent openings (*see figure* **3-9**). Install a minimum of 1 square foot of net free area for every 750 cfm of fan capacity. However, more vent area is better for optimal whole-house fan performance because the air flow is less restricted.

The net free area of most manufactured vents is marked somewhere on the vent. (The net free area is about half of the actual area of the vent and accounts for resistance caused by screens and louvers.)

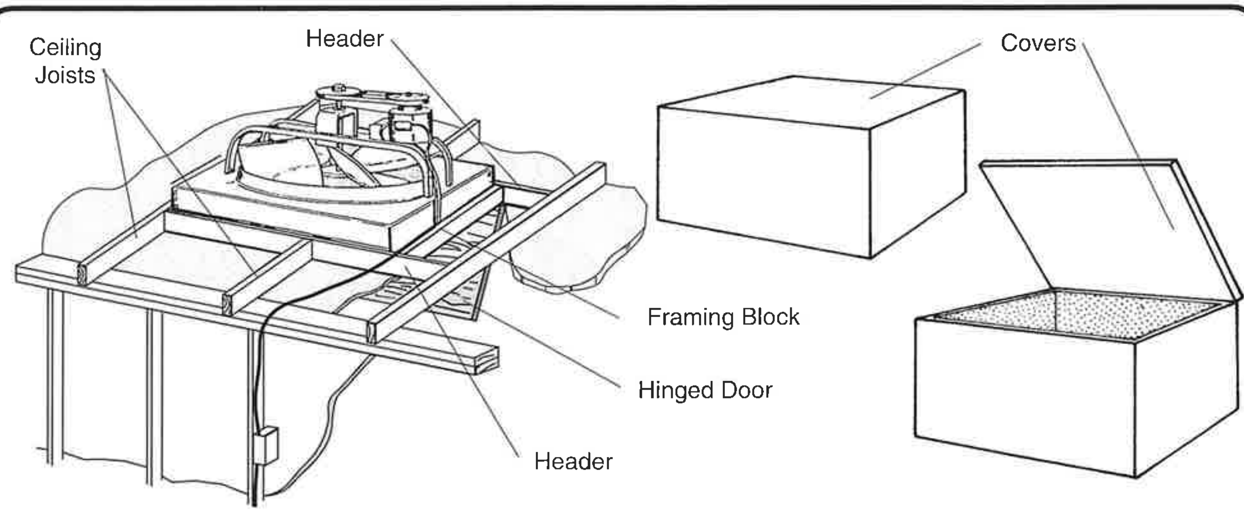
To determine the suitable size of a whole-house fan in cubic feet per minute, first determine the volume of your home in cubic feet. To calculate volume, multiply the square footage of the floor area in your home that you want to cool by the height from floor to ceiling. Take that volume and multiply by 15 to 40 air changes per hour, depending on how much ventilation you want. Then, divide by 60 minutes to get cubic feet per minute of capacity for the whole-house fan (*see formula below*).

$$\text{Whole-House Fan Capacity (cfm)} = \frac{\text{Floor Area (sq.ft.)} \times \text{Ceiling Height (ft.)} \times \text{15-40 Air Changes/Hour}}{\text{60 Minutes/Hour}}$$

A whole-house fan can be noisy. Install the fan on solid supports with rubber or felt gaskets to dampen noise from vibration. A large-capacity fan running at a low speed makes less noise than a small fan operating at high speed. Larger fans also cool the home and attic quickly in the evenings and mornings, when the cooler outdoor air can remove heat that accumulated during the hotter parts of the day.

A 2- or 3-speed fan control is a nice option for a whole-house fan. You can ventilate the entire house quickly at high speed, or just maintain gentle air circulation with less noise.

Follow the manufacturer's instructions for installing a whole-house fan. Most fans provide a template to outline the hole to be cut in the ceiling. One side of that rectangular hole should run along the inside of a ceiling joist (or bottom truss chord). Before you start cutting be certain where the edge of the joist is and check for wires and other obstacles. The distance between

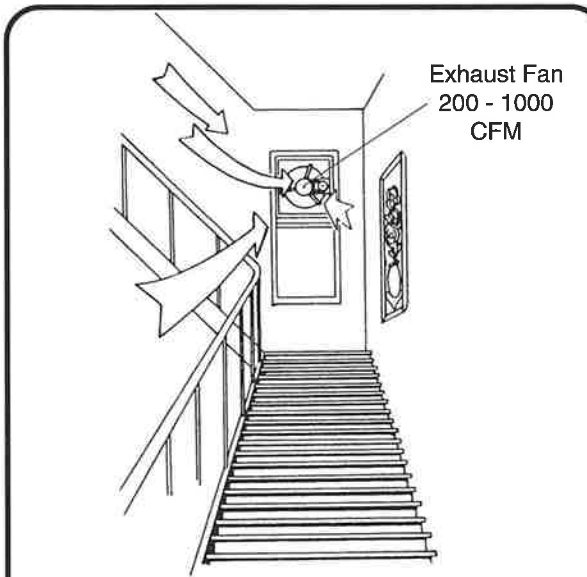


***3-11 Installation of a Whole-House Fan -** This view of a whole-house fan from the attic shows how it is installed. Any one of the three covers shown on the drawings will seal the fan off in the winter.*

joists is usually less than the size of the fan, so you'll have to cut through at least one joist to create a hole large enough for the fan. Build a support consisting of two new headers and a framing piece between them (*see figure* **3-11**). Fasten new framing members securely with screws and adhesive to strengthen the opening and reduce vibration.

Connect the fan to its own 115-volt circuit. This prevents overloading an already busy circuit, and allows you to turn off the breaker in the winter months and prevent someone from accidentally turning the covered fan on and burning out the motor.

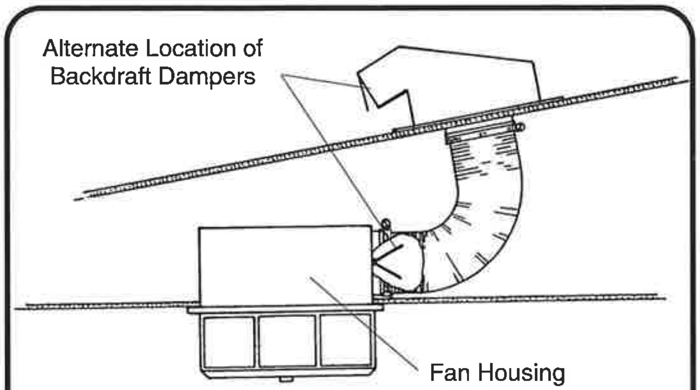
Some fans come with a tight-sealing winter cover (*see figure* **3-11**). If your fan doesn't have such a cover, or if your attic access doesn't allow you to cover the fan easily, then you can fabricate a cover for the grille on the ceiling. A seasonal cover held in place with rotating clips or spring clips and sealed with foam tape works well. If you switch between air conditioning and cooling with a whole-house fan as the summer weather changes, build a tightly-sealed, hinged door for the fan opening that is easy to open and close when switching cooling methods.



***3-12 Window Fan** - A powerful window exhaust fan on the leeward side of the house can ventilate part of a large house or all of a smaller house.*

3.5 Smaller Ventilation Fans

Window fans are best used in windows facing the prevailing wind or away from it to provide cross ventilation (*see figure* **3-12**). Window fans can augment any breeze or create a breeze when the air is still. If the wind direction changes in your area, use reversible type window fans so you can either pull air into the home or push air out, depending on which way the wind is blowing. Experiment with positioning the fans in different windows to see which arrangement works best. **You can save up to 50 percent on cooling costs by ventilating with fans rather than running air conditioners during mild weather and at night.**

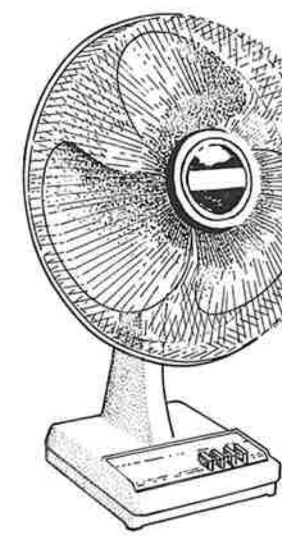


***3-13 Exhaust Fan Backdraft Dampers** - Kitchens and bathrooms need exhaust fans to remove heat and moisture at their source. Exhaust fans must have backdraft dampers to limit air leakage from outdoors.*

Use exhaust fans in the kitchen and bath to remove heat and humidity when cooking and bathing. In humid climates, it makes sense to run the exhaust fan until windows and mirrors are clear of steam. Use a half-hour timer to control the fan, which helps keep the bathroom dry and mold-free. A newer type of control called a dehumidistat can control exhaust fans by the level of humidity in the air. These controls can be very effective at holding humidity at a reasonable level except at times when the humidity outdoors is higher than the setting on the dehumidistat.

New exhaust fans are rated for noise. You'll likely use a quiet fan more than a noisy one, so look for one that produces less than 3 sones of noise. Use larger-size fans (80-100 cfm for a bathroom, 160-200 cfm for a kitchen) if the outlet is connected to flexible duct, because the flexible duct resists air flow more than the fan ratings indicate. It's better to use galvanized steel duct sealed at the joints.

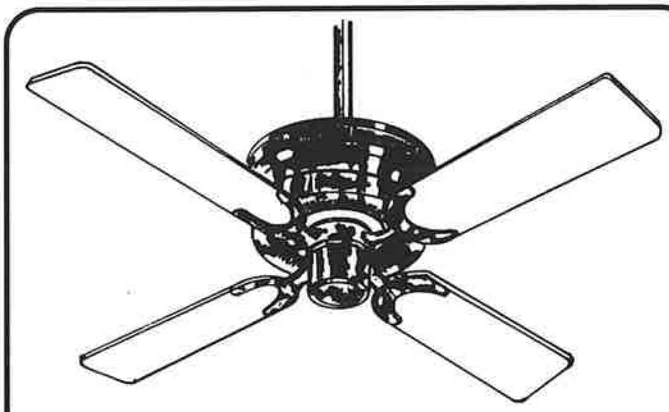
Exhaust fans must vent outdoors. Venting them into the attic can cause moisture problems. Another common problem is air leakage around the fan housing. If the housing is not sealed tightly to the ceiling of the room, then hot, humid air from the attic can leak into your home through the gaps around the housing. Be certain the fan has a backdraft damper in one of the two locations shown in figure 3-13.



***3-14 Oscillating Fan** - The most popular and cost-effective cooling device available.*

3.6 Indoor Air Circulation

Air circulating fans are very effective and should be used with air conditioners, evaporative coolers, whole-house fans, or by themselves. Circulating fans save cooling energy by increasing air movement over the skin to help you feel cooler. Ceiling fans and various types of portable fans provide more comfort at less cost than any other electrically powered cooling strategy (*see figures* **3-14** *and* **3-15**). There are many options: small personal fans can sit on tabletops, or heavier units sit on the floor or on metal stands with wheels.



***3-15 Ceiling Fan** - The low-cost cooling champion of the world. To minimize cooling costs, install one in every room.*

Air circulating fans may allow about a 4 degree rise in the thermostat setting with no decrease in comfort. Savings in cooling costs range from 15 to 40 percent. Scientific tests by P.O. Fanger in 1970 indicated that people feel just as comfortable in gently moving air (1.7 miles per hour) at 82°F as they feel in calm air at 78°F. The same tests showed that a large majority of people said they felt comfortable at a temperature of 82° and a relative humidity of 100 percent—when the air speed around them was 3.4 miles per hour. To take full advantage of this "wind chill effect," install ceiling fans and portable fans in every room and turn up the speed until paper begins to rustle on tabletops. Air speed should be as high as possible without creating a nuisance.

Ceiling fans are the most effective fans for large rooms. Ceiling fans range from 36 to 52 inches in diameter. A 36-inch fan services a room 12 feet by 12 feet or less. Use a 42- or 48-inch fan for rooms up to 14 feet by 18 feet. Larger rooms require a 52-inch fan, or multiple fans.

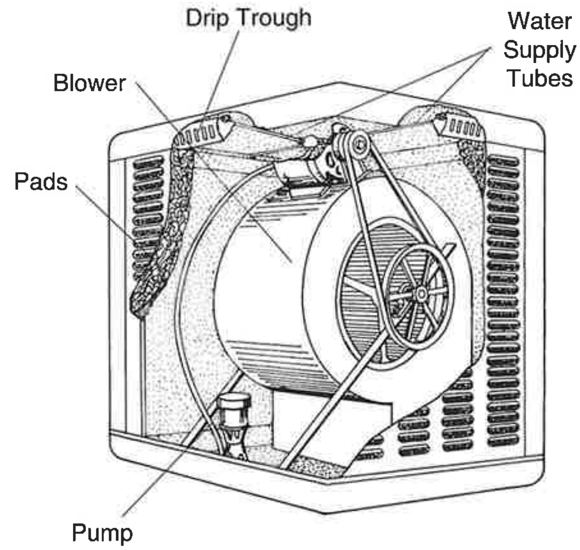
Ceiling fans produce high air speeds with less noise than oscillating fans or box fans. High quality ceiling fans are generally more effective and quieter than cheaper ones. **Ceiling fans are a key element to providing low-cost comfort in your home.** Consider installing one in every room.

Portable circulating fans provide local air circulation and cooling in areas where people spend most of their time. Circulating fans only help in rooms that are occupied. Turn fans off in unoccupied areas.

Notes:

4.1 Introduction

This section provides information on evaporative coolers, room air conditioners, heat pumps, and central air conditioning systems. Each of these mechanical cooling systems cool air through evaporation: evaporative coolers by evaporating water, and air conditioners by evaporating a refrigerant like Freon. You can learn how each type of cooler works, how to perform simple routine maintenance, and how to save energy when using these mechanical cooling devices.



***4-1 Evaporative Cooler** - Most evaporative coolers are down-flow units mounted on the roof. However, ground-mounted units are easier to service.*

Some cooling system service requires specialized experience and training. Cooling equipment that is not properly maintained and serviced can be dangerous and inefficient. Even if you don't do any of the basic service or maintenance yourself, this guide provides enough information about cooling systems so you can purchase high-quality equipment, maintenance, and repair services.

4.2 Evaporative Coolers

Evaporative coolers (also called swamp coolers) are a popular and energy efficient cooling strategy in the warm, dry climates of the western states (*see figure* **4-1**). The lower your summertime relative humidity, the more an evaporative cooler can drop the temperature (*see Table* **4-A**).

Outdoor Temperature	Outdoor Relative Humidity					
	5%	10%	15%	20%	30%	40%
80°F	56°F	58°F	60°F	61°F	64°F	67°F
90°F	62	64	66	68	72	75
100°F	68	70	73	75	79	
110°F	74	77				
120°F	79					

***Table 4-A Evaporative Cooler Performance** - Evaporative coolers reduce the temperature of the outdoor air and provide cooled air to the home. The temperature of the air leaving the cooler, shown in the white area, depends on the outdoor temperature and relative humidity as shown here.*

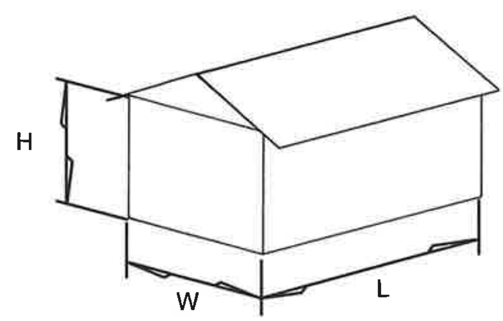
Evaporative coolers use 18 to 25 percent of the energy of air conditioners, and cost about half as much to install. Unlike central air conditioning systems, evaporative coolers provide a steady stream of fresh air to the home.

Evaporative cooler fans move air through absorbent pads that are saturated with water. Some of that water evaporates, reducing the temperature of the hot outdoor air. As this cooler air is forced into the house by the fan, it pushes warmer air out through the windows or out through vents called "up-ducts." The absorbent pads are made of aspen wood fibers, glass fibers, or specially formulated paper.

A water pump in the reservoir pushes water through tubes into a drip trough which then drips water onto the pads (*see figure* **4-1**). A float valve connected to the home's water supply keeps the reservoir supplied with fresh water to replace the evaporated water.

Evaporative coolers operate under different principles than air conditioners. Evaporative coolers reduce air temperature and do not actually remove heat from the air. They compare in performance to an air conditioner with a SEER between 30 and 40, which is 2 to 3 times the SEER of the most efficient air conditioners (*see Section 4.3.3, Ratings for Air Conditioning Systems*).

