YOUR MOBILE HOME

ENERGY AND REPAIR GUIDE FOR MANUFACTURED HOUSING

FIFTH EDITION

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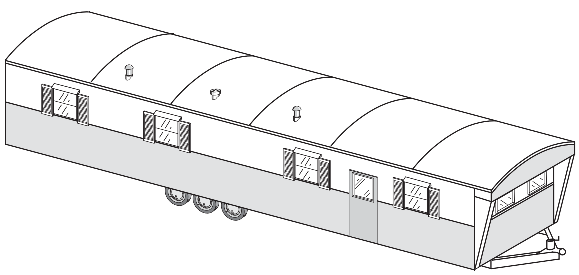
Foreword

This book is about homes built in factories, on steel trailers, and hauled to their home site by trucks. Before 1950, these small manufactured homes were called house trailers. From the mid-fifties to the late seventies, they were known as mobile homes. From the late seventies until now, the industry has been trying to rename their larger, newer cousins: manufactured homes.



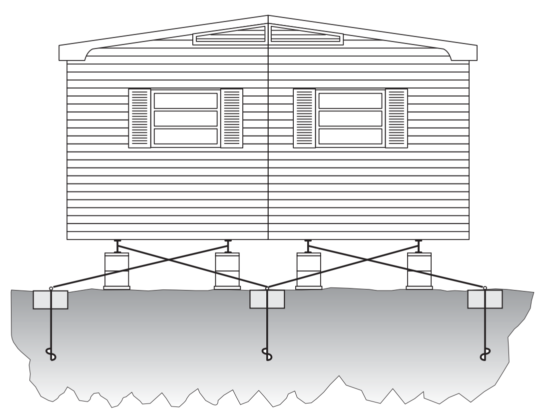
We use the terms mobile home and manufactured home interchangeably with each other. The term mobile home is in the dictionary and many people use it. Manufactured home is the term preferred by the industry, but it's not quite as commonly used as mobile home. So we're stuck with both terms for now.

Mobile or manufactured homes are regulated by the Department of Housing and Urban Development (HUD) through a national code, called the Manufactured Housing Construction and Safety Standards—the HUD Code for short. A HUD-Code home is yet another term for mobile or manufactured home.

The most important feature of manufactured homes for their customers is their low cost. The average manufactured home of today costs around $50,000 compared to $175,000 for the average site-built home. Mobile homes aren't generally as roomy and they don't hold their value as well as site-built homes, although hundreds of thousands of metal-sided and metal-roofed mobile homes from the 1960s and 1970s are still in good repair.

Since the first edition of this publication was released in 1991 our readers have been asking new questions, sending new information, and making suggestions about how to improve this book. This fifth edition benefits from the suggestions of all these readers, as well as the experience and advice of additional experts we have consulted.

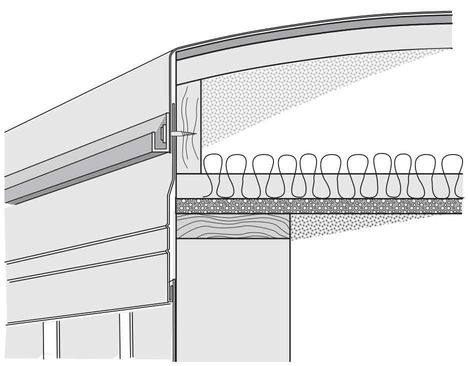
Most older mobile homes can be cost-effectively renovated and weatherized. These older mobile homes are a valuable housing resource. You can perform a fairly major renovation for $5 to $10 per square foot, compared to at least $25 per square foot for purchasing a new manufactured home. Once renovated, an older model can provide many more years of affordable housing.



Too few installers and homeowners realize the importance of proper siting, foundation, and installation. To their credit, many manufacturers have written good installation manuals. If all mobile and manufactured homes were installed on dry ground to manufacturer's specifications, foundation-related problems would be few.

Hurricanes and earthquakes can, unfortunately, do a lot of damage to mobile homes. Insufficient tie-downs and the inadequate strength of site-assembled joints can indeed lead to the home's destruction during these natural disasters. That's why we've provided chapters that show you how to strengthen foundations, floors, walls, and roofs and so prevent or minimize damage.

Moisture problems in manufactured housing are caused principally by wet sites, and occasionally be high occupancy. Manufacturing defects that aggravate moisture problems include inadequate insulation that causes cold interior surfaces, and duct leakage that draws wet air into the home. We address all of these issues here.



The main energy problem in manufactured housing has always been inadequate insulation. Duct leakage is also very common and can be a serious energy problem. Air leakage through the shell of the home, and poor heating efficiency are especially common in older models. Yet some new mobile homes, especially those built in the Pacific Northwest, are very energy-efficient. The good news is that research and experience proves how the energy upgrades outlined in this book can reduce the cost of heating and cooling older mobile homes by up to 40 percent.

Remember that any work you do to improve your home's efficiency should also improve the building's strength, repair any moisture damage, and lengthen its service life. These goals are often met by the very same projects.

You should attempt only those tasks that you feel confident in performing. While you may be able to repair a roof or replace a window, for example, moving a mobile home is strictly for professionals. While you may be able to insulate a wall, you'll probably want to leave electrical projects to the electricians.

We've designed this book so you can find the information you need quickly. Use the Table of Contents to find the general topic you're interested in, such as cooling or heating. Use the Index to find specific topics, such as room air conditioners or space heaters. If you are stumped by a technical term, turn to the Glossary. Look to the Appendices for detailed charts and tables. And you can search the Bibliography for useful references and additional reading.

We hope this book helps you improve your manufactured home so it is safe, comfortable, and efficient. Your home should be nothing less.

– John Krigger, January 2006

Chapter 1 Mobile and Manufactured Homes

This chapter is a primer on mobile or manufactured housing. After exploring their history, we discuss financing, purchasing, and locating your home. The chapter concludes by reviewing manufactured-housing construction, building codes, and research that influenced this book's energy recommendations.

History of Mobile Homes

Camping trailers first appeared in the early 1920s when motoring Americans, who had already embraced cars and camping, conceived a more comfortable and convenient home on wheels. Early camping trailers were lightweight home-made units which combined salvaged automotive chassis parts with the simple wood technology used in yachts. They were called "trailers" because they "trailed" behind the vehicles that pulled them.

In the 1930s, manufactured camping trailers became familiar sights on highways. Some families starting living year-round in these trailers at locations called trailer parks.

Larger trailers, which provided more space and comfort for permanent residents, came to be known as house trailers. In the 1940s, these 8-foot-wide house trailers provided homes to tens of thousands of transient workers and veterans returning from World War II.

Figure 1-1 Sheepherder's Wagon

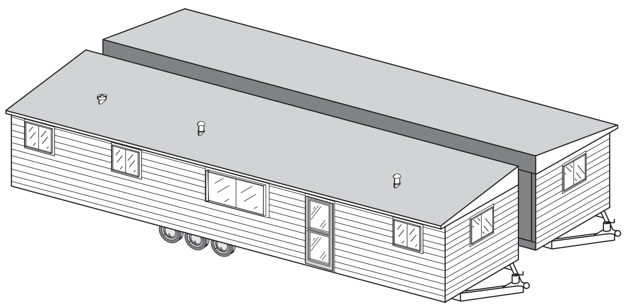
Homes on wheels predate the settlement of America.

In the early 1950s, manufacturers began producing house trailers that were 10 feet wide. They called these new trailers mobile homes. In 1953, the Trailer Coach Manufacturers Association changed its name to the Mobile Home Manufacturers Association (MHMA), signaling the birth of the new product—more a permanent home and less a transient vehicle.

The features of these new mobile homes evolved away from the rounded, aerodynamic corners of a car and towards the boxlike construction of a house. This mobile home with its house-like architectural features has dominated the low-cost and rural housing market since the late 1950s.

In the late 1960s, double-section mobile homes, called double-wides, appeared and since then have become ever more popular. Today's double-wide and triple-wide manufactured homes are almost indistinguishable from site-built homes.

Figure 1-2 Evolution of Manufactured Homes



Manufactured homes evolved from the house trailer, popular in the 1930s and 1940s, to the double-wide homes popular today.

In 1975, the MHMA changed its name to the Manufactured Housing Institute (MHI). With this name change, the Institute began calling its product a manufactured home, instead of a mobile home. The public has been slow to adopt this new terminology, however. The term "mobile home" persists in common usage today along with "manufactured home".

Figure 1-3 Modern Double-Wide

Many modern double-wides are almost indistinguishable from site-built homes, especially when carefully landscaped.

Figure 1-4 House Trailer versus Mobile Home

The 1950s-era house trailer (left) still has rounded features, while the 1960s-era mobile home (right) is more square off and modern-looking. Both are well-maintained and still in service.

Name changes to these industry organizations and their products reflect somewhat of an identity crisis. House trailers and their occupants were occasionally branded with a social stigma reminiscent of European Gypsies, many of whom lacked a permanent home. The term "mobile home," coined by industry pioneer Elmer Frey, sought to remove that stigma, which persisted nevertheless because of the metal siding, metal roofing, and the trailer chassis.

When the industry changed its product's name to manufactured home, more wood siding and asphalt shingles were used. By replacing metal siding and metal roofing, the industry hoped to make the homes appear more like site-built homes.

Most of this identity crisis and social stigmatization related more to perceptions than to function. Many older mobile homes were well-made. Even 20-to-40 years after their construction, they remain quality, low-maintenance housing. Unfortunately, the metal siding, metal roofing, and metal windows that stigmatized them were also essential elements of their low-maintenance exteriors. The substitution of wood siding, plastic siding, and asphalt roofing increased maintenance.

In the past, the most pervasive mobile home consumer complaints were caused by low insulation levels, improper installation, and retailer sales practices. Improper installation and low insulation levels left many homes uncomfortable and easy targets for moisture-based deterioration.

Today's modern manufactured homes, however, compare very favorably to site-built homes in most parts of the country, especially in the Pacific Northwest where they are built to model energy conservation standards. The advantage of manufactured homes over many site-built homes, from an energy perspective, is their simplicity. Custom home builders and their clients have a tendency to create needlessly complicated homes, which suffer thermal lapses and cost overruns due to their complexity. Mobile home manufacturers resist this trend because of the transportation and low-cost imperatives imposed by the buying public.

Mobile Home Construction

Today, mobile or manufactured homes are built in approximately 240 factories nationwide. They are built in long, narrow sections on steel trailers with wheels and axles. Mobile homes are designed in single or multiple sections to be hauled over roads to permanent locations.

Single-wide homes dominated the market until the 1980s, but now double-wides are more popular. Most single-wides are manufactured to widths of 14 or 16 feet. (Older single-wides are 10-to-14 feet wide). Using sections 12-to-16 feet wide, double-wide and triple-wide homes reach total widths of 24-to-48 feet and look very much like site-built homes. Standard lengths for mobile home sections range from 40-to-80 feet.

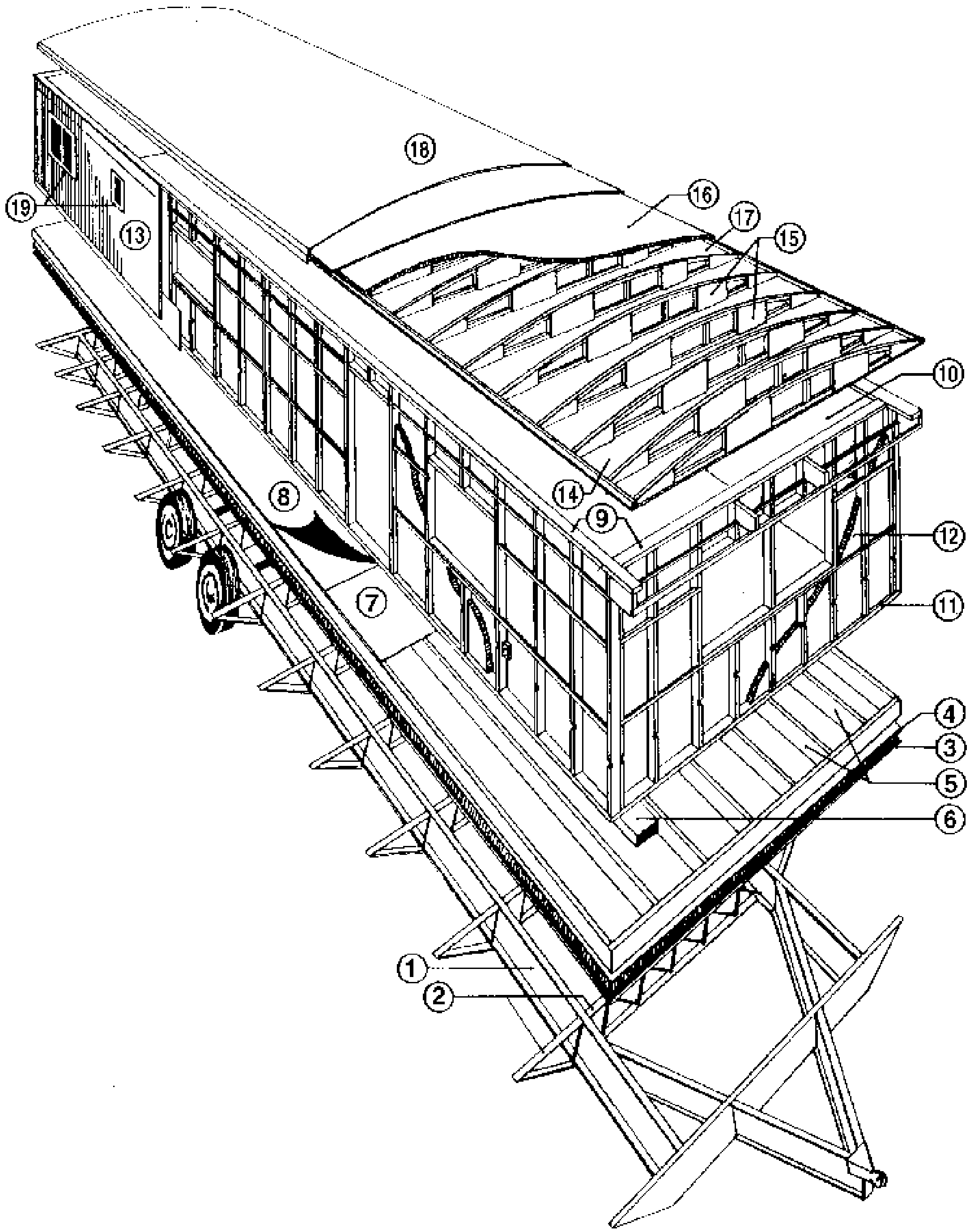
Mobile or manufactured homes are single-story, wood-framed homes with wood floor joists, wall studs, and roof trusses. The wood framing in roofs and floors is lighter than that of site-built homes because manufactured homes are engineered to save lumber and to be lightweight for easier transport. Transportation considerations also dictate their long narrow shape and low roof height—each section usually being less than 16 feet wide and 12-to-13 feet high.

Mobile home manufacturing differs from site-built house construction. Mobile homes employ a number of unique features and construction practices to cut costs and to produce a portable home. The following is a brief list of ways a mobile home differs from a site-built home:

1. Its wooden frame is bolted to a steel chassis that remains with the home throughout its service life.
2. It is constructed in long and narrow segments with shallow roof cavities to limit the home's height measured from the road, for clearance under bridges.
3. Its roofs, walls, and floors are assembled in large pre-built segments on a factory assembly line.
4. Its floors and exterior walls may only have one layer of sheeting, not two like many site-built homes.
5. It utilizes single framing, rather than double framing, around door and window openings.
6. Its interior wall paneling provides structural rigidity for keeping metal-sided mobile-home walls rectangular.
7. It incorporates sealed-combustion furnaces that get their combustion air from outdoors. These furnaces, an industry standard since the early 1970s, are safer than furnaces used in site-built homes.