Evaporative coolers work well when the dew point is below 55°F (*see Section 1.3, Elements of a Comfortable Environment*). When the dew point is above 55°F, conden-



Minutes Per Air Change

Zone 1	Zone 2	Zone 3
3	2	1.5

Cooler Sizing Guide

1. Determine size of area to be cooled:

   Length x Width x Ceiling Height = Cu. Ft. of Interior
2. Select recommended air exchange number from the map chart.
3. Divide air exchange number into cu. ft. of interior:

   Cu. Ft. x Air Exchange = CFM Evaporative Cooler Size
4. Answer will be CFM cooler size.
5. If CFM cooler size requirement exceeds largest cooler size available, a split system will be necessary.

(Courtesy of Tradewinds)

4-2 Evaporative Cooler Sizing Guide - *Evaporative coolers perform well in Zones 1 and 2, but are not very effective in many areas of Zone 3.*

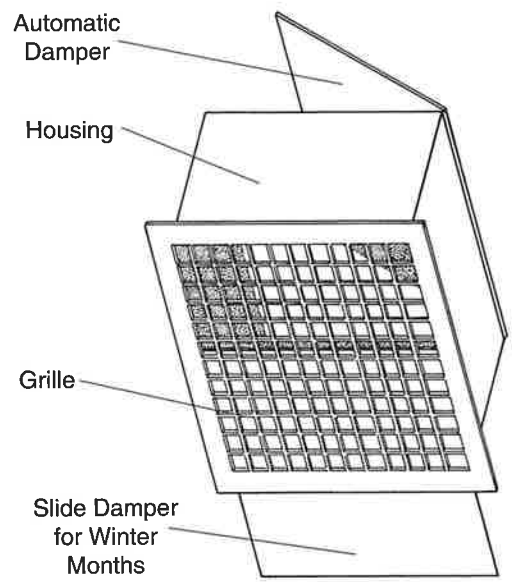
sation in the ducts and elsewhere may be a problem. Dew points are announced on weather reports in many areas.

Expect to pay between $900 to $1800 for an evaporative cooler, ductwork, and installation.

4.2.1 Sizing and Selection

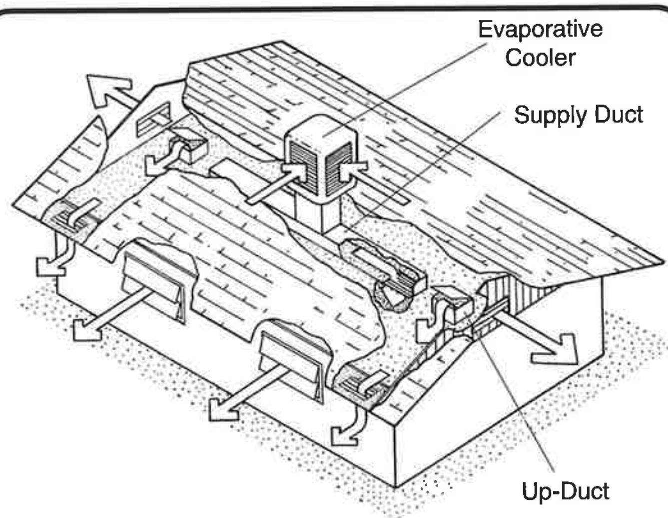
Evaporative coolers are rated by the number of cubic feet per minute (cfm) of air that they deliver to the home. Most models range from 3,000 to 25,000 cfm. Manufacturers recommend providing enough air-moving capacity to change the entire volume of the home every 1.5 to 3 minutes, depending on climate (*see figure* **4-2** *for sizing method*).

Open the windows or vents on the leeward side of the home to provide 1 to 2 square feet of opening for each 1,000 cfm of cooling capacity. Experiment to find the right windows to open and the correct amount to open them. If the windows are open too far then some hot, outdoor air will enter. If the windows are not open far enough the humidity in the home will become excessive, and the air will feel sticky. Regulate cooling by opening windows in the areas you want to cool, and closing windows in unoccupied areas. This concentrates the cooling in the occupied areas.



***4-3 Up-duct** - Up-ducts substitute for open windows in homes where security is an issue. Up-ducts exhaust hot air from the home while the evaporative cooler is operating. Up-ducts require effective attic ventilation (see Section 3.3, Attic Ventilation).*

Up-ducts are vents in the ceiling that exhaust warm air as cooler air comes in from the evaporative cooler. Up-ducts are preferred by home owners who do not feel secure leaving windows open (*see figure* **4-3**). Up-ducts can help maintain a positive pressure in the home so that hot air does not enter open windows in windy areas. If you exhaust the air into the attic, it is very important to have adequate attic

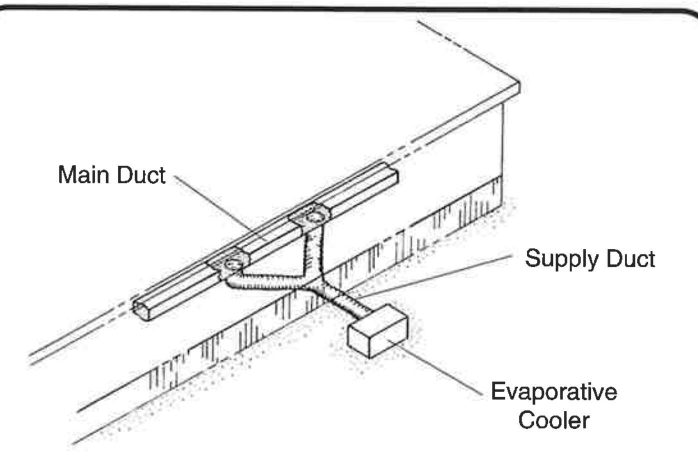


***4-4 Roof-Mounted Evaporative Cooler** - Roof-mounted evaporative coolers discharge air into the home through a main outlet, or through ducts as shown here.*

ventilation (*see Section 3.3, Attic Ventilation*). Attic vents should have 1 to 1.5 times the area of the up-ducts.

4.2.2 Installation

Evaporative coolers are installed in two ways: the cooler outlet blows air into a central location, or the cooler outlet joins ductwork which distributes the cool air to different rooms in the house. Single outlet installations work well for compact homes which are open from room to room. Ducted systems are required for more spread-out homes with hallways and multiple bedrooms.



***4-5 Ground-Mounted Evaporative Cooler** - Manufacturers recommend two supply inlets when the cooler shares ductwork with a furnace because of the high air flow from the cooler. The supply duct from the cooler may also terminate at a large register in a central area.*

Most people install down-flow evaporative coolers on the roofs of their homes (*see figure* **4-4**). However, some experts on evaporative cooling prefer ground-mounted horizontal units (*see figure* **4-5**) for easier maintenance and less risk of roof leaks.

A horizontal-flow evaporative cooler sits on a concrete pad. The large supply duct from this unit connects to one or two large, central registers indoors or to ducts in the basement or crawl space. The best place for a horizontal-flow evaporative cooler is in the shade on the windward side of the home. The wind helps circulate cooled air through the unit and into the home. The windward location also discourages recirculating the exhaust air from the house.

Evaporative coolers produce high air flows; the ductwork connected to them should be sized appropriately. It may be necessary to split the air flow from the evaporative cooler into two supply ducts, and splice these ducts to the existing ducts in two locations (*see figure* **4-5**).

Coolers that share ductwork with forced-air furnaces require the same types of dampers used with packaged air conditioners. The dampers (*described in Section 4.5.4, Shared Ductwork*) prevent heated furnace air from blowing into the idle evaporative cooler during the winter, and prevent moist cool air from blowing into the furnace during the summer. Moist cool air can condense and cause rust inside the furnace.

Control evaporative coolers with thermostats to minimize energy use, water use, and maintenance. Thermostats also reduce the chance of over-cooling with unnecessary nighttime operation.

An evaporative cooler should have two speeds and a "vent only" option. This option permits using the evaporative cooler as a whole-house fan during mild weather. When using the vent only option, the water pump does not operate and the outdoor air is not humidified.

Filters remove most of the dust from incoming air—an attractive option for homeowners concerned about allergies. Filters can also reduce the tendency of some coolers to pull water droplets from the pads into the blades of the fan. Most evaporative coolers do not have air filters as original equipment. Filters can be fitted on the cooler during or after installation. They increase the need for regular maintenance.

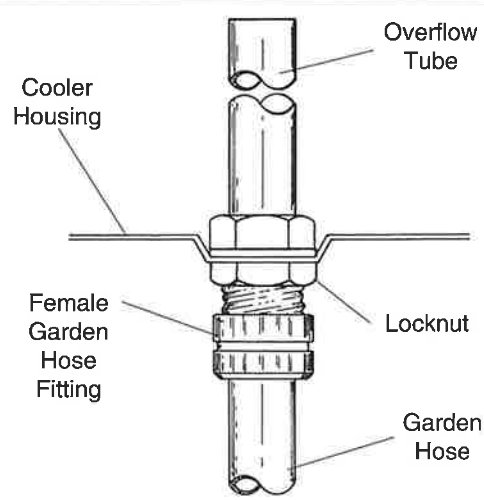
Small horizontal-flow units are sometimes installed in windows to cool a room or section of a home. These portable evaporative coolers work well in moderate climates, but may not be able to cool a room adequately in hot climates. Room evaporative coolers are becoming more popular in areas of the western U. S. with milder summer weather. They can reduce the temperature within a single room of dry air from the high 80°s or low 90°s to the low 80°s or high 70°s.

4.2.3 Evaporative Cooler Maintenance

Most problems with an evaporative cooler are caused by neglecting basic maintenance. The more it runs, the more maintenance it needs. **An evaporative cooler will definitely need a major cleaning every season, and may need routine maintenance several times during the cooling season.** In very hot climates where the cooler operates much of the time, look at the pads, filters, reservoir, and pump as often as once a week.

Replace the pads at least twice during the cooling season, or as often as once each month during continuous operation. Some paper and synthetic cooler pads can be cleaned with soap and water or a weak acid according to manufacturer's instructions. Filters should be cleaned when the pads are changed or cleaned. **Caution:** *Be sure to disconnect the electricity to the unit before servicing it.*

Dust from the air, and minerals and dirt from the water, collect in the reservoir. Save yourself a lot of work and money by draining your reservoir regularly. Draining the reservoir keeps the water quality good. All coolers have a drain fitting at the bottom of the unit. This drain fitting is connected to an overflow tube that guards against too high a water level in the reservoir, much like the overflow devices in toilets and bathtubs (*see figure* 4-6). To drain the reservoir, shut off the water, connect a garden hose to the fitting on the outside



***4-6 Drain Fitting and Overflow** - The reservoirs of evaporative coolers are drained through fittings like this. When you remove the overflow tube, the water drains out of the reservoir through a garden hose attached to a fitting on the outside of the cooler cabinet.*

of the cooler cabinet, and then unscrew the overflow tube.

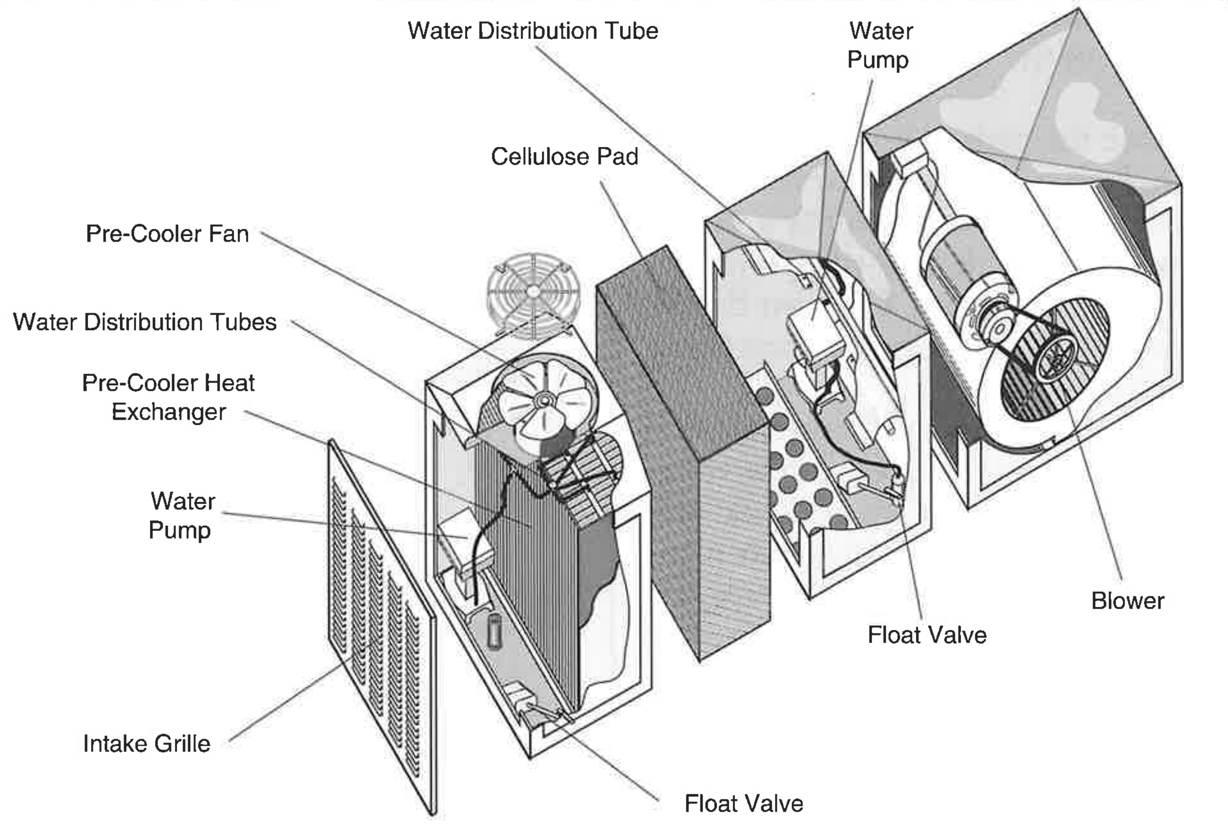
Inspect the fan blades; if there is any significant amount of dirt on the blades, clean the blower thoroughly using the same techniques described in Section 4.4.3, Cleaning the Blower. Scrape the scale off the louvers in the cooler cabinet and clean the holes in the drip trough that distributes the water to the pads (*see figure* **4-1**). The reservoir should be thoroughly cleaned each year to remove biological matter, scale, and dirt.

Pay particular attention to the intake area of the circulating pump. The pump and the float assembly are the source of many maintenance problems in evaporative coolers. Most manufacturers recommend painting the reservoir area once a year with a water-resistant coating.

Annual maintenance also includes checking the blower belt for wear and tightness. The belt shouldn't move more than one inch when you press it firmly. You should also check for leaks in the float valve when you turn the water back on.

4.2.4 Two-Stage Evaporative Coolers

Two-stage evaporative coolers are a newer, more efficient cooler which use a pre-cooler, more effective pads, and more efficient motors (*see figure* **4-7**). The pre-cooler cools the incoming air



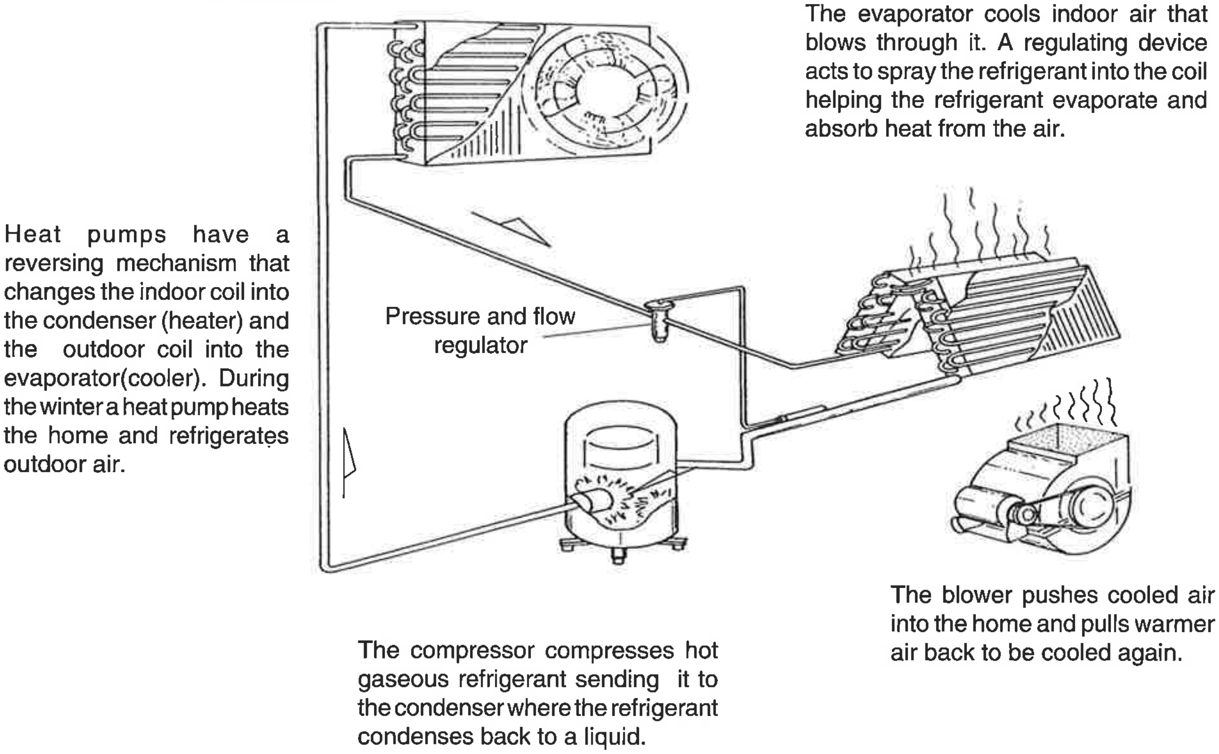
***4-7 Two-Stage Evaporative Cooler** - Water evaporating inside the pre-cooler heat exchanger cools the air intake. That air temperature is further reduced when it passes through a water-saturated cellulose pad. These newer evaporative coolers provide the most efficient cooling for homes in dry climates.*

without adding any moisture to the air. This pre-cooling provides an extra 3° to 9°F temperature drop, so the air feels drier and more like it has been refrigerated. These systems are gaining greater acceptance, especially in the southwest, as customers become more aware that refrigerants may be destroying the ozone layer of the earth's atmosphere.

Two-stage coolers provide comfort much more efficiently than air conditioners. Two-stage evaporative coolers are not rated with SEERs like air conditioners, but if they were, the SEER would be well over 40 (*see Section 4.3.3, Ratings for Air Conditioning Systems*).

4.3 Air Conditioning Systems

Mechanical air conditioning systems are expensive to operate. Therefore, it is important to use all of the low-cost cooling strategies first, to save energy and provide better comfort. The three most effective low-cost cooling strategies are: shading or reflecting solar heat, indoor air circulation, and ventilation. Air conditioning is appropriate only when the less expensive options discussed earlier cannot adequately overcome the heat and humidity.



***4-8 Air Conditioning System Operation** - This illustration shows the major components of a central air conditioning system and explains their operation. The refrigerant collects the heat from indoors, the compressor moves the refrigerant outside, and the heat is then released outdoors.*

Air conditioning system efficiency relies on good maintenance. Good maintenance minimizes cooling costs; neglect maximizes cooling costs. Careful thermostat control by the residents is also a key ingredient to keeping cooling costs to a minimum. **For every degree Fahrenheit that a house thermostat setting is raised, air conditioning costs are reduced 3 to 6 percent.** Keep the thermostat set at 78°F or higher and, when you leave, turn the thermostat up to 84°F or higher. The air conditioner will run longer than usual when you return, but you will save energy and money because the unit ran very little or not at all while you were gone. Automatic setback thermostats work well for residents with consistent schedules.

Room air conditioners can cool a room where occupants spend most of their time. They are usually less expensive to operate than central air conditioning. Always use fans to circulate air when using air conditioning.

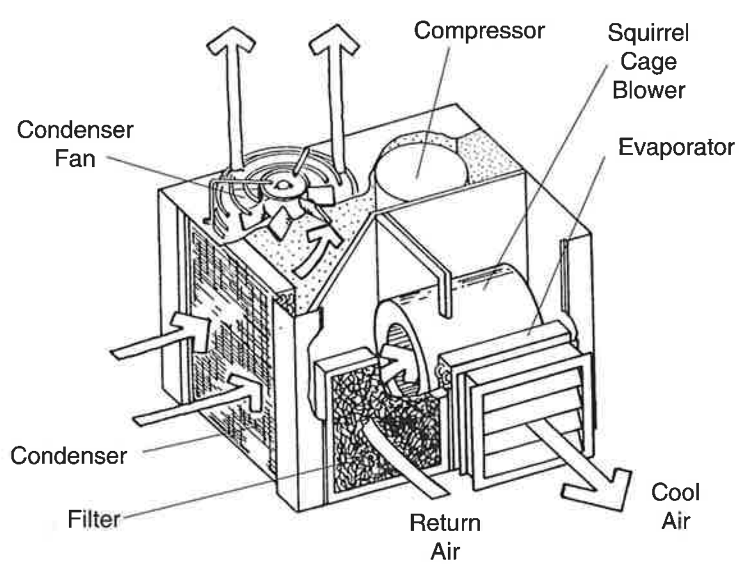
4.3.1 Introduction to Air Conditioners

Air conditioners gather heat from the home and move it outdoors. An air conditioner works like a refrigerator. A refrigerator cools one area (inside the refrigerator cabinet) while releasing heat into another area (the kitchen).

Heat pumps work exactly the same way as air conditioners, but they provide both heating and cooling. All of the measures discussed for air conditioners apply to heat pumps (*see Section 4.3.8, Heat Pumps*).

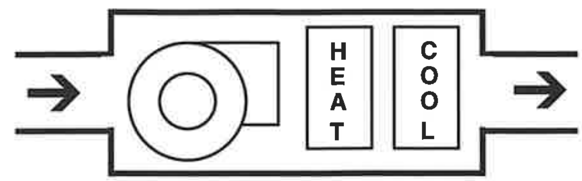
Air conditioners cool the home using a coil called the evaporator. They dump the heat outdoors via a coil called the condenser. A compressor moves the heat-transferring fluid called a refrigerant between the two coils. A heat pump works the same way but the flow of refrigerant is reversed during the winter and the indoor coil becomes a heating coil rather than a cooling coil.

The refrigerant absorbs large amounts of heat from inside air as it changes from a liquid to a gas in the evaporator. You've felt this evaporator effect if your index finger has ever felt numbed with cold while using a spray can. When the liquid evaporates at the spray nozzle, it absorbs heat from the surrounding air and cools your finger. In the same way, the refrigerant in an air conditioner evaporates and removes heat from the indoor air.



***4-9 Packaged Air Conditioner** - The packaged air conditioner contains the evaporator, the condenser, the compressor, and all the other parts in a cabinet located outdoors. Indoor air is circulated through the evaporator and cooled in this horizontal air handling unit. Outdoor air circulates through the condenser which removes the heat collected from the indoor air.*

Indoor moisture condenses on the cold evaporator coil. This dries the air and makes the home more comfortable in humid climates. The amount of water that an evaporator must remove to provide comfort is part of the design and selection of air conditioning systems (*see Section 4.3.5, Sizing Air Conditioners*).



4-10 Horizontal-Flow Air Handler *- This is the most versatile type of air handler. Horizontal-flow air conditioners and heat pumps are installed on roofs, in crawl spaces and attics, and outdoors on concrete slabs.*

The compressor pumps the hot gaseous (evaporated) refrigerant into the condenser. There the refrigerant condenses from a gas back to a liquid. Outdoor air blown through the condenser coil removes heat from the coil.

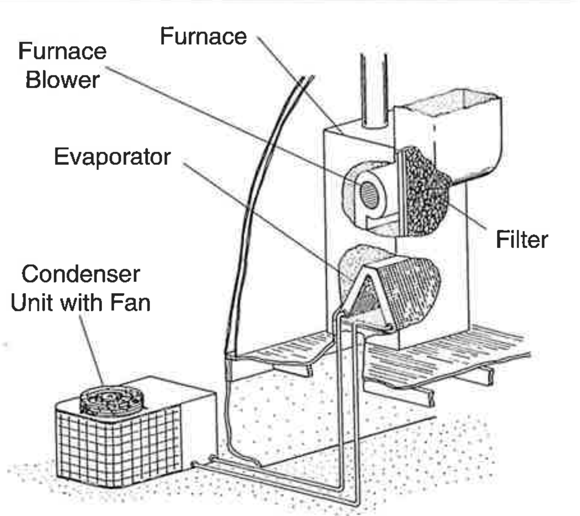
Figure **4-8** gives a graphic explanation of the cooling process utilized by an air conditioning system.

4.3.2 Types of Central Air Conditioning Systems

Central air conditioners are either packaged units or split-system units. The difference between these two types is the location of a major component called the air handler. Packaged units have outdoor air handlers and split systems have indoor air handlers.

The air handler is a steel cabinet containing the blower and the evaporator. It is connected to supply and return ducts. The supply ducts carry air from the air handler to the living spaces. The return ducts carry air from the house back to the air handler.

Split-system air conditioners have an indoor air handler that is very often a gas, oil, or electric furnace. The furnace is equipped with a cooling coil. The condenser, fan, and compressor are located outdoors in another cabinet (*see figure* **4-11**). Split-system air conditioners have one of three types of air handlers: up-flow, down-flow, or horizontal-flow. The names describe which way the blower moves air. Study figures **4-10, 4-12,** and **4-13** for an explanation of these different types.



4-11 Split-System Air Conditioner *- This down-flow furnace has a compartment for the cooling coil. Most up-flow and horizontal furnaces will have their cooling coils in the supply ductwork adjacent to the furnace.*

Packaged air conditioning systems (also called unitary air conditioners and self-contained air conditioners) have the compressor, condenser, evaporator, and two fans all contained in a single cabinet located outside the home (*see figure* **4-9**).

Packaged air conditioning systems may also contain a gas furnace or some electric resistance heating coils enclosed in the same cabinet with the cooling unit and blower. Packaged air conditioners are usually horizontal-flow units, mounted on the roof or on a concrete slab outside.

4.3.3 Ratings for Air Conditioning Systems

Central air conditioners are rated by how much heat they remove for each watt of electric power they draw. Before January 1, 1979, the rating was called the Energy Efficiency Ratio (EER). This rating didn't take into account the energy that the air conditioner wastes getting started.

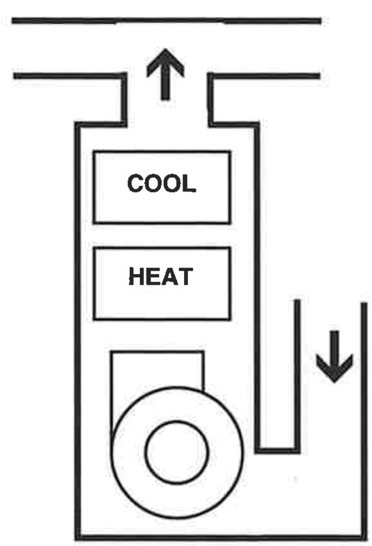
In 1979, all manufacturers of central air conditioners were required to rate central air conditioners by their Seasonal Energy Efficiency Ratio (SEER). The SEER predicts seasonal performance better than the EER because it accounts for the energy that is wasted every time the air conditioner starts up. The SEER ratings of air conditioners are included in the Air Conditioning and Refrigeration Institute directory which is published in April each year (*see Appendix* C).

Room air conditioners are still rated by the EER. The ratings are listed by the Association of Home Appliance Manufacturers (see Appendix C). The American Council for an Energy Efficient Economy lists the most efficient central air conditioners and room air conditioners in their annual guide, *The Consumer Guide to Home Energy Savings* (*see Bibliography*).

The EER and SEER are ratios of cooling capacity. The capacity of the air conditioner in Btus per hour are divided by the watts of electric power it draws (SEER or EER = Btus/hour ÷ watts). The higher the EER or SEER, the more efficient the air conditioner.

The SEERs of central air conditioners sold today range from 7.5 to almost 17. This means that the most efficient air conditioners produce twice as much cooling for a dollar's worth of electricity as the least efficient models.

Room air conditioners are generally less efficient than central air conditioners and the EERs range from 5 to 12.

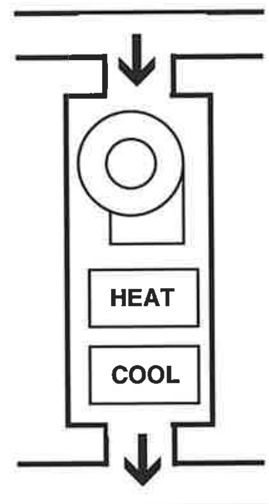


4-12 Up-Flow Air Handler - *Return air enters the bottom and the heated or cooled supply air exits through the top into the supply plenum and ducts. Up-flow air handlers are popular in homes with basements.*

4.3.4 High-Efficiency Central Air Conditioners

In a 1983 experiment, the Florida Public Service Commission equipped twelve homes in Miami with two central air conditioners each: an efficient model (SEER - 11.3) and a standard model (SEER - 6.5). The experimenters ran the standard air conditioner for one week and then ran the high efficiency model for a week. The average savings for using the high efficiency air conditioners was 30 percent. The annual savings averaged about $300 per home.

If you buy a new air conditioning system, choose a high efficiency unit with the right characteristics for your cooling requirements and climate. You will save money in the long run.



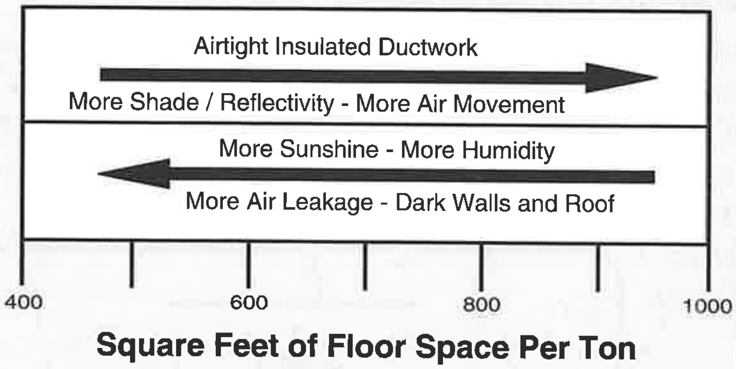
***4-13 Down-Flow Air Handler** - Return air enters the top, is heated or cooled, then exits the bottom into supply ducts. These types of air handlers are popular in manufactured homes and in homes with crawl spaces. Supply ducts run under the floor.*

Air conditioner efficiency has improved steadily since the 1970s energy crisis. The improvements include: bigger coils, improved coil design, and more efficient electric motors for the compressor and the fans. Today the most efficient models have compressors and blowers powered by variable speed motors. They rate as high as 16.9 SEER. These new air conditioners run much of the time, eliminating many inefficient start-ups. The older systems make the conditioned air colder than necessary, then shut off so the house doesn't get too cold. The newest systems adjust the speed of the compressor and blower to meet the demand for cooling.

When selecting a high efficiency air conditioning system, the contractor should determine the proper size of the system and select the right condenser and evaporator to attain the rated efficiency. **Replacing your current air conditioning or heat pump system will not give you the rated efficiency unless you replace the indoor coil along with the other components.** Experts still disagree on whether very high efficiency units can remove enough moisture in very humid climates. Air conditioning systems with SEERs more than 12 should be sized and selected carefully to ensure adequate moisture removal. Expect to pay $600 to $1200 more for a very efficient central air conditioner.

4.3.5 Sizing Air Conditioners

The most important consideration to achieve comfort and minimize energy cost is to select the correct size air conditioning equipment. Consider cooling, moisture removal, and energy efficiency. The evaporator, condenser, compressor, fan, and fan speed should fit each particular home's cooling requirements, and these parts should be matched to each other.



***4-14 Sizing Air Conditioning Systems** - The above illustration shows how factors such as climate and energy efficiency affect the ideal size of an air conditioner. The size of an air conditioner is rated in tons (12,000 Btus per hour per ton). The chart shows how many square feet of floor space can be cooled by a ton of air conditioning capacity in the hottest weather depending on the factors shown on the chart.*

It's normal for a correctly sized air conditioner to run from 15 to 30 minutes each hour when the outdoor temperature is 85° to 90°F. The unit should run almost constantly when the outdoor temperature is above 95°F.

Cooling comfort is produced by dropping the air temperature and removing the humidity. The air conditioner must run for significant periods of time to remove moisture. It pulls the indoor air through the evaporator coil, where the moisture falls out and is piped away through a drain. An oversized air conditioner cycles frequently, removes less moisture, and wastes energy. If your air conditioner runs all the time, it does not necessarily mean that it is sized correctly. It could be oversized but working extra duty to overcome maintenance, repair, or adjustment problems.

The capacity of air conditioners to remove heat from a home is measured in Btus per hour, or "tons" of cooling capacity. Each ton equals 12,000 Btus per hour (1 ton = 12,000 Btus/hour). The air conditioner should have a ton of capacity for every 400 to 1,000 square feet of floor space, depending on your home's energy efficiency and climate (*see figure* **4-14**).