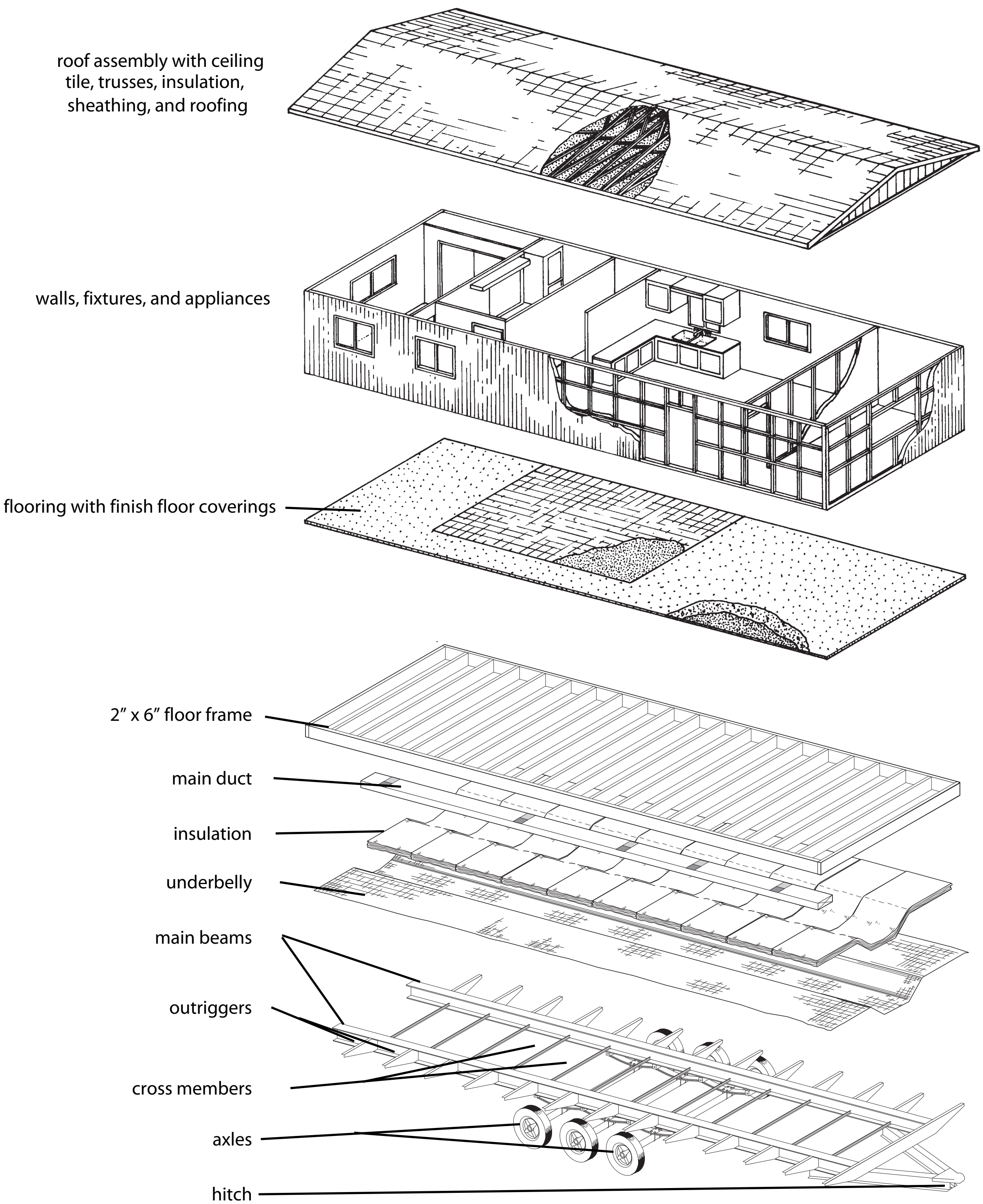
The above differences do not necessarily make a manufactured home better or worse than a site-built home.

Figure 1-5 Typical Components of a Mobile Home



1. Steel chassis; 2. Steel outriggers and cross members; 3. Underbelly; 4. Fiberglass insulation; 5. Floor joists; 6. Heating/air conditioning duct; 7. Decking; 8. Floor covering; 9. Top plate; 10. Interior paneling; 11. Bottom plate; 12. Fiberglass insulation; 13. Metal siding; 14. Ceiling board; 15. Bowstring trusses; 16. Fiberglass insulation; 17. Vapor barrier; 18. Galvanized steel one-piece roof; and 19. Metal windows.

Figure 1-6 Mobile Home Assembly



The chassis, floor, walls, and roof are assembled separately, then moved by cranes, and fastened together on the assembly line.

Mobile Home Manufacturing

Understanding the ways that mobile homes are built will aid in repairing, maintaining, and weatherizing them.

Different parts of the home, such as the floors, walls, and roof, are built separately and then assembled on the production line. The first part of the home to be built is the welded steel chassis. The standard chassis consists of two steel I-beams with cross members and outriggers welded to them. The hitch assembly and axle assemblies are usually bolted to the I-beams, rather than welded, so they can be removed when the home is set up at the site.

The floor assembly is constructed separately. Water lines, waste lines, ducts, insulation, and underbelly are all attached to the floor before the floor assembly is bolted to the chassis. Particleboard flooring, carpet, and linoleum are installed before any interior walls are erected.

The furnace, bathtubs, and interior walls are installed before the exterior walls are attached to the floor. Both interior and exterior walls are preassembled on tables, with interior paneling or drywall attached to the framing before the wall assembly is placed on the floor.

The roof assembly—the ceiling attached to the roof frame—is built separately in another part of the factory, placed on top of the walls, and then fastened in place. Roofing and siding are installed after the roof and wall cavities are wired and insulated. After the exterior siding is attached, the windows and doors are installed. Finally, the interior trim work is completed and the home is prepared for transport.

Study the construction drawings in this book. Note that interior walls usually rest on carpet or linoleum and that the ceiling tile extends over the wall's top plate. This is useful information, in case repairs or energy improvements involve changes to these areas.

Mobile Homes: Affordable Housing

Nearly 19 million people or 7.5% of the U. S. population occupy 9 million mobile homes. Most customers appreciate the low payments and relatively quick outright home ownership that manufactured housing provides them. Currently, about one-in-three new homes is a manufactured home.

Mobile homes comprise about 6% of all the single family households in the United States. In many rural areas they comprise more than 50% of all single-family housing. Of approximately nine million mobile homes in service today, four million were built in the 1960s and 1970s; five million were built in the 1980s and 1990s.

Mobile homes are a very affordable housing resource. Used mobile homes can be bought for as little as $1000, although buyers are encouraged to be cautious. Older units may require extensive repair and weatherization to bring them up to modern standards of comfort and energy efficiency. Still, the low purchase price allows buyers to invest in necessary repairs, weatherization, foundation construction, and home installation.

New mobile homes are also a housing bargain. The average new manufactured home costs about $35,000 versus about $120,000 for a new site-built home. They feature many of the same comfortable features as site-built homes with far less financial investment.

Buying a Mobile Home

When buying a mobile home, be sure to seek the advice of knowledgeable and independent experts. Manufactured-home service technicians or mobile-home park managers are familiar with new and used models. With each new opinion gathered, you will be able to make better decisions.

Your most important decision involves money. Manufactured housing is attractive from the aspect of cost. However, many buyers fail to appreciate all the costs involved in purchasing and installing their home.

Mortgage payments, energy costs, and park fees are usually the highest monthly costs. There are also many initial costs to plan for. Find out from the sellers, loan officers, local officials, and mobile-home park managers about the following initial costs:

1. Down payment
2. Moving fee
3. Installation charges
4. Skirting cost
5. Utility connection fees
6. Landscaping expenses
7. Permit fees
8. Finance charges

There are substantial monthly housing costs in addition to your loan payment. These other housing-related monthly expenses may include:

1. Lot-lease or land payment
2. Mobile-home park maintenance fees
3. Energy costs
4. Water and sewer costs
5. Garbage hauling fees
6. Insurance premium

As you add up these costs, remember that loan officers generally believe that your home loan payment—including principle, interest, taxes, and insurance—should not exceed 30% of your monthly income. Most loan officers also believe that your total loan payments for all types of loans should not exceed 40% of your monthly income.

Before making any purchase decision, total all the projected initial costs and all the projected monthly expenses to make absolutely sure you can afford the purchase.

Buying a New Mobile Home

Before you buy a new mobile home, consult friends or relatives who own manufactured homes. Ask them about their purchase and what they might do differently.

Find out as much as you can about models and features from product literature, trade shows, and unbiased sources like park managers and repair persons before you begin talking seriously with sales representatives.

In general, features like recessed entrances, built-in porches, and tilt-out or slide out additions are not good values. Recessed entrances and built-in porches occupy space that could be better used as ordinary indoor living space. Sheltered entrances, porches, and room additions are better added during or after installation than built in at the factory.

When you do begin talking with sales representatives, take your time. Examine every aspect of the potential purchase carefully. Talk to several dealers. Give each sales person a list of features you want and a list of costs you expect to be included in their price quote. This way you will be able to avoid confusion as to what each dealer's price quote includes. Although they may insist that prices will increase tomorrow or next week, ignore any attempt by sales persons to rush your decision.