"One ton per 400 square feet of floor space" is a rule-of-thumb used to estimate the size of central air conditioners in older, less efficient homes. However, sizing the system smaller to provide one ton per 650 square feet of floor space will provide better efficiency and humidity control in most homes built since 1975. Central Power & Light of Texas sizes air conditioners for very energy-efficient homes with features like ceiling fans, radiant barriers, window shading, airtight ducts, and light-colored roofs and walls, at about one ton per 1,000 square feet of floor space. These rule-of-thumb values are presented here for general information only and should not be used to size air conditioners.

It was standard practice in the past to oversize the air conditioner by 10 to 50 percent to ensure that it was big enough to cool the home. However, researchers at Texas A & M and others found that air conditioners that are undersized by 10 to 20 percent are more efficient and more effective at removing moisture.

Reputable contractors size air conditioning systems accurately through careful hand calculations or with computer programs. The Air Conditioning Contractors of America publishes a calculation procedure called Manual J, which is the standard method for sizing central air conditioners. Several air conditioning manufacturers and others have developed computer programs based on Manual J or on other calculation methods. To ensure correct sizing, ask your contractor to show you the hand- or computer-generated calculations for your system. Ask the contractor to install the smallest size air conditioner capable of cooling your home. Also ask about moisture removal capacity of the system and sensible heat factor (SHF).

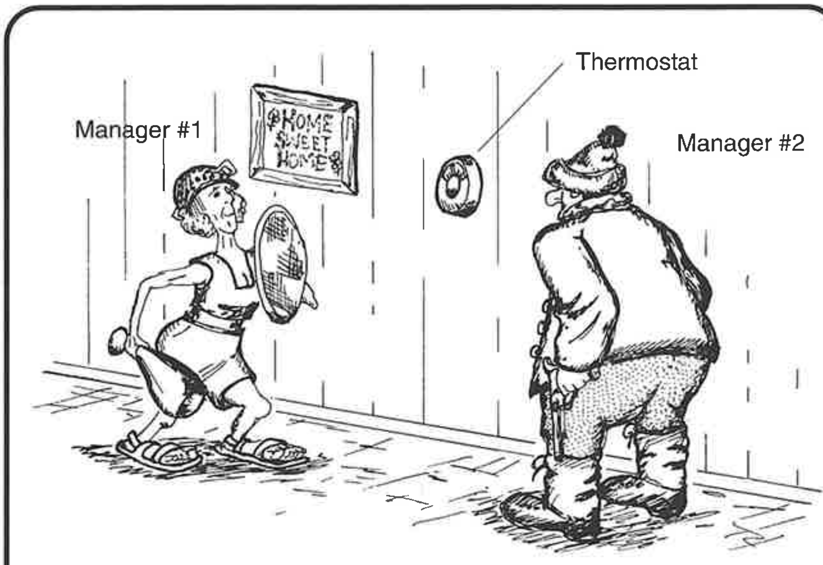
The SHF is a very important sizing consideration that rates the air conditioner on its ability to remove moisture. The SHF is a decimal number between 0.5 and 1.0. The lower the SHF, the more moisture the unit will remove from the air. The SHF depends on the size and construction of the evaporator coil and on the fan speed.

Homeowners in dry and moderate climates should purchase a unit with high SHF, because they need less moisture removal and air conditioners with high SHF are more efficient. However, homeowners in humid climates will probably want an SHF of between 0.67 and 0.77 to reduce humidity and the accompanying mold, mildew, and microscopic pests. Make sure your contractor thinks about moisture removal when sizing your central air conditioning system. A relative humidity of less than 40% will surpress mold, mildew, and other microscopic pests which are linked to respiratory problems.

Proper sizing and equipment selection are especially important with new higher efficiency air conditioners. These new energy-efficient units must have a low enough SHF to provide adequate moisture removal. An oversized new air conditioner won't reach its potential high efficiency, nor will it remove enough moisture to provide adequate comfort.

4.3.6 Control of Central Air Conditioners

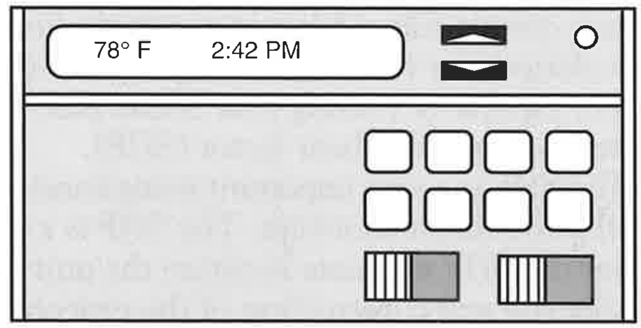
The location of your thermostat can cause problems in controlling cooling systems. Thermostats should be shaded from direct sunlight. A thermostat located on a warm outside wall may cause the air conditioner to operate erratically. In that case, move the thermostat. Turning the thermostat past the desired temperature will not make the air conditioner cool your home any faster and it will waste energy. Pacific Gas and Electric has reported that "dueling managers," (*see figure* **4-15**) who move the thermostat



4-15 Dueling Managers - *Air conditioning systems operate erratically and inefficiently when residents move the thermostat setpoint between different comfort settings.*

setting back and forth to suit their different comfort demands, cause air conditioning systems to operate erratically and inefficiently.

Residents who leave and return at regular times every day can save money and increase the comfort and convenience of both cooling and heating by using automatic setback heating/cooling thermostats (*see figure* **4-16**).

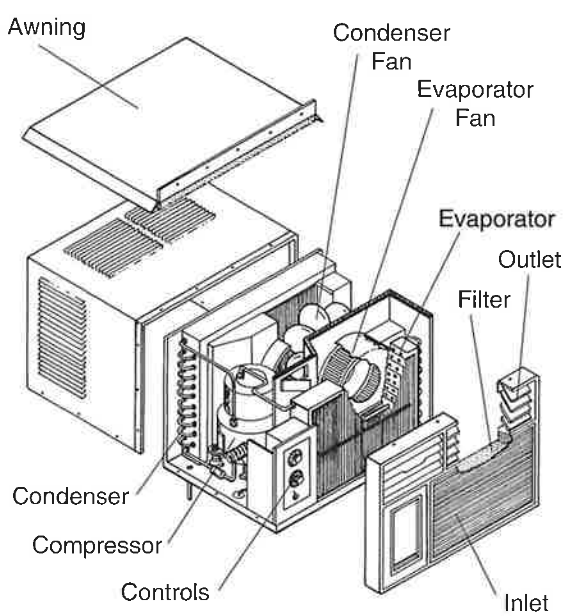


4-16 Automatic Thermostat *- These timing devices automatically raise the temperature when occupants leave the house and lower the temperature just before they return. Automatic thermostats can reduce cooling costs 10% or more.*

Thermostats often do not provide good comfort control in very humid climates. Manufacturers of automatic controls are developing air conditioning controls that will respond to both temperature and humidity. And manufacturers of air conditioning equipment have developed variable speed equipment that will be more flexible in providing both cooling and humidity control in the future.

4.3.7 Room Air Conditioners

Room air conditioners are small packaged air conditioning units installed in windows or in an exterior wall. All room air conditioners manufactured after January 1, 1990, have an energy efficiency rating (EER) of at least 8. The most efficient units have an EER of around 12. However, you can still buy room air conditioners with EERs as low as 5.3 unless you shop carefully.



4-17 Room Air Conditioner *- The evaporator, or cooling coil, faces indoors, and the condenser coil faces outdoors in this type of air conditioner.*

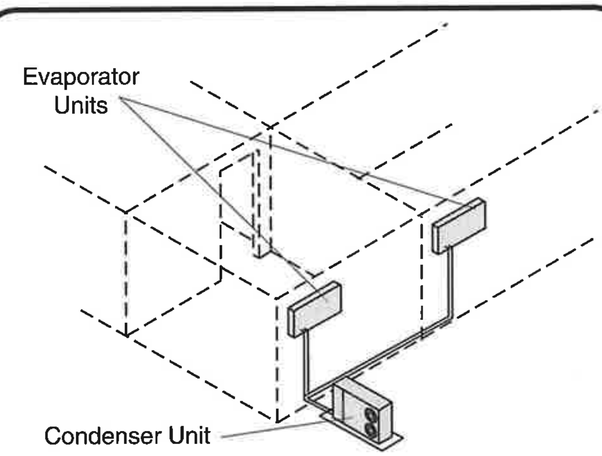
The energy efficiency rating is computed by dividing cooling capacity, measured in Btus per hour by the watts of power used (*see Section 4.3.3, Ratings for Air Conditioning Systems*). The federal government requires all air conditioners to carry a yellow energy label listing cost-of-operation, including the EER. The higher the EER, the more efficient the air conditioner and the lower its operating cost. A model with a high EER may cost more to buy, but will return your investment quickly in energy savings.

The evaporator, condenser, compressor, controls, and all other parts are contained in the cabinet of the room air conditioner (*see figure* **4-17**). The evaporator and its fan face indoors, and the condenser and its fan face outdoors. Warm air from the room enters through a filtered section of grille in the front cover of the unit, moves through the cooling evaporator coil, and comes back into the room through the unfiltered section of the grille. The heat from indoors is released outdoors by the condenser and its fan.

Room air conditioners do not have ducts and don't have the inefficiencies associated with ducts. Circulate air with ceiling fans and portable fans while operating room air conditioners.

Room air conditioners can save substantial energy and money over central units. They cool a specific comfort area where the occupants spend most of their time instead of cooling the whole house.

Caution: *The National Electrical Code allows a room air conditioner drawing less than 7.5 amps to be plugged into any 15 amp household circuit. However, you should not have any other major appliance on the same circuit. Room air conditioners should be powered by their own dedicated electric circuit if they draw more than 7.5 amps. A dedicated circuit means that you do not power anything else with that circuit.* Room air conditioners rated at more than 14,000 Btus per hour normally use 230 volt dedicated circuits.



***4-18 Split-System Room Air Conditioner** - These cooling systems use an outdoor condenser and one or more indoor evaporators mounted to the wall or ceiling. The advantages are individual room temperature control and no ductwork. There is also no need for a large opening in the wall since the only connection between the outdoor unit and indoors are refrigerant lines.*

The most important maintenance task for the homeowner is to keep the filter and the coils clean. ***Caution:*** *Unplug the room air conditioner before servicing it.* The filter is visible and easily removed from the front of the unit. Most filters are made of foam rubber designed to be cleaned with soap and water.

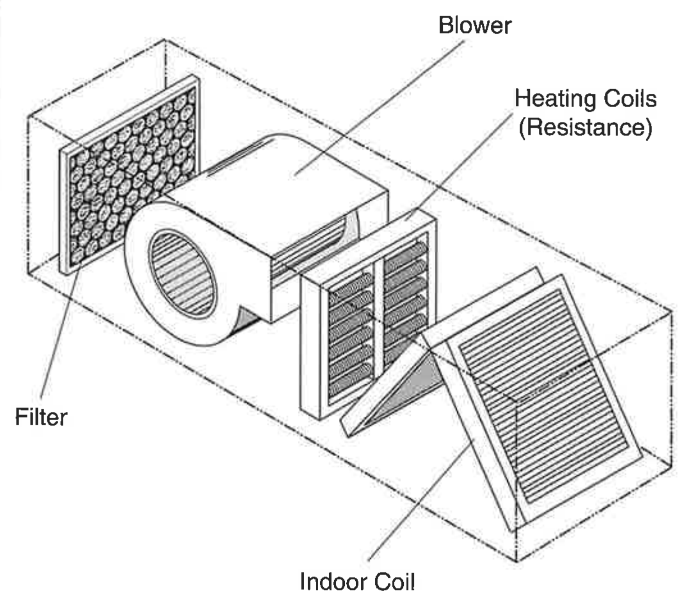
In some models, the insides of the air conditioner slide out of the cabinet for cleaning and servicing. With others, you must remove the unit and disassemble the cabinet for major cleaning. Surface dirt and lint can be removed from the unit while it's in place. If either of the coils is very dirty, spray it with a household detergent or coil cleaner, then spray again with clean rinse water. Be careful to keep the water away from electrical components. Let the unit dry completely before using it or storing it. At the same time, straighten any damaged fins with a fin comb as described in Section 4.4.2, Cleaning Evaporator Coils.

There are three energy conservation measures specifically for room air conditioners, besides the general recommendations discussed above.

1. Seal thoroughly around the perimeter of the room air conditioner's cabinet to prevent warm air leaks in summer and cold air leaks in winter.

2. During the heating season, remove the room air conditioner and close the window, or cover the indoor side with either plastic sheeting or an insulated removable box. Do not cover the unit on the outside, unless you also have an indoor cover, because warm, moist, indoor air leaking into the unit can form condensation.

3. If possible, shade the room air conditioner from direct sunlight. Shading prevents buildup of heat in the cabinet and allows the condenser and its fan to operate more effectively. Allow at least 18 inches of clearance over the room air conditioner so the shade awning does not restrict air flow.



4-19 Horizontal Unit *- This horizontal heat pump or air conditioner shows the location of the major components which need service: the filter, the blower, and the indoor coil.*

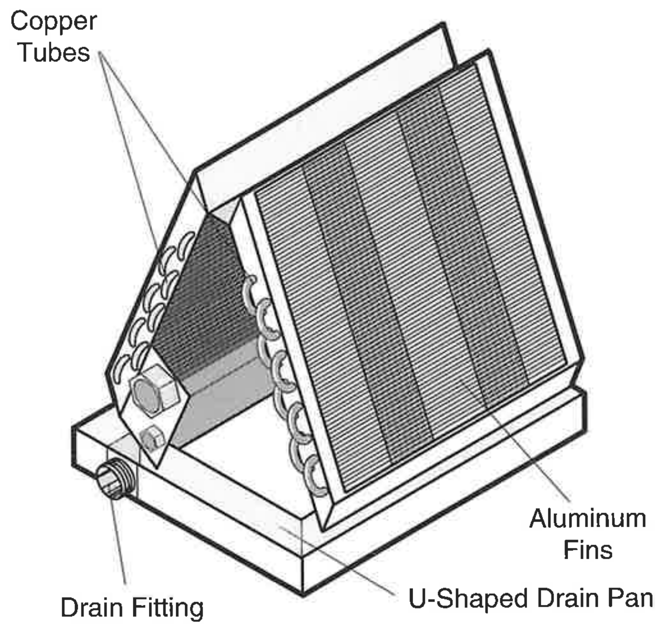
Several manufacturers make split-system room air conditioners with two main parts, like the system illustrated in figure **4-11** on page 41. The evaporator or indoor unit attaches to a wall or ceiling indoors (*see figure* **4-18**). The condenser is located outdoors and is a smaller version of the unit shown in figure **4-25** on page 53. You can connect two or more room units to the same condenser unit, with refrigerant lines running from each indoor unit to the condenser outside. Split-system room heat pumps use the same design (*see Section 4.3.8, Heat Pumps*).

Split-system room air conditioners and heat pumps eliminate duct leakages because they have no ducts, they do not require a large opening through a window or wall, and they allow zone cooling and heating.

Several manufacturers make portable room air conditioners that sit completely inside the room and do not remove heat from the home. Instead, they cool one part of a room while heating another. These models are **not** recommended.

4.3.8 Heat Pumps

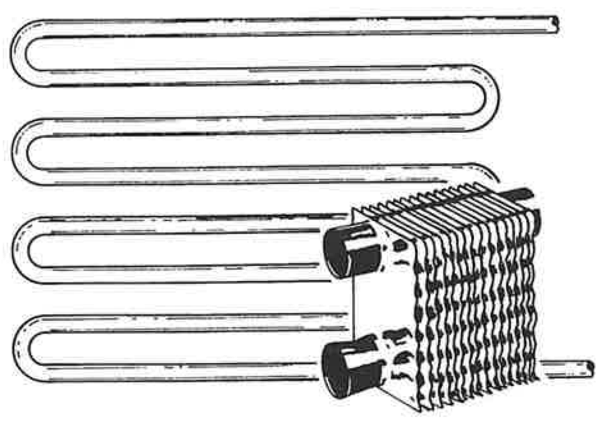
Electric heat pumps work like the mechanical central air conditioning systems described in Section 4.3.1 (*see figure* **4-19**). The difference between an air conditioner and a heat pump is that a heat pump is reversible. Instead of calling the coils the evaporator and the condenser, they are called the indoor coil and the outdoor coil, because they change functions when the system changes from heating to cooling.



***4-20 A-Coil** - The indoor coil of split-system heat pumps and air conditioners is an A-shaped panel of tubes and fins. A U-shaped pan under the bottom catchs and removes water which condenses on the coil.*

Heat pumps can provide very efficient electric heating in addition to efficient cooling. Heat pumps move heat into the home during the heating season, and out of the home during the cooling season. They are almost identical to air conditioners except for a few extra parts that allow the refrigerant to follow two different paths: one for heating and one for cooling.

Heat pumps are either packaged units or split systems just like air conditioners. Heat pumps require the same routine maintenance procedures as central air conditioners.