Remember that future energy costs are particularly important. Each manufactured home is rated for specific climate zone, wind zone, and snow-load zone. The dealer may prefer that you buy an in-stock model. But, for a few hundred dollars more, you can likely order an energy-conserving model that will markedly improve your comfort and save you thousands of dollars in energy costs over the home's life span.

Financing and Insurance

Financing and insuring manufactured homes is somewhat different from site-built homes. There are two types of mortgages for manufactured homes. The traditional mobile-home mortgage—called a chattel mortgage—finances the home as a piece of personal property separate from the land it occupies. This lending convention recognized that mobile homes could be moved from their original installation.

The second mortgage option is a conventional real estate loan, which assumes that the home is permanently sited and combined with the land it occupies. Compared to the chattel mortgages, conventional mortgages offer a better interest rates and longer terms. A conventional mortgage makes the home easier to sell with the property. To qualify for a conventional mortgage, the home must usually be installed on a permanent foundation.

The meaning of the term "permanent foundation" is widely misunderstood and debated. For more on this important topic, see *"Permanent Foundations" on page 38*.

Mortgage companies require homeowner's insurance. Homeowner's insurance covers loss from a variety of causes such as fire and flood. Homeowner's insurance also covers liability, in case someone is hurt on your property through your negligence.

Researching insurance agents and insurance companies is a good way to start your insurance shopping. Look for an agent and company that have years of experience with manufactured-home insurance. Ask other homeowners, dealers, and park managers who they recommend.

Before buying insurance, list personal property, furnishings, clothing and valuables and take photos, both inside and outside, of the home and its contents. The list and photos will aid insurance adjusters in settling claims and will help you prove uninsured losses, which are tax deductible.

Think about the various perils that threaten your home—floods, wind storms, earthquakes, hail and so on. What level of financial help you would need to recover from each of these? How will you and your agent value your home and is that dollar figure acceptable to you? Make sure your policy covers all the important perils that might occur in your region. Before shopping for insurance, decide how much risk you can bear because you will need to make decisions on limits, exceptions, and deductibles. The more risk you give the insurance company, the more they will charge you.

You can get a cheaper rate for choosing a policy with more limits and exceptions and a higher deductible. The deductible is the money the insurance company deducts from the repair or replacement cost—money you would have to provide to recover from a misfortune. These choices of are an important and individual decision.

Homeowners whose homes are seriously damaged or destroyed will tell you that the money they paid for insurance was well worth it. However, many people pay insurance for decades and never collect. The more you know about your actual risk and your financial future, the better decision you can make.

Buying a Used Mobile Home

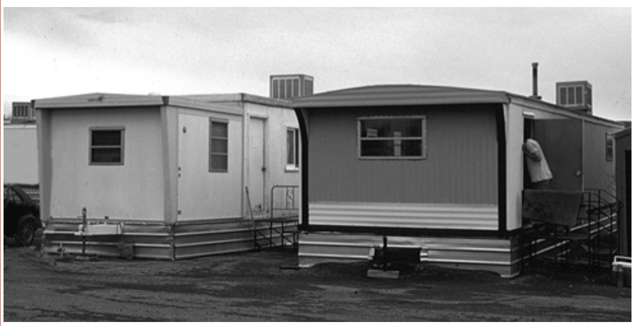
Used mobile homes are among the best values on today's housing market.

The price of used mobile homes varies widely. The most important factors for determining these prices are: the home's state of repair, local demand for used mobile homes, available lots in the area, and zoning restrictions. Due to these variations, it usually pays to shop for a used home throughout at least a 100-mile radius from your home site.

Many used mobile homes are usually not well-insulated. If left uncorrected, this lack of insulation may lead to excessive energy costs. Your housing budget should include money for energy improvements, so energy costs won't become a constant drag on your income.

Since purchase prices vary with the home's state-of-repair, you should honestly evaluate your own abilities and those of friends or professionals who will make necessary repairs and improvements. Normal wear and damage may make a home look unattractive and will likely lower the home's price. These flaws are often easy to repair. If you're handy with tools, a fixer-upper may be your best bet to owning a home at a very low cost. In general, avoid homes with major structural damage to the floor or roof unless you are a good carpenter.

Figure 1-7 Used Mobile Home



Homes built in the 1960s and 1970s are commonly sold for a few thousand dollars. Add 5-to-10 thousand dollars in repairs and weatherization, and you can have a good home for about the same price as a good used car.

Inspecting a Used Mobile Home — Inspect a used mobile home very carefully before deciding to buy. Reading this entire book before beginning to inspect prospective homes will prove valuable. Refer to all the book's various chapters on mobile home components and repair. When you are ready for the actual inspection:

Stand back from the home 25 feet at one end and sight along both edges of the roof and floor. Is the home sagging anywhere? Does the wall bow in or out?

To assess damage to the underbelly, lie on your back in several locations underneath the home.

Look for places where you might see into the wall, floor, and ceiling cavities to inspect insulation.

Open and close windows and doors to judge how well they operate. If the home has been sitting on a lot for a while, some doors and windows may stick or not close tightly. They will probably work OK when the home is installed and leveled.

Look at the water heater and its closet for signs of water damage. Also check the kitchen and bathroom walls, floors, and tub enclosures for water damage. Stains on the ceiling indicate whether condensation or roof leaks are causing moisture damage there.

Write down the make and model of the furnace and air conditioner (if present) from its name plate or compliance certificate. (*See "Understanding Compliance Certificates" on page 220*.) See if you can still get parts for those makes and models.

Inspect the roof from a ladder. Or better yet, walk on the roof. If you're not familiar with metal roofs, they may seem a little flimsy. Stay close to the edge if you're not sure of the roof's strength. If you weigh less than 200 pounds, you should be able to stand on a roof truss's midpoint—you can feel the truss with your feet—without bending it much. Roof metal should be fairly tight without large high spots and low spots. Don't worry about surface rust—that can be coated over. Shingle roofs should appear flat when you look across their surface from different viewpoints on the ground or from a ladder. When you walk on them, shingle roofs should feel more solid than metal roofs and should not sag between trusses or feel mushy.

Look in the electrical service panel box for the type of wire. Avoid buying a home with aluminum wiring which is white/silver in color. Copper wire is what you want and it's copper-colored (*See "Aluminum Wiring" on page 204*).

Refer to this book's index under "inspection" for more information on inspecting a home's particular components.

After you have carefully inspected a used mobile home, you may want to buy it. Before you do, you should obtain satisfactory answers to the following questions:

1. Do the heating and air-conditioning systems work?
2. Do the appliances work?

3. How much interior refurbishment is needed?
4. Is the inside floor level and flat?
5. If the mobile home has to be moved, are the axles, hitch, and wheels operable?
6. What are my capabilities to make necessary repairs to this particular mobile home?
7. What are the capabilities of my friends or local professionals to repair or insulate this particular mobile home?

If you find satisfactory answers to these questions and if the price is right, you likely have a winner. Remember that minor repairs and weatherization may not consume many expensive materials, but they can consume many hours from you or your hired labor. Also remember that major renovation and weatherization projects must be carefully planned and prioritized to maximize benefits and keep costs affordable. If the mobile home still feels right after answering the above questions, buy it.

Repair & Weatherization Projects

Reading this book will likely help you appreciate the need for various repair and weatherization projects. You probably won't be able to accomplish all the projects at once. Do them as your budget allows. Try not to let necessary repair, maintenance, and weatherization go unattended for too long. Always keep in mind the importance of a safe and comfortable home.

To decide what measures to perform, you should:

1. Identify your maintenance and energy problems.
2. Identify repairs and weatherization projects to solve those problems.
3. Determine the cost of each project.
4. List the projects with costs in order of importance.
5. Talk to suppliers and contractors; obtain bids for labor and materials.
6. Decide who will do each project.
7. Make schedules for completing each separate project and all projects together.

The following information is intended to help you clarify priorities for repair and weatherization projects.

Selecting Repair Projects

The structural strength of the foundation, walls, floor, and ceiling are the most important priorities for maintaining the value and livability of a home. Any weakness or damage to these areas is your first repair priority. During any repair or renovation project, plan to improve or at least maintain the home's structural strength. Consider every piece of sheeting, stud, truss, joist, and fastener as an essential structural component. Use structural-grade screws, construction adhesive, galvanized nails, and galvanized-steel straps and plates to reinforce the home's major joints, especially if you live where windstorms or earthquakes are common.

Plumbing leaks, roof leaks, and site-related moisture problems share the top priority because they can severely damage the structure. Electrical and heating problems are also urgent because they affect the comfort, health, and safety of the residents.

When buying a used home, interior refurbishing may take priority over non-urgent exterior repairs. Interior remodeling of an occupied residence should usually be avoided because it can have a devastating effect on domestic tranquility.

Repair priorities and procedures are discussed throughout this manual in the sections relating to the home's particular components. Plan these repair projects carefully. Assemble all the necessary tools and materials before you begin.

The repair procedures discussed in this book are limited to those which are most important to the home's comfort, energy-efficiency, safety, and longevity. The book titled Mobile Home Fix-It Guide has more information than this book on general repairs to mobile homes. Books on home repair are also useful for many parts of a manufactured home which are similar to site-built homes, for example door locks and faucets.

Selecting Weatherization Projects

If you live in a manufactured home with high energy costs, you need to determine the most efficient and cost-effective ways to lower those costs. Cost-effective means that energy savings will pay back the cost of an improvement within a reasonable period of time. The weatherization measures discussed in this book will generally pay for themselves in 2-to-10 years. (*See "Energy Project Summary" on page 222*)

Prioritize your weatherization projects. Complete the most urgent and cost-effective projects first. There are four major factors that should guide your choice of weatherization projects and how much money you can cost-effectively spend on each:

1. Energy use and energy cost. The more you pay per unit of energy and the more energy you use, the more weatherization projects will save you. (*See "Mobile Home Energy Rating" on page 219.*)
2. Climate. The hotter your summers and colder your winters, the more money weatherization projects will save you. (*See "Regional Cooling Solutions" on page 214.*)
3. Problem severity. Problems that waste the most energy deserve the highest priority. Replacing missing window glass will save more than replacing worn-out weatherstripping. Window shading devices have priority over new air conditioners.
4. Project cost. The cost of various energy conservation measures varies widely from place to place and situation to situation. Insulation costs vary according to your region's labor costs. Windows get more expensive the farther you live from the factory. The more a project costs, the longer it takes to pay for itself in savings.

Locating your Mobile Home

Finding the location for your manufactured home is a vital decision. Many manufactured homes have been seriously damaged by natural disasters. Floods and hurricanes are particularly destructive. The most important information to gather about a potential site for your mobile home is that site's disaster history and future prognosis. Are hurricanes or tornados common in the area? Is the site in a flood plain? Is the site near a major earthquake fault, and what are the chances of an earthquake?

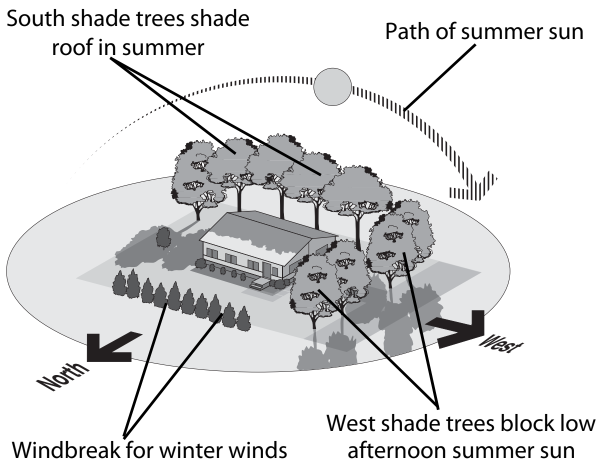
Try to avoid low-lying sites and sites near water bodies. Nearby lakes, ponds, or streams can contribute to moisture problems, as can high ground water.

When you find a possible site, pay close attention to the possible orientations of your home and the requirements of your chosen mobile home community.

Orientation

When inventorying a site for your manufactured home, think carefully about the direction its sides will face. The home's orientation affects not only the view through windows, but also your monthly energy bills. If you have hot summers and you face the home's long sides toward the east and west, you may have maximized your home's solar heating and its resultant cooling costs. Likewise a west-facing long side with many windows may bear the brunt of winter's prevailing wind leading to high heating costs.

Figure 1-8 Locating a Manufactured Home



Locating a Manufactured Home - If you have the option, orient your home's long side toward the south. Provide south shade for the high summer sun during the day. Block afternoon summer sun from the west. Provide a windbreak toward the prevailing winter winds.

If you have a choice of orientation, point the home's long side toward the south. The southern wall's windows catch winter sunshine, but avoid the summer sun's most intense rays coming from overhead. With this orientation, the short sides face east and west—the directions of low-angle summer solar heat—preventing the sun from baking the home's longer walls with their greater window area. Cold winter winds commonly come from the west and northwest, so pointing your home's short sides in those directions prevents the prevailing wind from buffeting the long wall's greater surface area.

Mobile Home Parks

If you plan on siting your mobile home in a mobile home park or in a manufactured housing community, get a complete list of costs, fees, and rules. Although the difference between a mobile home park and a manufactured housing community is mostly semantic, sometimes the manufactured housing community may have newer homes and more restrictive land covenants. And, park residents may even own their own land.

Figure 1-9 Mobile Home Parks

Find out all their requirements and talk to existing tenants about conditions in the park.

Make sure you completely understand all the community's requirements. Be certain that you can live with these rules before locating your home there or buying a home in that particular park or community.

Many states have laws governing landlord/tenant relations in mobile home parks and in manufactured housing communities. The American Association of Retired Persons (AARP) has researched and written model legislation designed to protect tenants from overly restrictive rules. Your state legislator, legislative research division, law library, public library, or the AARP should be able to inform you about your state's laws.

Codes and Standards

Manufactured homes are built in factories by a national building code requiring their design to resist snow loads, wind loads, and extreme summer and winter temperatures. This national building code—known as the HUD Code—governs only their manufacture. Later additions and renovations may be regulated by local building codes.

Mobile home installation and foundations are governed by different model building codes or by state codes specially adopted for the purpose.

Figure 1-10 HUD Insulation Standards —1976 vs. 1994 — A Comparison

		1976 Thermal Standards			1994 Thermal Standards		
		Zone 1	Zone 2	Zone 3	Zone 1	Zone 2	Zone 3
Single-Wide	Ceiling	R-11	R-11	R-19	R-14	R-19	R-19
	Wall	R-7	R-7	R-13	R-11	R-13	R-19
	Windows	Single aluminum	Double aluminum	Double aluminum	Double aluminum	Double aluminum	Double wood or vinyl
	Floor	R-7	R-11	R-14	R-11	R-19	R-19
Double-Wide	Ceiling	R-11	R-11	R-19	R-14	R-22	R-22
	Wall	R-7	R-11	R-11	R-11	R-13	R-19
	Windows	Single aluminum	Double aluminum	Double aluminum	Double aluminum	Double aluminum	Double wood or vinyl
	Floor	R-7	R-11	R-19	R-14	R-19	R-22

HUD strengthened its insulation standards as of October 1994. This table gives typical R-values and window types used to meet the 1976 and 1994 HUD Code's thermal standards. Note that the climate zone map changed when the 1994 thermal standards took effect.

American National Standards Institute

In the late 1950s and early 1960s, competition between mobile home manufacturers was brisk, sales high, and quality sometimes poor. Inconsistent manufacturing led the American National Standards Institute (ANSI) to develop construction standards for mobile homes in 1963, on behalf of the Mobile Home Manufacturers' Association. By 1973, 45 states had adopted the ANSI Standard, making it the basic reference for design and construction.

In the early 1970s, reports by the Center for Automotive Safety prompted Congress to investigate mobile home construction practices. Instead of relying on sometimes spotty state-by-state enforcement, Congress opted to establish federal standards for mobile-home construction. In 1974, Congress passed the Manufactured Home Construction and Safety Standards Act. This legislation ordered the U.S. Department of Housing and Urban Development (HUD) to establish and enforce a mobile home construction code.

HUD Code

In 1976, HUD adopted its Manufactured Home Construction and Safety Standards, commonly called the HUD Code, as the nation's only applicable building code for mobile home construction. The HUD Code set minimum performance standards for roof strength, wind resistance, mechanical equipment, thermal performance, safety, and other construction details. These standards gradually came into force in the late 1970s, increasing the quality of mobile homes nationwide.