***4-21 Coil Construction** - Evaporator and condenser coils are made from copper tubing and aluminum fins. Air moves through the tiny spaces between the fins. The air is either cooled or heated depending on whether the coil is an evaporator or a condenser. (Courtesy of Lennox Industries)*

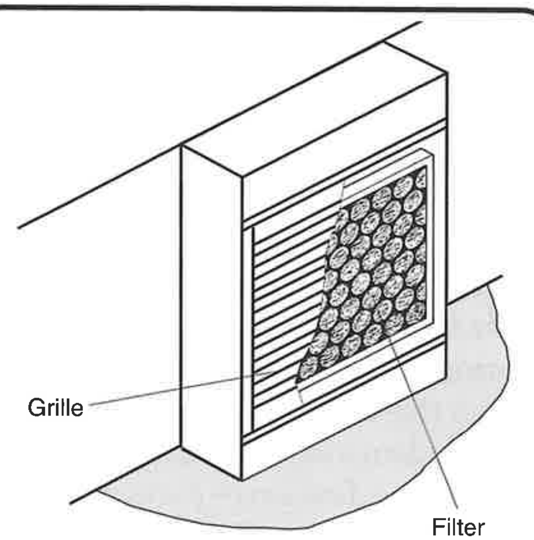
Heat pumps have electric resistance coils that are activated if the indoor coil is not providing sufficient heat. Electric resistance heat is far less efficient than a heat pump so you don't want any electric resistance heat until the heat pump cannot maintain a comfortable temperature. An outdoor thermostat should prevent the coils from operating until the outdoor temperature is below 40°F.

Servicing heat pumps requires special training because of their complicated electric controls and their reversible roles of heating and cooling.

4.4 Air Conditioning System Maintenance

You can achieve impressive savings through simple maintenance tasks. A recent study funded by Pacific Gas and Electric found that heat pumps (which are just reversible air conditioners) are routinely neglected by homeowners. The maintenance and repair procedures described here saved an average of 27 percent of the electricity consumed in heat pump systems. A study by Gulf States Utilities predicted homeowner savings from $6 to $77 per month, if standard maintenance procedures are carried out.

Many of the maintenance and repair jobs described here can be performed by a person who is moderately handy with tools. Refer to the owner's manual or the service manual for specific information about your cooling equipment. If you lack the skills and confidence to perform routine maintenance, hire a reputable cooling contractor to inspect, repair, and maintain the system as outlined below. As part of this maintenance job, the contractor could show you the location of the components of the system and teach you how to perform routine maintenance.



***4-22 Alternate Filter Location** - Filters are often located behind central return air grilles.*

The four most common problems with central air conditioners are: oversizing, low air flow, improper refrigerant charge, and leaky ducts.

Properly sized air conditioning equipment is very important for both efficiency and comfort. There isn't much you can do about an existing oversized air conditioner. But, when buying a new one, don't assume that your existing unit is sized properly. Have the cooling contractor calculate the proper size of equipment by considering: average summer temperature and humidity, the size of your home, the solar load, air leakage, and the amount of heat generated indoors (*see Section 4.3.5, Sizing Air Conditioners*).

If the air flow in the system is inadequate, a trained technician should fix the air flow problems to make the system operate efficiently (*see Section 4.5, Air Flow and Ductwork*).

Either a low or high refrigerant charge makes the air conditioning system perform poorly and inefficiently. A trained technician should measure the charge to tell if the refrigerant charge is high or low and then adjust the charge if necessary (*see Section 4.4.5, Checking Refrigerant Charge*).

Leaky ducts are a widespread problem that affect most central air conditioning systems. Seal the leaks to improve efficiency and save energy costs (*see Section 4.5.2, Sealing Leaky Ducts*).

The whole air conditioning system works better if the components are kept clean (*see Sections 4.4.1 through 4.4.4*). **Caution:** *Disconnect electricity from the air conditioning unit* *before any maintenance work is begun*. Clean the coils and clean or replace filters very regularly, and clean the fan blades, grilles, motors, compressors, and controls before excessive dirt accumulates. Oil the motor and fan bearings once a year with a few drops of 20 weight electric motor oil.

4.4.1 Keeping Filters Clean

All evaporators in home cooling systems should be protected by air filters. The filters for central air conditioning systems are located: adjacent to the blower in the main return air duct (*see figure* 4-19); in the cabinet of the air handler; or behind the grille of a central return register (*see figure* 4-22). **Dirty filters block a significant percentage of air flow and drastically reduce cooling efficiency.**

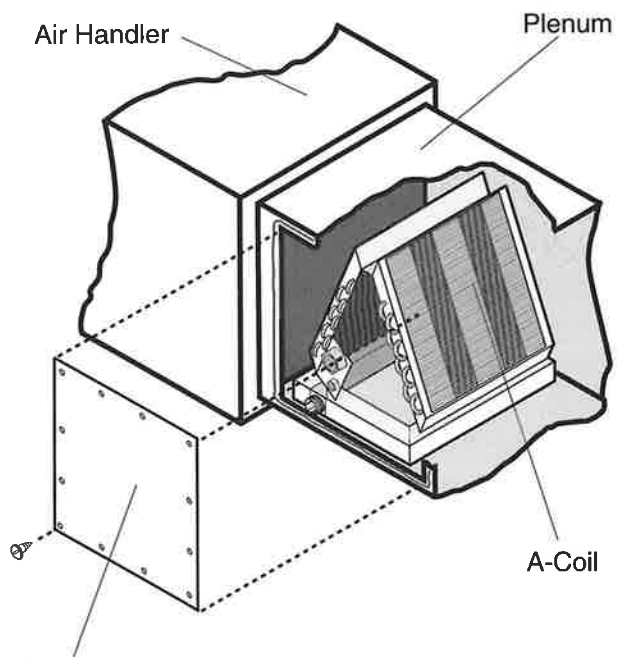
The filter should be changed or cleaned each month that the air conditioner is in use. The average air conditioning system will lose about 1 percent efficiency per week because of decreasing air flow due to dirt on the filter. A clean filter also keeps the evaporator coil clean longer.

4.4.2 Cleaning Evaporator Coils

Even with clean filters, the evaporator coil (*see figure* 4-20) will get dirty and lose more than 5 percent efficiency per year. Clean the evaporator every 3 to 5 years. Neglecting cleaning will shorten the life of the blower and the compressor, and lead to excessive cooling costs.

Cleaning evaporator coils is simple. All coils can be cleaned using similar methods. However, getting to the coil may be difficult.

The evaporators in packaged air conditioners and room air conditioners are usually fairly easy to reach by removing an access panel or part of the cabinet. Evaporators in split-system air conditioning systems are often more difficult to reach. You may have to cut a hole in the main supply duct or remove the blower to get enough room to work. If you have to cut a hole in the duct, use stiff galvanized steel to make an access panel big enough to overlap the hole a couple of inches all the way around (*see figure* 4-23). Fasten the access panel with sheet metal screws spaced about two inches apart, and caulk the edge of the patch with silicon caulking.

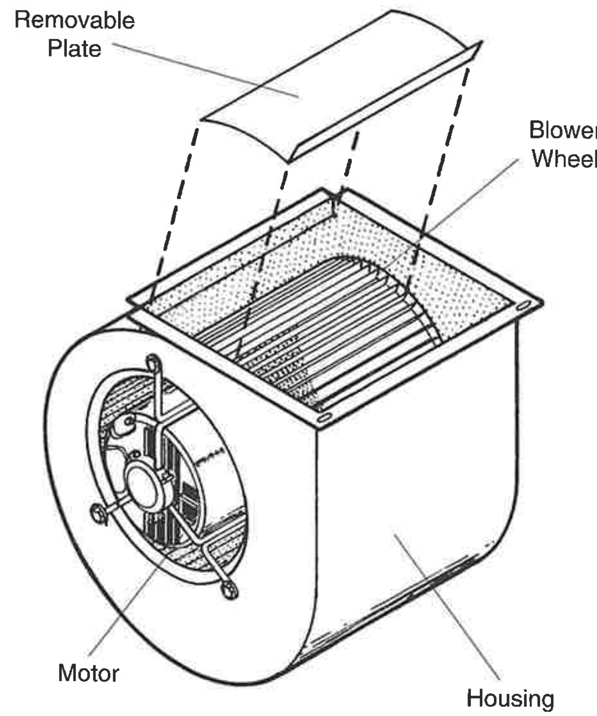


4-23 Plenum With A-Coil *- Evaporator coils are often located inside the plenum adjacent to the air handler. Sometimes an access opening with a metal cover panel must be installed in the duct in order to clean the evaporator.*

All you need to clean the evaporator coil are a couple of spray bottles, a pair of rubber gloves, and some rags. A small whisk broom or bristle brush is also useful.

Coils have a dirty side facing the air flow coming to the blower, and a clean side facing away. If you can reach the dirty side, brush away the loose dirt and lint. ***Caution:*** *Be careful not to bend the soft metal fins*. Then spray the cleaner into the coil from both sides, if possible, and give the cleaner some time to loosen the dirt. If necessary, brush the surface of the coil again to remove the more stubborn dirt.

Next, spray the rinse water into the coil. The cleaner and rinse water will drain into the pan or trough beneath the evaporator. If you can reach the pan, clean it too, and remove the dirty water.



4-24 Squirrel Cage Blower *- These fans are used in almost all air handlers and evaporative coolers. Dirt on the blades of the blower reduces the efficiency and the capacity of the cooling system.*

The most important part of cleaning the coil is loosening the dirt. The water which condenses on the coil during operation will rinse the coil if it can't be rinsed thoroughly because of inadequate space.

Select a cleaner for the type of dirt deposits on the evaporator coil. If the dirt deposits are light and dry and do not seem to have penetrated the inner parts of the coil, then a strong household cleaner will probably do the job well. If the dirt is heavier and packed into the coils, use a special foaming cleaner designed to penetrate the coil and push the dirt out. If the dirt is greasy and stuck firmly to the surfaces of the coil, professionals use a caustic or basic cleaner that cuts through the grease and loosens the dirt. Don't use the caustic cleaner unless the coil is greasy. The foaming cleaners and caustic cleaners are available at heating and cooling supply stores. ***Caution:*** *Use rubber gloves to protect your hands from these strong cleaners*.

While cleaning the evaporator, check the drain in the pan or trough to make sure that it is open. If the drain is plugged, clean it so water from the evaporator will flow out. A plugged drain can hold excess water in the pan and encourage mold growth. Sometimes fins on the coil are damaged by careless shipment or installation or by ice formation on the coil. You can repair bent and flattened fins using a "fin comb." This plastic tool has teeth that fit into the spaces between the fins; it straightens the fins as you pull it through them (*see figure* **4-27**). The fin comb is sized by how closely the fins are spaced apart in "fins per inch."

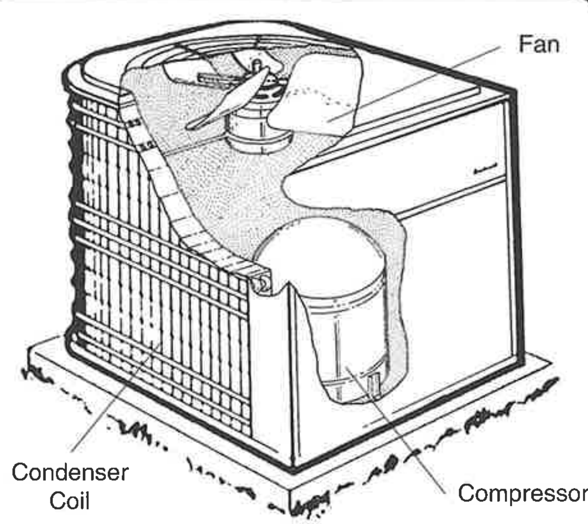
A clean evaporator is absolutely necessary to the proper and economical functioning of an air conditioning system. If you can't clean the evaporator yourself, then pay a professional to do it. It's a "pay me now or pay me later" situation. Pay now for service now, or pay high utility costs, suffer with poor performance, and burn up your compressor later.

4.4.3 Cleaning the Blower

Dirt on the blower blades greatly reduces their ability to move air over the cooling coils. The amount of air flow over the cooling coils directly affects cooling efficiency.

Although the blower can sometimes be cleaned in place, remove it to do a much better job. **Caution:** *Before cleaning the blower, shut off power to the air conditioner at the breaker box or main switch.* Some blower motors are connected to the main control box by a foolproof plug. Other blowers have individual wires connected to terminals in a control box. Label the wires and terminals as you disconnect them so there is no possibility of improper reconnection.

It is not usually necessary to remove the blower wheel from the motor and housing, but you may need to remove a plate in the blower housing (*see figure* **4-24**) to get more space to work on the fins of the blower. Clean the blower wheel with compressed air or with a brush and vacuum cleaner. Cylindrical hair styling brushes work well to clean blowers without removing the blower wheel from the housing.



***4-25 Outdoor Condenser Unit** - The fan in the outdoor unit pulls outdoor air through the condenser coil, cooling the coil and releasing the heat collected from the indoors. The refrigerant charge of the air conditioning system is measured at the compressor.* (Courtesy of Lennox Industries)

4.4.4 Maintaining and Cleaning Condenser Coils

Avoid activities that create airborne material which could be sucked into the condenser. Cutting grass or allowing children to play near the condenser stirs up dust and grass that can quickly plug the coils. Dryer lint can also plug the coils—be sure your dryer vent is located at least 10 feet away from and downwind from the condenser.

Dirt collects on the outside of the coils and is easily visible (*see figure* **4-25**). Clean the condenser whenever it appears dirty. If the condenser gets very dirty and you neglect it, the low air flow can burn out the compressor and leave you with a large repair bill.

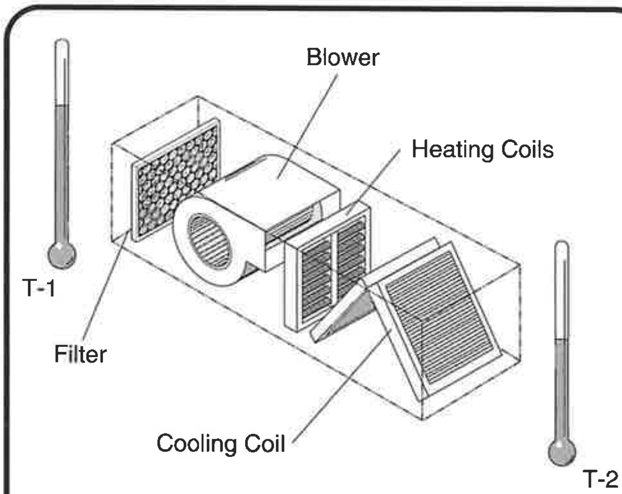
Cleaning condenser coils is similar to the technique for cleaning evaporator coils. First remove the loose dirt and debris carefully with a bristle brush. (You will often have to remove the top or side panels of the condenser unit to get access for cleaning.) Spray the coils with a household cleaner or a coil cleaner if there is stubborn dirt on the coils. Rinse the coils with a garden hose, from the inside out, to force dirt out the way it came in. ***Caution:*** *Be careful not to damage the fins. Keep the water pressure low.* Straighten damaged fins with a fin comb as described in Section 4.4.2, Cleaning Evaporator Coils.

4.4.5 Checking Refrigerant Charge

A 1988 research report stated that 70 percent of all air conditioners tested in the Phoenix area had an incorrect refrigerant charge. The ideal amount of refrigerant is specific to each air conditioner and installation. **Either too much or too little refrigerant in the air conditioner reduces its efficiency, lowers its cooling capacity, and shortens the life of the compressor.** A correctly charged system contains refrigerant to within a half ounce of the ideal amount.

Many air conditioning technicians do not regularly check refrigerant charge. Insist that your air conditioning contractor check the refrigerant charge during a maintenance call, and correct an improper charge.

More is not better for refrigerant in an air conditioner. Overcharging is extremely harmful to your air conditioner and it increases your cooling costs. Never add refrigerant or let a service technician add refrigerant without determining if the system needs refrigerant and, if so, exactly how much.



*4-26 **Measuring Temperature Difference** - The difference in temperature between the inlet and outlet of the air handler, while either the heating or cooling coils are activated, gives an estimation of air flow. Measuring the temperature rise across the heating coils is the more accurate way to measure air flow.*

Checking refrigerant charge requires measuring indoor temperature, humidity, outdoor temperature, suction pressure, and system head pressure. Only trained air conditioning technicians are qualified to measure refrigerant and to charge an air conditioning system (*see figure* **4-25**). It requires special knowledge, tools, and equipment. The correct charge for a central air conditioning unit (with matched indoor and outdoor coils) or a packaged unit is stamped on the nameplate of the unit. The correct charge can always be achieved by vacuuming the refrigerant out of the lines into a device that recovers the refrigerant. The technician then weighs in the proper amount of refrigerant.