The National Conference of States on Building Codes and Standards (NCS/BCS) is HUD's code consultant and enforcer. State Administrative Agencies (SAAs) and private inspection agencies, under the direction of NCS/BCS, inspect manufacturers and investigate consumer complaints. You can obtain a list of SAAs from NCS/BCS (*See "Businesses and Organizations" on page 226*). Enforcement of the HUD Code is complete when the home is delivered. After that, local codes may regulate future additions or renovations if changes to the home require a building permit.

The 1976 HUD Code set thermal standards for new mobile homes, depending on their location. The HUD Code divided the country into three climate zones and established average R-value requirements for mobile homes. The table on this page gives examples of the R-values and window types that could be used to meet these 1976 thermal standards and also the revised 1994 standards discussed below.

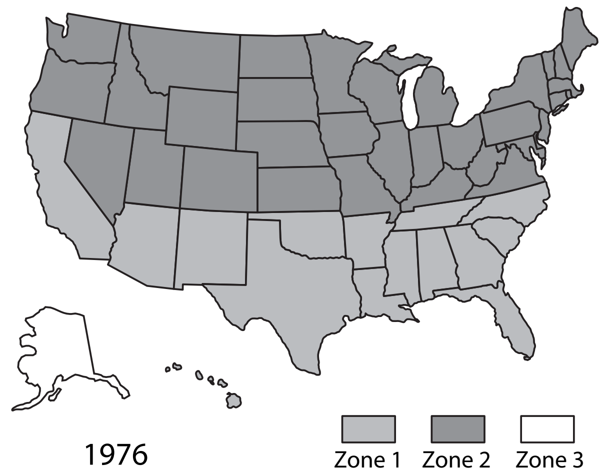
In 1985, sections were added to the HUD Code that set maximum formaldehyde emissions by building products. HUD also required manufacturers to provide whole-house ventilation systems as options in new manufactured homes in the same year.

HUD Code changes, which took effect in the fall of 1994, raised minimum insulation requirements for manufactured homes. HUD also changed its thermal zone map in 1994. Although some temporary confusion may arise, these changes will ultimately provide for more site-appropriate construction.

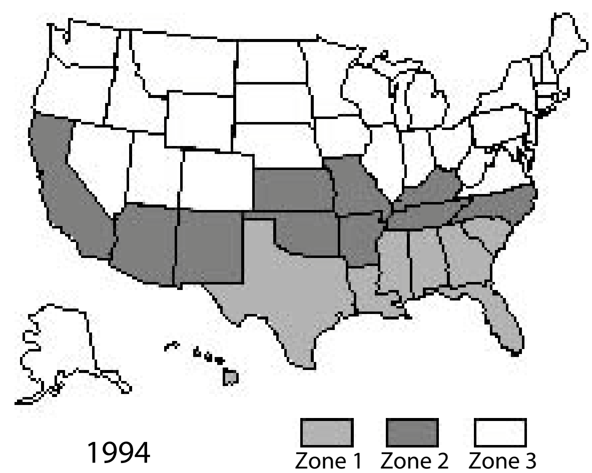
In short, a home built after October 1994 may be certified for a different numbered zone than a similar home built before the 1994 code change. The reason for this map change was to more accurately reflect the climatic differences between different sections of the country. Check the two maps included here for a comparison.

The 1994 revisions also mandated whole-house ventilation and attic ventilation (*See "Ventilating the Indoors" on page 64*).

Figure 1-11 HUD Climate Zone Maps



In this original zone map from 1976, most of the middle and northern U.S. was in Zone 2. Alaska was the only Zone-3 state until the 1994 changes.



1994 revisions to the HUD Code redrew zones to provide more accurate differentiation than the 1976 map. The entire northern U.S. is now in Zone 3, the middle states are in Zone 2, and the southern states are in Zone 1.

HUD Code: Then and Now — Mobile homes built before the 1976 HUD Code are generally less energy-efficient than those built after 1976. These older mobile homes may have some or all of the following characteristics:

- Little or no insulation;
- No vapor barrier in the ceiling;

- 1-to-2 inches of fiberglass insulation wrapped around the outside of wall, floor, and roof framing;
- 2-by-2 or 2-by-3 wall studs;
- Un-insulated supply and return air ducts in the floor or ceiling; and
- Jalousie windows.
- Mobile homes that conform to the 1976 HUD Code must have:
- Insulation in walls, floor, and ceiling;
- A vapor barrier in the ceiling;
- An underbelly of rigid or flexible material to prevent the entry of rodents, water, and road dirt;
- At least 2-by-4 exterior wall studs;
- Supply and return ducts for heating systems that are enclosed in the heated envelope. Or, if not enclosed within the heated envelope, they must be insulated to R-4; and
- Single-hung or slider windows with storm windows in the northern U.S.

Manufactured homes built after October of 1994 must have:

- Higher insulation levels in walls, floors, and ceilings than the 1976 requirements;
- Vent fans in kitchens and bathrooms;
- Whole-house ventilation of 0.10 air changes per hour; and
- More ground anchors, if the home is located in a windy region.

Installation Standards for Manufactured Homes

The American National Standards Institute (ANSI) publishes standards for building foundations and installing mobile homes. And, the Manufactured Housing Institute (MHI) publishes the Model Manufactured Home Installation Manual which serves as a guide for the installation manuals written by manufacturers.

A few states have adopted their own standards for installing manufactured homes. Many more have adopted the ANSI Standard for installation: The 1994 revised edition of the ANSI 225.1 standard is available from NCS/BCS. Manufacturers and lenders consult HUD's Permanent Foundations Guide for Manufactured Housing for guidance on foundations.

Mobile homes must usually meet specific local code requirements for the connection of utilities like water, sewer, natural gas, and electricity. Some local building departments look to the HUD Code for guidance in regulating modifications to mobile homes. Other building officials look to local codes for guidance.

Local Codes

Local codes are enforced by local building departments as part of the process of issuing building permits. Local or state building officials and fire marshals interpret the building codes and are responsible for enforcing them. Cities, counties, and states—the building officials' employers—may adopt any of several common building codes covering construction practices, fire prevention, and safe installation of plumbing, wiring, and mechanical devices for site-built homes. If the city or county has not adopted building codes, then the building codes adopted by the state usually apply. These codes can be used to regulate utility connections, additions, and renovation of manufactured homes.

Most local building authorities lack knowledge or interest in mobile homes. Many state and local building departments simply exempt mobile homes from building codes. Even if local codes apply to mobile homes, most repairs and weatherization improvements aren't considered to be major changes and will usually not require a building permit or inspection.

Mobile Home Research

Research conducted during the past 10 years shows that energy savings of 25% to 45% are achievable through effective energy retrofit or building greater efficiency into new homes.

New-Home Research

In 1992, the Bonneville Power Administration (BPA) signed an agreement with all 18 home manufacturers in the Northwest to produce only homes that met the Model Conservation Standards. The BPA, a federal energy producer and broker, paid incentives of $2500 per home to purchase the energy savings from these manufacturers and their customers and to prevent price increases to customers.

Figure 1-12 Comparison of New Manufactured Homes

City	HUD space Heating kWh/yr.	MAP Space Heating kWh/yr.	Annual Savings kWh/yr.	Annual Savings $/yr. @ $0.08/kWh	Percentage Savings
Portland, OR	8,364	4,737	3,627	$290	43%
Spokane, WA	13,888	8,574	5,314	$425	38%
Missoula, MT	16,299	10,129	6,170	$493	38%

MAP Homes with energy saving features, costing about $1915 per home, use about 40% less energy for heating than standard HUD homes. Portland has a mild winter climate; Spokane is moderate; Missoula has a more severe winter climate.

This BPA program, called the Manufactured Homes Acquisition Program (MAP), paid incentives on 50,000 MAP homes between 1992 and 1995. These homes contained many improvements over homes built to HUD Code including the following.

1. Vinyl double-pane windows with low-e glass instead of aluminum single-pane windows with aluminum storm windows
2. Wall insulation of R-19 or R-21 instead of R-11
3. Floor insulation of R-33 instead of R-22
4. Attic insulation of R-30 to R-49 instead of R-19
5. Doors having R-5.3 instead of R-2.6
6. Measures to reduce duct air leakage
7. Measures to produce a more airtight shell
8. Intermittent or continuous mechanical ventilation

In 1995, Ecotope, Inc. of Seattle published a report documenting the savings produced by building homes to MAP energy standards versus HUD energy standards. Energy savings for these measures were estimated by utility bill analysis, on-site testing, and computer modeling. The energy savings of MAP homes compared to standard HUD homes was approximately 40% with annual kilowatt-hour savings ranging from 3900 kWh to 6600 kWh, depending on climate.

Existing-Home Research

From 1988 to 1991, the National Renewable Energy Laboratory (NREL) conducted mobile-home energy-conservation experiments. These experiments, funded by the U.S. Department of Energy, tested the effectiveness of weatherization and energy conservation measures in cold climates. Many of the conservation methods tested by NREL are described in this book.

During the experiments, seven mobile homes were tested before and after the following conservation measures were installed:

1. Interior storm windows
2. General repairs including air sealing and duct repair
3. Blown underbelly insulation

4. Wall insulation
5. Blown roof-cavity insulation
6. Rooftop insulation
7. Insulated skirting

NREL scientists used a procedure called coheating to monitor changes in heat loss after conservation measures were installed in the mobile homes. This procedure used 100%-efficient electric space heaters to heat the homes. The electrical energy used by the space heaters was easily measured, so it was relatively simple for scientists to accurately determine hourly heat-loss.

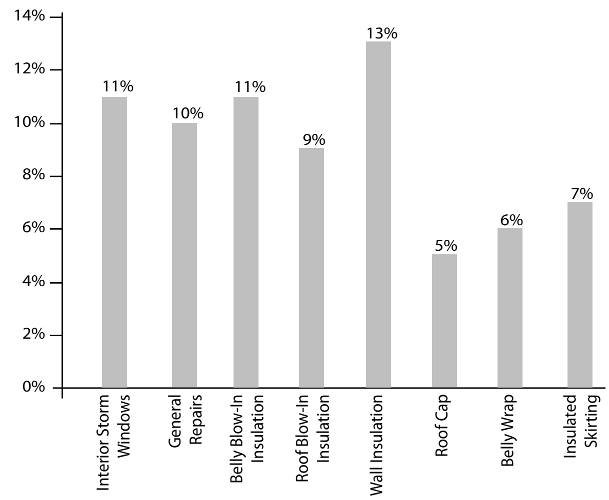
Figure 1-13 NREL Testing Site

NREL scientists used a warehouse as an environmental chamber to accurately measure retrofit energy savings in older mobile homes.

Knowing existing heat-loss, scientists could measure the heat-loss reduction after installation of each conservation improvement. They also measured heating efficiency and how it changed as a result of weatherization and tune-up procedures. NREL scientists also accurately measured air leakage by using a tracer gas. They employed 28 fans to simulate wind to measure the effect of wind on heat loss before and after conservation measures were installed.

The heat loss percentage reductions for individual conservation measures is shown in the bar graph. The average overall heating energy-use reduction was 43%. Follow-up field tests by NREL and the Colorado Department of Housing indicate that actual savings in real, lived-in homes varies from 25% to 35% from the package of retrofits described here.

Figure 1-14 Heat Loss Percentage Reduction for Conservation Projects



This bar graph show the average reduction in heat loss for the energy conservation projects tested by NREL.

The most important findings from this study on weatherization measures for cold climates are summarized below:

1. The most cost-effective measures for colder climates appear to be: air sealing and duct repair, furnace tune-up, blown roof insulation, interior storm windows, and blown floor insulation.
2. Furnace tune-ups, sealing duct leaks, and underbelly insulation directly increase the overall heating efficiency of a mobile home. The average increase in efficiency from these experiments was 15%.
3. Wall insulation can be a practical and cost-effective energy conservation measure on mobile homes.
4. Blown-in floor insulation slightly outperforms insulated skirting in still-air conditions.
5. Blown-in floor insulation significantly outperforms skirting in windy conditions, pro-

viding 42% greater savings than skirting with a 3.5 m.p.h. wind.

6. Fastening insulation to the top of the roof or the bottom of the floor is not as effective as filling the roof and floor cavities with blown-in insulation.
7. The conservation measures listed above are more cost-effective in a 3.5 m.p.h. wind than in calm wind conditions.

NREL scientists also found that average newer manufactured homes are at least as airtight as average site-built homes. The average natural ventilation rate for new manufactured homes was found to be around 0.25 air change per hour. HUD used this figure to estimate the natural ventilation rate for its new whole-house ventilation code that took effect in 1994.

The above NREL studies focused primarily on how mobile homes respond to cold climates. For mobile homes in very warm climates, adding wall and floor insulation may not be cost-effective, especially if the walls and floor already contain some insulation. However, roof insulation is doubly cost-effective in warm climates.

Figure 1-15 Filling Roof Cavities with Blown Insulation

This retrofit produced the best and most predictable energy savings of all the retrofits tested by NREL.

Chapter 2 Foundations

There are two types of foundations for manufactured homes. The traditional foundation system applied to most homes is the *pier-and-anchor foundation*. In order to qualify mobile-home buyers for HUD real-estate mortgages, HUD describes a number of more substantial foundations that HUD refers to as *permanent foundations*.

In existing mobile homes, repairs to the foundation have priority over other repair or weatherization projects. If ground movement caused by poor drainage or an inadequate foundation continues, it will likely reduce the potential benefits of repairs and weatherization.

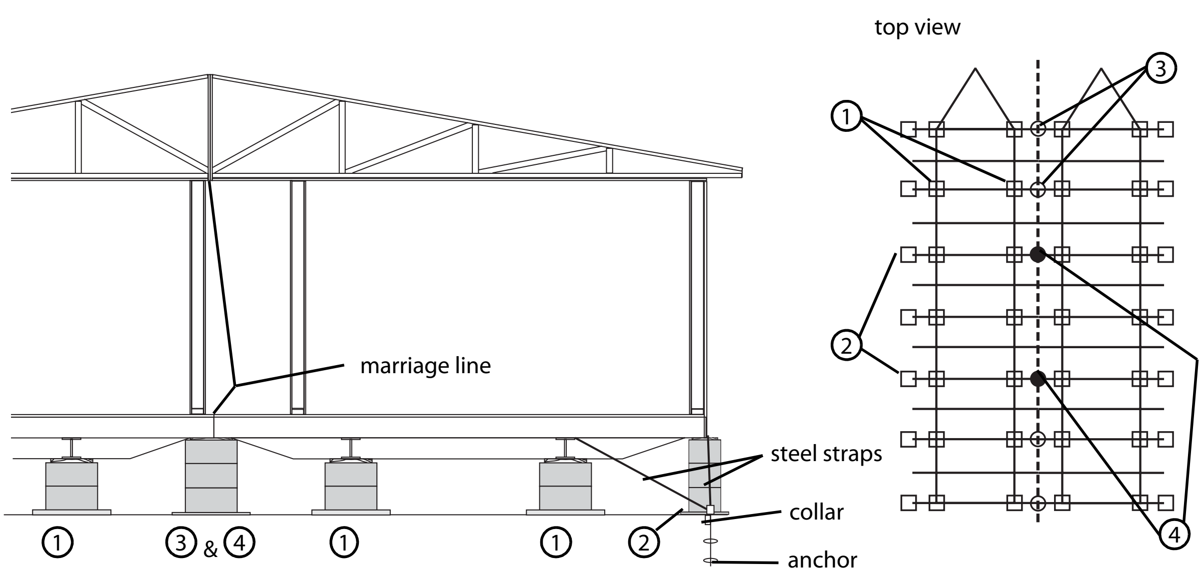
Any foundation should protect a home from movement in the following two ways.

1. The foundation should support the home without settling or rising due to soil conditions.
2. The foundation should be fastened to the home to prevent the home's sliding, falling off the foundation, or turning over due to uplift or lateral forces caused by windstorms or earthquakes.

There are a number of common problems with existing foundations that threaten the well-being of homes and their occupants.

1. Footing area is inadequate to support the home and prevent settling.
2. Footings and piers aren't located where they're supposed to be or they're spaced too widely apart, causing sagging or springy floors.

Figure 2-1 Pier-and-Anchor Foundation Components



1. Main Beam Pier: Required on all mobile homes, usually 8 feet apart. 2. Perimeter Support Pier: Required on both sides of doors or windows more than 6' wide and at regular intervals in northern and mountain regions with heavy snow loads. Also required on many double-section homes. 3. Marriage Line Pier: Required at regular intervals on most multi-section homes. 4. Ridge Column Support Pier: Required in specific locations on the marriage line under walls that serve as columns.

3. Footings laid on inadequate soils rise from frost-heaving or the expansion of clay.
4. Lack of tie downs make a home's sliding, falling off the foundation, or turning over possible in windstorms or earthquakes.
5. Tie-downs may deform the chassis and floor due to uplift from frost heaving or clay expansion.