Refrigerants do not wear out and do not need to be replaced, unless the system has a leak or needs major repairs. If your air conditioning system needed refrigerant any time since you installed it, there is probably a leak. Refrigerant leaks should be repaired by a professional because refrigerant is expensive and its release damages our earth's atmosphere. **The Clean Air Act of 1990 forbids the release of refrigerants from home air conditioners into the atmosphere.** Contractors must use special equipment to recover refrigerant after July 1, 1992.

4.5 Air Flow and Ductwork

Studies indicate that approximately half of all existing air conditioners have lower air flow than that required for good efficiency. These reports found that 35 to 70 percent of all duct systems attached to central air conditioners have significant leakage. Either of these problems by themselves can waste 10 to 30 percent of the energy a home uses for air conditioning.

4.5.1 Air Flow

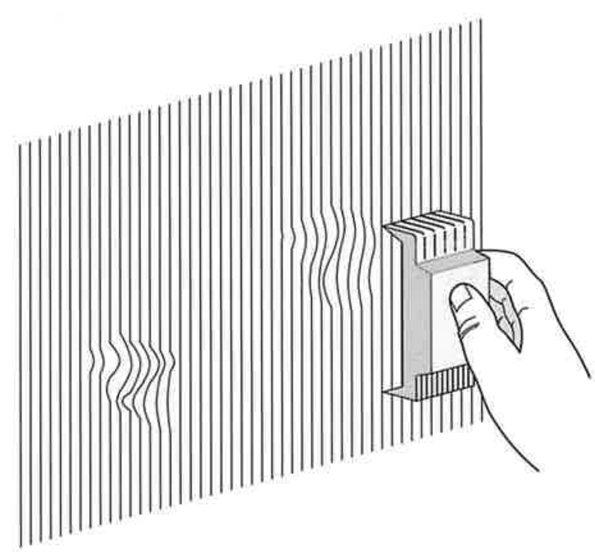
Most home air conditioning systems are forced air systems. They employ a large blower mounted in a steel cabinet called either a furnace, an air handler, or an air conditioning unit.

The blower moves the air through a closed loop of ducts. It sucks air from the home (called "return air"), and forces the air through an evaporator coil which cools the air. The cool air flows through the supply ducts and out the registers into the rooms. The warmer room air returns to the air conditioner, where it is cooled.

The cooling capacity and the efficiency of the system depend on adequate air flow. There should be about 400 cubic feet per minute of air flow in the system for each ton of air conditioning capacity. **Experts in air conditioning say there is no way to compensate for low air flow except increase the air flow.**

Service technicians measure the air flow in the air conditioning system in a variety of ways. The most reliable way is measuring the temperature rise across resistance heating coils (if present) which share the same air stream as the cooling coil. Various types of air pressure, velocity, and flow meters are also used. The temperature difference between supply and return air should be 15° to 21°F when the air conditioning system is operating. A reading outside this range could indicate a problem with air flow or refrigerant charge (*see figure* **4-26**).

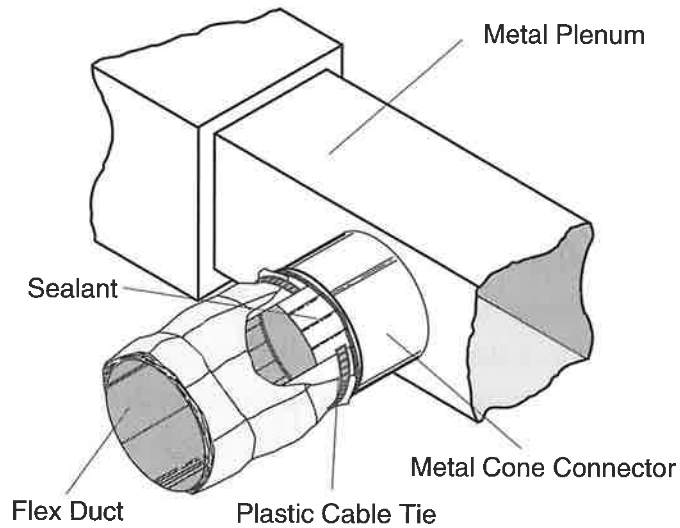
If the air flow falls short of the manufacturer's recommendations, the technician may increase the air flow by cleaning the evaporator coil, increasing fan speed, enlarging registers, adding more ducts, or enlarging the ducts to increase the air flow. Adding or enlarging ducts may seem drastic but in some cases might be the only remedy for poor cooling efficiency and high cooling costs.



4-27 Fin Comb *- Fins of a coil are often bent by ice forming on them or during installation. Bent fins are a severe air flow problem. Fin combs straighten bent fins.*

Restrictions to air flow have the greatest impact on the return air side of the system; so, repairs should start with the return ducts. Every supply register must have an unobstructed airway back to a return register. Blockage of supply or return air ducts and registers can pressurize or depressurize portions of the home, resulting in greatly increased energy use.

Typical ways to improve free air return to a central return air register are cutting off the bottom of doors, or installing louvered grilles in doors. Be sure to maintain an inch or more clearance under interior doors in rooms without return registers.



***4-28 Flex Duct** - Flex duct is used in many modern air conditioning installations. The joints between metal connectors and flex duct should be made as shown here and not with duct tape.*

Obstructions in the supply air duct system include dents in the ducts, debris inside the ducts, and bent and dirty registers. These are major problems in some homes. Insulated flex-duct is used in many modern homes. Flex-duct is often kinked at support brackets, at bends, and where the flex-duct is installed through tight spaces. If you have flex-duct and some supply registers do not provide adequate cooling, check for kinks and depressions in the flexible duct. Make sure that the bends are as gradual as possible. Improper joints in flex-duct can be a leakage problem (*see figure* 4-28).

Supply registers can have severe blockages if the fins have been flattened by foot traffic or if they are dirty. Registers with flattened fins should be replaced, or the fins straightened, to allow adequate air flow. Clean dirty registers.

Inspect ducts with a flashlight, a trouble light, and a mirror. Secure all wall and floor registers with screws so children do not put toys and other objects into the ducts. **Do not block registers with furniture, drapes, or other objects.**

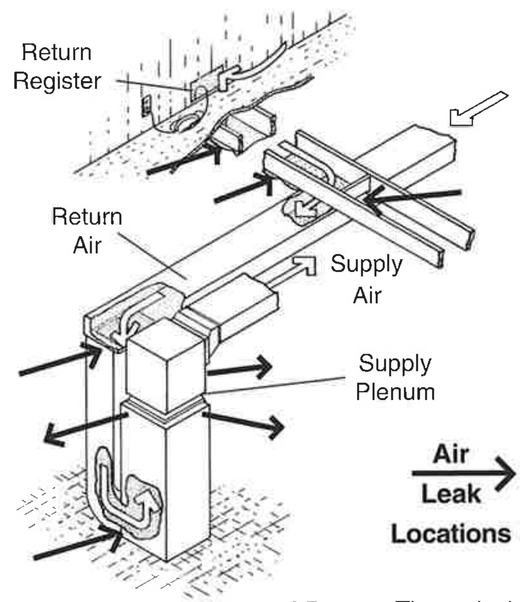
Supply registers closest to the air handler sometimes deliver more cool air to the rooms closest to the furnace. You may be able to change the air flow by moving the adjustable vanes in registers, or by sealing off portions of the registers closest to the air conditioner. It is not usually a good idea to block off registers altogether because this reduces air flow and cooling efficiency.

4.5.2 Sealing Leaky Ducts

Florida Solar Energy Center research in 160 homes showed that turning on an air conditioner more than doubled the average air leakage rate. An average of 16 percent of the return air was air from outdoors that had leaked into the return ducts. Supply ducts had significant air leakage, too. Duct repair reduced air conditioner energy use by more than 17 percent.

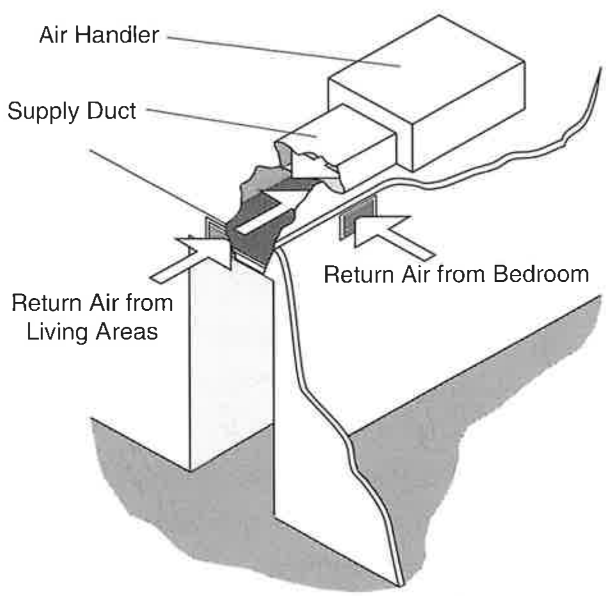
Keep in mind that a forced-air duct system should be a closed system. Airtight ducts from the air handler supply air to the house, and return it to the air handler. There should be no openings besides the registers. And, the registers should seal tightly to wall, floor, and ceiling surfaces.

Some of the worst return air leaks occur in the air handling unit, at the joint between the cabinet and the supply and return air plenum (*see figure* **4-29**). The plenums are sheet metal boxes that connect to the top, bottom, or side of the air handling unit. They serve as the main outlet and inlet to the air handler. Some return plenums use plywood or fiberglass duct board boxes, which are not airtight.



***4-29 Up-Flow Air Handler and Ducts** - The typical duct leak locations are marked by arrows that indicate whether air is entering or escaping the duct.*

Joints between the return plenum and the main return air ducts may also be very leaky. Holes in the cabinet of the air handling unit can be major leaks, too.



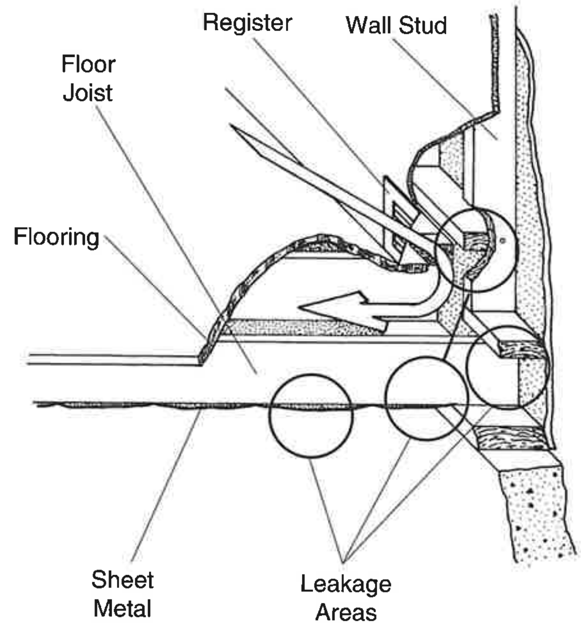
***4-30 Drop-Ceiling Air Return** - Hot air from the attic is drawn into the drop-ceiling air return and into the home unless the top of the cavity formed by the drop ceiling was sealed carefully during construction. Be sure to check the joint between the air return and the air handler.*

Caution: *Major air leaks near the air handler can be a safety problem if there is a combustion furnace in the air handler. The leaks can cause pressure imbalances that interfere with chimney operation.* Inspect the plenums, ducts, and connections near the air handler and seal these areas carefully and completely.

Air conditioning contractors often use spaces behind walls, below floors, and above ceilings as return ducts. These cavities can be a source of air leaks. If the wall, floor, or ceiling cavity serving as the return air duct has openings to the outside or to an area which is not cooled (like the attic), then hot humid air can enter the duct system (*see figure* **4-30** *and* **4-31**). The heat and humidity in this air will overwork the air conditioner and cost you money. Remove the return register grille and examine the cavity for holes and cracks. A trouble light, flashlight, and mirror will help you locate the leaks.

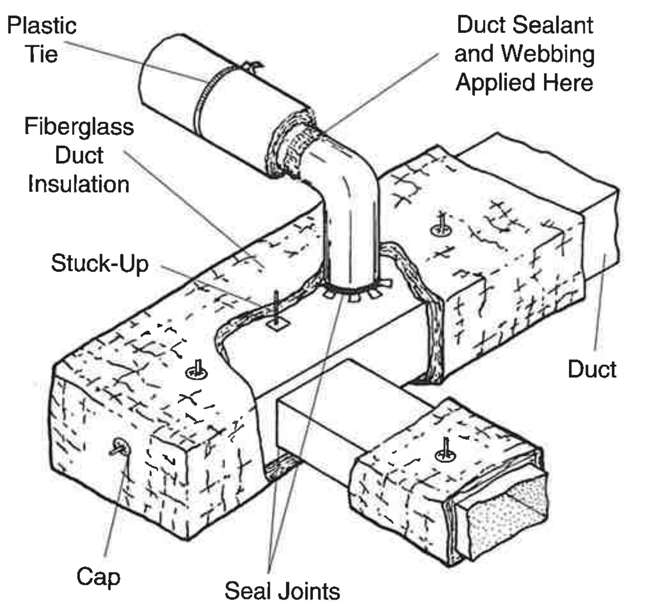
In very damp climates, the cabinets of packaged air conditioners may rust. Rust holes can create large leaks in the supply or return air passageways. If the metal sides, bottom, or divider panel rusts from the water in the evaporator pan, warm outside air mixes with the cool indoor air circulating through the cabinet.

Rust often means that the air conditioner must be replaced. You may be able to salvage it by fastening sheet metal patches to the holes, and sealing them with duct mastic.



***4-31 Return Air Registers** - Air return registers and ducts which use wall, floor, and ceiling cavities sometimes have openings to the outdoors, attic, or basement.*

Rust formation is accelerated if the air conditioner cabinet is placed directly on a concrete slab without spacers providing a dry air space beneath the cabinet. If the air conditioner sits directly on the slab buy rubber spacers to put under the corners of the cabinet, to hold the unit off the slab.



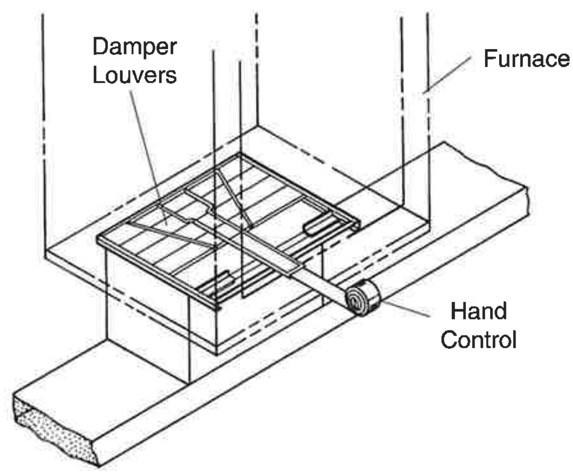
***4-32 Duct Sealing and Insulation** - Air conditioning ducts should be insulated when they are located in hot attics. The joints should be sealed first because the insulation does not stop air leakage.*

4.5.3 Insulating Ducts

It pays to seal all the leaks in ducts that run through a warm area like the attic. Pay particular attention to return ducts. It makes good economic sense to both seal and insulate ducts that run through hot attics. First, seal the ducts as described above, then insulate them. Duct insulation by itself does not seal air leaks.

Ducts can be insulated using various methods. Careful installation ensures that the materials are used to their best advantage.

Seams should be as tight as possible. Carefully cut around obstacles to avoid gaps in the insulation. Mechanical fasteners hold insulation in place better than tape. Duct insulation depending entirely on tape to hold it in place will eventually fall off. You can use wire or plastic twine wrapped around the duct and insulation and stapled into nearby wood framing to fasten duct insulation. This method is very effective and requires no special tools or fasteners. Plastic ratcheting ties or wire are effective fasteners for insulation on round ducts (*see figure* **4-32**).



***4-33 Manual Damper** - This damper prevents cooled air from entering a down-flow furnace during the summer. It is used with packaged air conditioners and ground-mounted evaporative coolers.*

A simple and effective way to insulate sheet metal ducts uses foil- or vinyl-faced fiberglass duct insulation fastened to the ducts with pin-type fasteners (*see figure* **4-32**). The pins are either glued or welded into place on the duct. The pin sticks out perpendicular to the plate.

The glue-type pins are called stuck-ups or stick pins. They have a perforated plate covered with construction adhesive that sticks to the duct. The other type of pin is welded to the duct, using a special device called a pin welder. The pin welder plugs into a 110-volt outlet and welds the pin to the duct.

Plan the pin spacing and locations in advance so you'll have a pin wherever you need one. There are no hard and fast rules for pin spacing and location—try to visualize how the pieces of insulation will fit on the duct and then provide plenty of pins to ensure a neat and secure installation.

Fiberglass duct insulation usually has a reinforced foil facing and is 3 to 4 feet wide. Attach the pin type fasteners to the duct, and impale the insulation foil-side-out on the pins. Fit metal washers over the pins to clamp the insulation loosely to the duct. Cut the protruding part of the pin for safety.

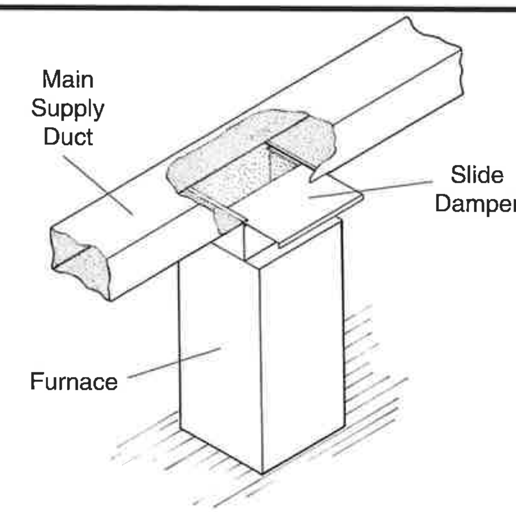
The insulation should wrap all the way around the duct. Position a pin at the overlapping edges to keep the lap together. Tape the seams with a high quality tape, like the aluminum foil tape sold by heating wholesalers.

Good quality fiberglass duct insulation and stuck-ups are usually sold by commercial insulation suppliers. Look under "Insulation" in a telephone directory to find a supplier who sells commercial or industrial insulation.

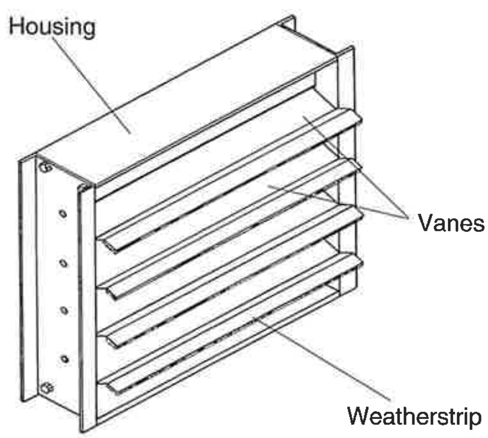
4.5.4 Shared Ductwork

Shared-duct systems commonly have problems with dampers, return registers, and duct connections. They can waste large amounts of heating and/or cooling energy. Inspect all ducts and connections for leakage, and be certain the dampers operate properly.

Many packaged air conditioners share ductwork with a standard home furnace. These shared-duct cooling systems require one damper in the furnace and another damper at the supply outlet of the air conditioner. The damper in the furnace prevents air conditioned supply air from entering the furnace during the cooling season (*see figures* **4-33** *and* **4-35**). The damper in the packaged air conditioner prevents furnace-warmed air from entering the air conditioner during the heating season (*see figure* **4-34**). Evaporative coolers need the same types of dampers when they share ducts with forced air furnaces. Central return registers for packaged air conditioners return indoor air to the outdoor unit and must be completely sealed during winter months.



***4-35 Slide Damper** - Dampers like this are used when a packaged air conditioner or an evaporative cooler shares ductwork with a furnace. The damper is closed in the summer to keep the cooled air out of the furnace.*



***4-34 Damper for Outdoor Air Handlers** - When a packaged air conditioner or evaporative cooler shares ductwork with an indoor furnace it must have a damper like this one to prevent hot air from flowing into the unit during the winter. The blades of this damper are pushed open by the force of the fan in the evaporative cooler or packaged air conditioner and they fall closed by gravity.*

Air Handler - A steel cabinet containing a blower with cooling and/or heating coils connected to ductwork which transports indoor air to and from the air handler.
Blower Door - A device that consists of a fan, a removable panel, and gauges used to measure and locate air leaks.
British Thermal Unit (Btu) - The quantity of heat required to raise the temperature of one pound of water one degree Fahrenheit.
Coil - A snakelike piece of copper tubing surrounded by rows of aluminum fins which clamp tightly to the tubing to aid in heat transfer.
Compressor - A motorized pump that compresses the gaseous refrigerant and sends it to the condenser where heat is released.
Condense - When a gas turns into a liquid as it cools we say that it condenses. Condensation is the opposite of evaporation. When a gas condenses into a liquid it releases heat.
Condenser - The coil in an air conditioning system where the refrigerant condenses and releases heat which is carried away by air moving through the coil.
Conduction - Heat flow from molecule to molecule in a solid substance.
Convection - The transfer of heat caused by the movement of a fluid like water or air. When a fluid becomes warmer it becomes lighter and rises.
Cooling Load - The maximum rate of heat removal required of an air conditioner when the outdoor temperature and humidity are at the highest expected level. Cooling load is calculated to determine the proper size for the air conditioning equipment based on outdoor temperature and humidity.
Cubic Foot Per Minute (cfm) - A measurement of air movement past a certain point or through a certain structure.
Decking - The wood material installed under the roofing material to support the roofing.
Dew Point - The warmest temperature of an object in an environment where water condensation from the surrounding air would form on that object.
Ductwork - The system of supply and return ducts that transport air to and from the air handler in a central air conditioning system.
Eaves - The edge of a roof. See also soffit.
Energy Efficiency Rating (EER) - A measurement of energy efficiency for room air conditioners. The EER is computed by dividing cooling capacity, measured in British Thermal Units per hour (Btuh), by the watts of power. (See also Seasonal Energy Efficiency Rating-SEER.)
Evaporation - The change that occurs when a liquid becomes a gas. Evaporation is the key process in the operation of air conditioners and evaporative coolers.
Evaporative Cooler - A device for cooling homes in dry climates that cools the incoming air by humidifying it.
Evaporator - The heat transfer coil of an air conditioner or heat pump that cools the surrounding air as the refrigerant inside the coil evaporates and absorbs heat.
Fahrenheit - A temperature scale used in the United States and a few other countries. On the Fahrenheit scale water boils at 212° and freezes at 32°.
Fin Comb - A comb-like tool used to straighten bent fins in air conditioning coils.
Heat Gains - Used in this book to mean unwanted heat that accumulates in homes making mechanical cooling desirable.
Heat Radiation - Heat energy that flies through space from one solid object to another.
Incandescent Lamp - The common light bulb found in residential lamps and light fixtures and sold in stores everywhere.

Internal Gains - The heat generated by bathing, cooking, and operating appliances that must be removed during the summer to promote comfort.

Low-E - Short for "low emissivity" which means the characteristic of a metallic glass coating to resist the flow of radiant heat.

Metabolic Process - Chemical and physiological activities in the human body.

Natural Ventilation - Ventilation using only natural air movement without fans or other mechanical devices.

Net Free Area - The area of a vent after that area has been adjusted for insect screen, louvers and weather coverings. The free area is always less than the actual area.

Oscillating Fan - A fan, usually portable, that moves back and forth as it operates, changing the direction of the air flow.

Packaged Air Conditioner - An air conditioner that contains the compressor, evaporator, and condenser in a single cabinet.

Payback Period - The number of years that an investment in energy conservation will take to repay its cost in energy savings.

Plenum - The piece of ductwork that connects the air handler to the main supply duct.

Radiant Barrier - A foil sheet or coating designed to reflect heat rays. Radiant barriers are not insulating materials.

Radiant Temperature - The average temperature of objects in a home like walls, ceiling, floor, furniture, and other objects.

Radiation - Heat energy which originates on a hot body like the sun and travels from place to place through the air.

Reflective - If radiant heat bounces off a surface, that surface is said to be reflective.

Relative Humidity - The percent of moisture absorbed in the air compared to air at the same temperature that is saturated with moisture and can hold no more. Air that is saturated is at 100% relative humidity.

Seasonal Energy Efficiency Rating (SEER) - A measurement of energy efficiency for central air conditioners. The SEER is computed by dividing cooling capacity, measured in British Thermal Units per hour (Btuh), by the watts of power used and adjusted for the entire cooling season. (See also Energy Efficiency Rating—EER.)

Soffit - The underside of a roof overhang which is normally sheeted with wood to form a box at the eaves.

Solar Gain - Heat from the sun that is absorbed by a building and contributes to the need for cooling.

Split-System Air Conditioner - An air conditioner that has the condenser and compressor outdoors and the evaporator indoors.

Top Cord - The top piece of a roof truss which supports the roof decking and serves the same purpose as a rafter.

Ventilation - The movement of air through a house for the purpose of removing unwanted heat.

Watt - A unit of measurement for the ability to do work or the ability to transfer heat.

Window Films - Plastic films, coated with a metalized reflective surface, that are adhered to window glass to reflect heat rays from the sun.

Prices of Cooling Options

The following prices reflect a reasonable estimate based on the experience of the author and conversations with experts in the field. Prices in your locality may be very different.

Cooling Option	Material Cost	Labor Cost	Total Cost
Energy-Efficient Refrigerator	$600		
Very Energy-Efficient Refrigerator	$2000		
Compact Fluorescent Bulb	$10-$15		
Blower Door Guided Air Sealing	$50-$150	$200-$500	$250-$650
White Latex Roof Coating (per sq.ft. materials)	40¢-65¢	10¢-25¢	50¢-90¢
Asphalt/Aluminum Roof Coating (per sq.ft.)	12¢-20¢	10¢-20¢	22¢-40¢
Radiant Barrier (per sq.ft.)	8¢-15¢	15¢-30¢	25¢-45¢
Attic Insulation Add R-19 (per sq.ft.)	6¢-15¢	35¢-55¢	40¢-70¢
Eight Foot Shade Tree	$45-$100	$30-$50	$75-$150
Window Films (per sq.ft.)	$.50-$150	$2-$3	$2.5-$4.5
Rolling Shade (per sq.ft.)	$2		
Venetian Blind (per sq.ft.)	$4		
Sun Screens (per sq.ft.)	$1-$2	$1-$2	$2-$4
Awnings (per sq.ft.)			$6-$9
Continuous Ridge Vent (per linear foot)	50¢		
Static Roof Vent (each)	$10		
Power Attic Ventilator	$80-$140		
Whole-House Fan	$250-$500		
Bathroom or Kitchen Exhaust Fan	$60-$100		
Oscillating Fan	$15-$35		
Ceiling Fan	$100-$200		
Standard Evaporative Cooler	$400-$1000	$200-$600	
Two-Stage Evaporative Cooler	$900-$1300	$200-$600	
Room Air Conditioner (EER - 8)	$300-$500		
Room Air Conditioner (EER - 12)	$500-$1000		
Central Air Conditioner (SEER - 8)	$600-$800	$400-$800	
Central Air Conditioner (SEER - 12)	$1200-$1400	$400-$800	
Central Air Conditioner (SEER - 16)	$1800-$2000	$400-$800	
Automatic Thermostat	$40-$70	$30-$60	$70-$130
Seal Ductwork	$10-$25	$40-$120	$50-$165
Insulate Ductwork	$40-$100	$100-$200	$140-$300

Cooling Measures Checklist

Use this checklist with the manual to identify areas needing improvement. See the applicable page of this guidebook for details about making the improvements.

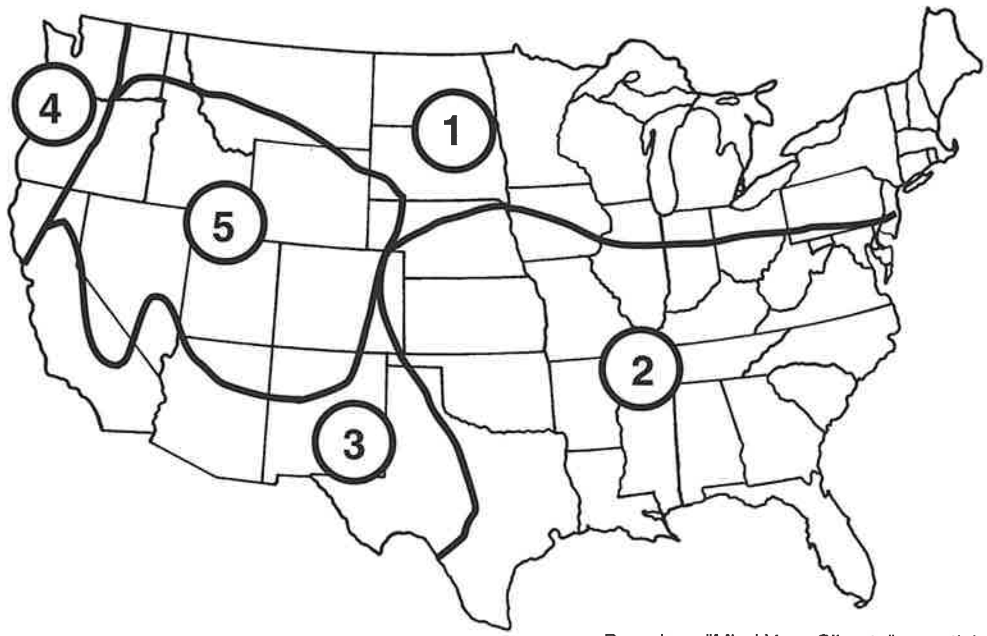
Cooling Measure for Consideration	Page #	Action ✓	No Action ✓	Cost $
Understand cooling principles	1			
Isolate washer, dryer, and water heater	7			
Fluorescent lighting and efficient appliances	8			
Reduce air leakage to minimum safe level	8			
Lighten roof color and wall color	11			
Install radiant barrier	12			
Install attic insulation	13			
Install window films	16			
Install shades or blinds	16			
Install sun screens	19			
Install awnings	20			
Increase use of natural ventilation	23			
Improve attic ventilation	25			
Install whole-house fan or window fan	27			
Install ceiling fans	31			
Buy and use oscillating fans	31			
Maintain evaporative cooler	37			
Purchase two-stage evaporative cooler	38			
Install automatic thermostat	45			
Consider new central air conditioner	41			
Consider new room air conditioner	46			
Clean or replace filter	50			
Clean evaporator coil	51			
Clean condenser coil	53			
Check refrigerant charge	54			
Check air flow	55			
Repair refrigerant leaks	54			
Seal air leaks in ductwork	56			
Insulate ductwork	58			
Check shared ductwork if applicable	60			

Organizations:

Air Conditioning and Refrigeration Institute (ARI) 1501 Wilson Boulevard, Suite 600 Arlington, VA 22209	703-524-8800
Air Conditioning Contractors of America 1513 16th Street, Northwest Washington, DC 20036	202-483-9370
American Council for an Energy Efficient Economy (ACEEE) 1001 Connecticut Avenue, Northwest, Suite 801 Washington, DC 20036	202-429-8873
Association of Home Appliance Manufacturers 20 North Wacker Drive Chicago, IL 60606	312-984-5800
Energy Rated Homes of America 100 Main St., Suite 406 Little Rock, AK 72201	501-374-7845
Florida Solar Energy Center 300 State Line Road Cape Canaveral, FL 32920	407-783-0300
Lawrence Berkeley Laboratory University of California Berkeley, CA 94720	510-486-4000
National Appropriate Technology Assistance Service (NATAS) National Center for Appropriate Technology (NCAT) P. O. Box 2525 Butte, MT 59702	800-428-2525 800-428-1718 (Montana)
North Carolina Alternative Energy Corporation P. O. Box 12699 Research Triangle Park, NC 27712	919-544-6149
Oak Ridge National Laboratory Efficiency and Renewables Research Section P. O. Box 2008, Building 3147 Oak Ridge, TN 37831-6070	615-576-7323
Southface Energy Institute P. O. Box 5506 Atlanta, GA 30307	404-525-7657

Appendix D

Regional Cooling Solutions



Based on: "Mind Your Climate" an article in the July/August 1982 issue of New Shelter. See Bibliography.

Zone 1 - Temperate

The temperate zone is characterized by four distinct seasons. Many areas have cold winters and hot summers. Hot spells tend to be brief. Northern and western regions have daily temperature swings of 20° to 40° F, making night time ventilation to remove heat a practical option.

Solutions for Temperate Regions

Temperate areas are the easiest to cool with low-cost methods. Move summer air with ceiling fans and oscillating fans. Stop solar heat gain with trees, shrubs, vines, and interior and exterior window shading. Ventilate whenever outdoor air is comfortable to remove solar gains and internal gains. Use whole-house fans in humid areas and evaporative coolers in drier areas instead of air conditioning. Air leakage control is important for air conditioned homes located in areas subject to spells of hot and humid weather.

Zone 2 - Hot and Humid

Heat and humidity dominate summer weather in this climate zone. Days are hot and humid, and nights are warm and often even more humid.

Solutions for Hot, Humid Regions

Reduce both air leakage and solar gain to minimize air conditioning costs. Limit indoor sources of moisture and take action to solve drainage problems outdoors to reduce dampness. Cover the ground in crawl spaces with plastic to reduce high humidity under the home. Move air inside the home with fans whenever cooling is needed. Perform regular maintenance on air conditioning equipment. Ventilate whenever outdoor air is comfortable (generally, when air temperatures are less than 80° F accompanied by relative humidity below 65 percent).

Zone 3 - Hot and Dry

Air temperatures can exceed 100° during heat waves in this region. Relative humidity is very low—usually less than 40 percent during the summer. The main cooling problem in this region is solar gain.

Solutions for Hot and Dry Regions

Use window shading devices to block at least 75 percent of solar heat. Choose light colors for roofs and walls. Use evaporative cooling instead of air conditioning if you have a choice, and use fans to circulate air indoors. Consider replacing central air conditioning with standard or two-stage evaporative cooling if air conditioning costs are high. Try to limit cooking and other heat-producing activities indoors during heat waves.

Zone 4 - Cool and Humid

Summer temperatures average in the 70°s, although temperatures can climb into the 90°s for brief periods. Relative humidities range from 40% to 100% and can present a cooling problem during warmer weather.

Solutions for Cool, Humid Regions

Shading and ventilation should provide adequate comfort most of the time. Increase air movement with fans during hot, humid weather. Limit indoor sources of moisture and take action to solve drainage problems outdoors to reduce dampness. Reduce high humidity under the home by covering the ground in crawl spaces with plastic.

Zone 5 - Dry and Mountainous

The large difference in elevations produces a wide difference in summer temperatures and the higher regions are cooler. Most populous areas in this region are below 5,000 feet and have relatively short summers that are hot and dry. Many areas of this region are windy.

Solutions for Dry, Mountainous Regions

Shade the south and west windows. Maximize the area of window opening during cool periods of the day to provide natural ventilation. Ventilate during the night, using fans if necessary, to remove heat. Evaporative coolers should be able to handle 100% of cooling needs in areas where ventilation is not adequate to provide acceptable comfort.

Appendix E

Heat Ailments

Heat Cramps

Heat cramps are the least serious heat ailment and can usually be treated by the sufferer. People who do physical work or who exercise in the heat may experience heat cramps at the end of the day.

Symptoms

- Pale, cool, and moist skin
- Weakness and nausea
- Fast pulse (sometimes)
- Heavy sweating
- Tingling in arms and legs
- Dull pain in abdomen
- Painful muscle cramps in arms, legs, or stomach

What To Do

1. Get out of the sun and heat.
2. Drink cool fluids with one teaspoon of salt dissolved in each quart of fluid.
3. Avoid strenuous activity for at least 12 hours.

Heat Exhaustion

Heat exhaustion takes at least a few hours to develop. It results from water and salt loss due to sweating in the heat. In most cases, sufferers remain conscious and can help themselves. Sometimes, however, the sufferer passes out and needs outside assistance.

Heat Exhaustion Symptoms

- Cool, moist skin
- Normal or lower-than-normal temperature
- Rapid, weak pulse
- Headache, nausea, fatigue, giddiness, loss of appetite, vomiting, or diarrhea
- Thirst
- Fainting or faint feeling
- Muscle cramps (sometimes)

What To Do

If you are conscious:

1. Get out of the heat and sun.
2. Place your feet up and your head down.
3. Drink cool fluids with one teaspoon of salt dissolved in each quart of liquid.
4. Take oral temperature every half hour. Call for help if temperature rises above 104° F.
5. Rest for 1 to 3 days.

If you find the sufferer unconscious:

1. Follow steps 1 and 2. Do not try to give an unconscious sufferer fluids.
2. Call for medical help.
3. Take body temperature, if possible.

Heat Stroke

Heat stroke is not as common as the other two heat ailments but it is more dangerous. Often, it is a result of an person's inability to perspire. The symptoms of heat stroke appear rapidly, especially the high body temperature, which can cause severe damage if not controlled. Since the sufferers may become unconscious or confused, they may be unable to help themselves and must have outside help.

Heat Stroke Symptoms

- Hot, dry, reddened skin
- Temperature of 104° to 106° F, sometimes higher
- Rapid pulse
- Headache
- Confused, agitated, or peculiar behavior
- Dizziness, fainting, or unconsciousness
- Abdominal pains or diarrhea
- Staggering or loss of balance

What To Do

1. Cool the sufferer.
2. Call an ambulance or get medical help.
3. If you can, take sufferer's temperature every half hour until it cools to 102° F.
4. When body temperature decreases to 102° F, cover the patient with a thin blanket or sheet to prevent chilling.

People at Greater Risk of Heat Ailments

- People with chronic diseases such as: diabetes, hardening of the arteries, heart disease, kidney disease, stroke, high blood pressure, respiratory ailments
- Overweight people
- Infants
- Athletes or military personnel in strenuous training
- Alcoholics
- People with circulatory problems
- People taking medication for various conditions such as: heart problems, ulcers, high blood pressure, tension, nausea or vomiting, Parkinson's disease
- People taking antihistamines, tranquilizers, laxatives, or sleep-inducers
- People who lose large amounts of water because they have the flu (diarrhea or vomiting) or because they have been working hard in intense heat and sweating heavily
- People with a fever caused by the flu or immunization shots
- People who can't sweat properly due to cystic fibrosis or other problems

Appendix E

Avoiding Heat Ailments

Get used to the sun gradually.

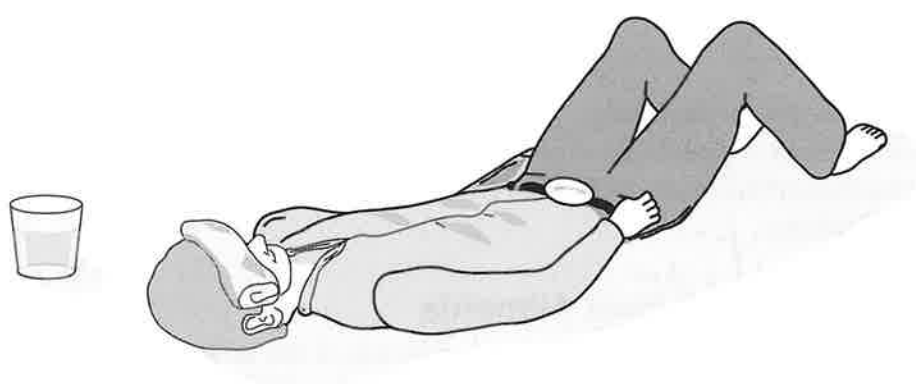
During the first hot spell of the year, don't work too long or hard in the sun. Gradually increase the amount of time in the sun each day.

Keep cool—avoid the heat and direct sun as much as possible.

- Limit activity during the most intense heat (10 a.m. to 2 p.m.).
- Take 5 to 10 minute breaks every half hour if you are working in the heat.
- Try to stay in the shade when you are outdoors.
- Wear lightweight, loose-fitting clothing.
- Wear a wide-brimmed hat in the sun.

Prepare yourself for the heat.

- Drink more fluids such as water, iced tea, vegetable juice. Avoid alcoholic beverages.
- Eat some salty food (unless you are on a low-salt diet).
- Watch for the warning signs of heat ailments when the temperature goes above 90° F such as nausea, dizziness, tiredness, fever, and flushed dry skin.
- Keep in touch with friends and relatives if you live alone.



Appendix E is based on a brochure titled, "Hyper-Thermia," published by the National Center for Appropriate Technology 1981. Reprinted with permission.

Selecting and Planting Shade Trees

Shade Tree Selection

"Tree form" is a tree's mature shape or silhouette and the arrangement of its branches and foliage. When selecting shade trees for your property, consider how the tree form and the tree's mature size will relate to your garden and house. An overly large tree will dwarf a small garden and may eventually cover the entire site with shade while a tree that stays small won't shade the roof.

Shade can be created by a single large shade tree with limbs that spread wide or by a grove of four or more of the same type of tree planted relatively close together. Many types of trees are suitable for grove planting. If you choose to plant a single shade tree, remember a slow-growing variety may require many years of growth before it can provide adequate shade for your roof, walls, and garden. Fast-growing species will give you the quickest cooling results. Remember that evergreen trees will give you shade all year while deciduous trees will only shade your house during the summer.

Shade tree selection checklist:

- How good is the soil depth, drainage, fertility, moisture, and aeration on the proposed site? Will the tree I'm considering do well in my soil type?
- Is the tree hardy in my area? Will this tree grow well in the area's climate and my garden's specific microclimate?
- Can this tree be used to screen undesirable views or shelter the house from winter winds?
- Will the tree eventually interfere with overhead lines, underground pipes, street lighting or traffic visibility?
- Will the tree tolerate pests and diseases?
- What is the tree's growth rate and life expectancy?
- How much maintenance and watering does the tree require?
- Will the tree I'm considering add something special to my site besides shade: flowers, fruit, wildlife cover, pleasing shape and color?
- How much space do I have for the tree to grow? What is the mature size of the crown and root ball of this tree? Is the tree the right shape and size for the proposed site?

Basic Tree Forms

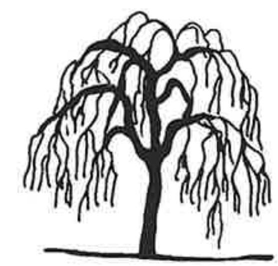
Fastigiate Extremely narrow, tapering to a point (Lombardy Poplar, Fastigiate Washington Hawthorn). Good planted in lines, as screens or shelterbelts. Usually fast-growing, give quick cooling results. Good for planting closer to buildings where a spreading tree would have to be constantly pruned.

Appendix F

Columnar Narrow, not having a pointed tip (Sentry Maple, Columnar Red Maple). Good for narrow sites, to shade rooftops if planted close together in line or grove. Good for planting farther from house on west and southwest, will still shade house roof and walls because of their height.

Spreading Tends to grow wider than tall (Sugar Maple). Good for roof shade and in areas where space is ample. Good as a single shade tree but can also be planted in a grove to provide a cool "ceiling."

Weeping Pendulous branches (Weeping Willow, Weeping Birch). Good where shade is desired close to the ground and where space is not limited. Attractive when silhouetted against background of evergreen trees.



Open Headed Loose branch structure, indistinct silhouette (Silk Tree, Honey Locust, Flowering Dogwood). Provides scattered shade, so may be good choice for east side of house to allow some morning light to reach windows. Usually make good lawn trees, since open foliage allows filtered sunlight for grass and shrubs to grow under tree canopy.

Round Top Distinctly round profile (White Oak, Sycamore). Usually requires plenty of room for the crown to grow. Good single specimen tree. Often can be pruned up to allow cooling breezes to flow under the canopy while still providing shade to walls and roof of house.

Pyramidal Almost conical outline (Douglas Fir, Magnolia, Acacia). Some, such as Douglas Fir, can be used as tall hedge or shelterbelt. Good either single or massed.

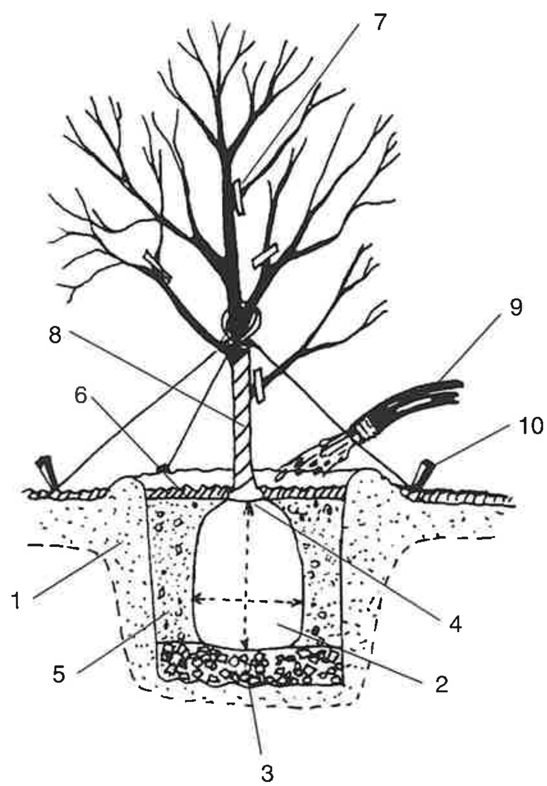
Planting Your Tree

The American Forestry Institute estimates that young trees will grow twice as fast when planted correctly and will live twice as long as trees which are improperly planted. Improper planting is the suspected cause of declining tree health in city and suburban plots where soil is compact. The more building activity there has been in an area, the more compact the soil is. The most important part of planting a tree is making sure the soil around the tree is loose. Most suburban and city soils need careful improvement before you plant trees or shrubs. Follow these steps when planting a tree.

1) **Prepare your soil.** If the soil is good—loose, well aerated, and high in organic matter—rototill or dig an area at least one foot beyond the spread of the roots. Poor soil should be cultivated with a rototiller to an area 5 or more times the diameter of the root ball. In either case, the larger the area of loosened soil, the better it is for the tree. Next, incorporate organic matter such as peat moss, compost, and topsoil into the soil in this area.

2) **Dig a tree pit** in the center of the area of loose soil. The hole should be one foot wider than the width of the root ball and about the same depth. For bare-root planting, the pit should be one foot wider than the root-spread in all directions. As you excavate, save the topsoil to use in planting the tree.

3) **Check soil drainage.** Fill the hole with water in the afternoon and check it again the next morning. If the water is gone by morning, then the drainage is good. If there is up to 4 inches of water in the hole, dig the hole deeper and add sand or gravel to the bottom to keep the tree roots out of the water. If you have more than 5 inches of water in the hole, the soil in that area is not adequately drained and any tree planted there will probably not be healthy.



4) **Place the tree in the hole.** First put a little of the topsoil in the bottom of the tree pit. Place the root ball so that it sits evenly on the bottom with the original top of the soil ball at ground level. It's better to plant too high than too low. If you are planting a container tree or shrub, try not to break the soil ball when you remove the tree from the container. Balled and burlapped trees should be planted with the burlap remaining around the ball. When planting a bare root tree, carefully spread the roots in the tree pit. Roots should not be tangled and curved around themselves.

5) **Fill the hole.** Secure the tree temporarily while you fill and gently tamp the tree pit. Fill around the rootball with topsoil mixed with compost and peat until the hole is 2/3 full. Slowly flood the pit with a hose—water forces air to the surface of the fill so that all roots will be in contact with soil—then finish filling the pit and water again. Gently jiggle the tree making sure it is positioned as you want it. Leave a 2 inch high rim of soil encircling the tree to keep water near the roots. A good rule of thumb is to make this watering basin twice the diameter of the rootball.

6) **Mulch.** Cover the ground with 3 inches of mulch in an area matching the spread of the branches. This covering will serve to retain moisture in the root area. Use bark, aged sawdust, pine needles, peat moss, or similar organic materials.

7) **Prune.** Most trees benefit from a pruning of about a third of the twigs and branches. This helps the tree establish its root system faster. Check with your nursery about trees which specifically do not do well with pruning.

8) **Wrap the trunk** with rolled paper wrap available from nurseries. This prevents sunscald and excess evaporation from the trunk of the tree during its first year. Remove the wrap the following spring.

9) **Water.** Know the watering needs of the tree species you've planted and keep a careful eye on your new plants for the first few weeks. Most trees and shrubs need a regular weekly watering during the first growing season. If a newly planted tree or shrub wilts during the hot part of the day, the rootball is not getting enough water.

10) **Stake the tree if necessary.** If the tree is in an area of high winds or heavy traffic or is especially top-heavy, you may support the tree by staking or guying. Newly established roots can break by the bending and twisting of the tree trunk in the wind, or the tree may be knocked crooked by a passerby. A spring planted tree should be staked over the winter. If you plant your tree in the summer or fall, keep the stakes up for one year. Remember to remove the stakes after one year; otherwise the stakes can become a *crutch* and the tree will tend not to build strength in its trunk. Tests have shown that *some* back and forth movement of the tree tops actually results in a stronger trunk and root system.

—Maureen Shaughnessy

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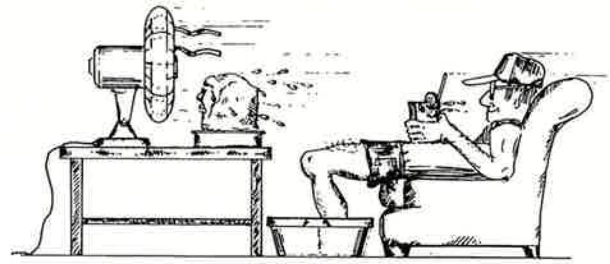
Sketches by Steve Hogan

Your

Home Cooling Energy Guide



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