This chapter attempts to explain how good foundations are constructed. Compare the foundations described in this chapter with your own foundation or with the foundations of homes you service.

Manuals

A pier-and-anchor foundation for each mobile home is prescribed by an installation manual written by that home's manufacturer. The manual explains how and where to support the home with piers, footings, anchors, and tie-downs. Owners requiring a foundation that doesn't use ground anchors should consult a structural engineer or obtain plans for a permanent foundation that fits the support specifications of their particular homes.

What if the original installation manual is missing and you can't find a replacement? Most installation manuals are based on the American National Standards Institute's ANSI Code A-225.1 (1994 Version). This is available from the National Conference of States on Building Codes and Standards (NCS/BCS). The Manufactured Housing Institute has a model installation manual that can also be used for guidance on foundations. (*See "Businesses and Organizations" on page 226*).

The U.S. Department of Housing and Urban Development (HUD) also has published a design manual for permanent foundations. This manual is written for engineers and offers little specific guidance to lenders, dealers, or installers. Many installers obtain good information about foundations from seminars and instructional materials by Manufactured Housing Resources. (*See "Bibliography" on page 227* and *See "Bibliography" on page 227*.)

There is a possibility your state has adopted a code for manufactured housing foundations and mobile home installation. To obtain a copy, check with your state's building-code officials.

For the best foundation, follow the installation manuals closely. This chapter does not attempt to substitute for the specific information contained in these manuals.

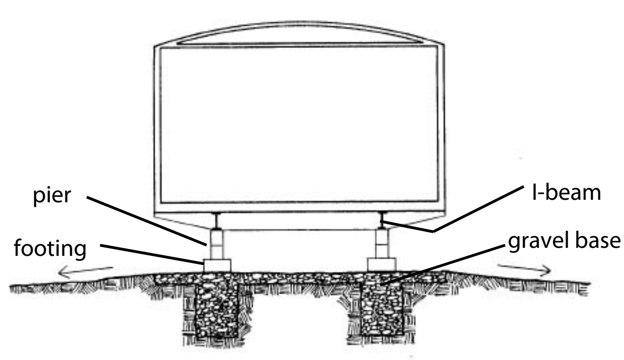
Foundation Siting

Mobile homes must be sited carefully. Poor site preparation and resultant poor foundations have caused more damage and deterioration to mobile homes than any other natural or human factor.

Site Drainage

Water is the worst enemy of foundations. The site must be prepared so that water runs away from the home and never collects underneath it.

Figure 2-2 Sloped Drainage



The ground should slope away from a mobile home. Water should never puddle around or underneath the home.

Ground water reduces the ground's weight-bearing capacity. This can lead to settling because the ground bears the home's weight. Ground water also contributes to frost heave—water in the soil freezing and expanding. Frost heave can raise a foundation as much as 4 inches.

Either foundation settling or frost heaving can distort a home's window and door openings, buckle its siding or roofing, hump its floors, and even break its structural materials.

Water in the ground also causes high relative humidity underneath a mobile home, where the home's skirting traps the humidity. This moisture can condense, wetting building materials in the floor. Moisture can also wick up into the walls, reducing insulation's thermal resistance and encouraging organic building materials to rot. Water rusts steel. Mold and mildew spores create odors and cause respiratory problems.

Site Preparation

It is essential to stop water from flowing or collecting under the home. If the site can't be drained, find another site or hire an engineer to design an elevated foundation.

The home should be placed on the highest ground available at the site. If the home must be sited in a lower area, build the site up with machine-tamped gravel to provide an elevated base. Consider removing surface soil first if it is silt or expansive clay. Install a drain system with ditches and drain piping, if necessary, to direct water away from the foundation.

A poorly prepared site is a difficult problem to correct and can seldom be as satisfactory as a site properly prepared in the beginning. In addition to drainage, consider the following when preparing the site for your manufactured home:

1. Learn from zoning officials or the park manager the required distances from the home to the street and to other homes.
2. Locate buried utilities with the utility company's help. When digging footings or installing ground anchors, wear lineman's gloves in case you hit buried utilities.
3. Locate obstacles such as power lines and tree branches. Can the home be maneuvered into place with minimal complications or interference?
4. Organic matter harbors moisture, insects, and rodents. Remove all plants, roots, leaves, and other organic material from the area underneath the home and an additional foot or two.

Soils for Foundations

Soil's weight-bearing capacity depends on soil type and level of compaction. Gravel and rock are the most supportive soil types. Clay, silt, and fine sand are the least supportive soil types. Soil weight-bearing capacity varies widely between loose soil and compact soil. For example: clay varies from 500 to 8000 pounds per square foot (psf); silt varies from 500 to 4000 psf; and gravel varies from 4000 to 10,000 psf.

Figure 2-3 Approximate Weight-bearing Capacity of Soils

Soil Type	***Weight-Bearing Capacity (PSF)***
Rock	20,000
Hardpan or Very Compacted Soil	10,000
Firm Sand and Gravel	8000
Loose Sand or Gravel	4000
Firm Silt and/or Fine Sand	2500
Firm Clay	1500
Loose Silt or Clay	1000

Weight-bearing capacity of soils depends on soil type and compaction level. These values may be reduced by ground water and weaker soils underneath.

Ground water and weaker soils beneath the supporting layer reduce a soil's weight-bearing capacity, so it's best to use values in the middle to lower end of these ranges, if you're not sure what's underneath.

An installer or engineer can estimate the soil's weight-bearing capacity with a *pocket penetrometer,* available through engineering supply stores. (*See "Businesses and Organizations" on page 226.*) Lacking this device, contact local experts such as building inspectors or agricultural extension agents to identify your site's soil type.

In general, soil consisting of rocks, sand, and gravel drains better and therefore resists settling and frost-heaving. Structural gravel is an ideal material to fill beneath footings or to elevate the ground underneath a new home. The gravel should have a variety of rock sizes and contain course sand but very little fine sand. Structural gravel compacts easily, drains well, and supports over 8000 psf when compacted and supported by equally supportive soil underneath.

Placing a foundation on clay, silt, fine sand, or fill-dirt require special foundation engineering and design, since these soil types may settle or expand. Clay expands when wet and shrinks when it dries out. Silty soils are very prone to frost-heaving.

Contact an engineer for advice about the foundation if any of these conditions exist:

1. The home must be located on loose clay, silt, fine sand, organic soils, or backfill;
2. Ground water is near the soil's surface; or
3. The foundation site is near a lake or river or in a flood plain.

Frost-Lines

The frost line is the maximum soil depth where water will freeze during the coldest winter weather. Frost lines are very important to the foundation's footings because frost can move the foundation.

If frost heaves the foundation, the home's chassis and framing deform. Window and door openings may be distorted, siding or roofing may buckle, and floors may become humped.

The standard way of protecting a foundation is to put the footings farther below the surface of the ground than frost will penetrate. Local building officials will help you determine how deep to install footings for protection from frost. *See "Foundation Design Reference" on page 216* for frost lines for U.S. locations.

The sheltering effect of the home and skirting often results in a shallower frost line (40% to 80% of the regional depth). This can affect the decision of how deep to dig the footing's base.

Pier-and-Anchor Foundations

Foundations consist of footings, piers, ground anchors, and tie-downs. Piers and footings support the home's weight. Anchors and tie-downs prevent wind and vibration from moving the home off its piers.

Approximate Weight of Manufactured Homes per Section

Component	Weight (lbs)	PSF
Home	14,000-32,000	13-25
Contents	24,000-40,000	40
Snow Load	0-60,000	0-60
Total Design Weight	**38,000-132,000**	**53-125**

The maximum weight of the home is the sum of: 1. The home's weight; 2. The maximum weight of the home's contents; and 3. The snow load prescribed for the region where the home is located.

Mobile homes weigh 40-to-80 pounds per square foot of floor space. This includes the home, its contents, and an anticipated snow load of 20-to-40 pounds per square foot—depending on typical snowfall in the region.

Homes with metal siding, metal roofing, and wood interior paneling are lighter than homes with shingle roofs, wood siding, and sheetrock interior paneling. Homes designed to support more snow are heavier than homes designed to support less of a snow load.

Footings are masonry or wood platforms that sit on or below the ground to support the home's weight. *Piers* are columns of concrete or steel sitting on the footing and supporting the main I-beam. The foundation should be designed individually for each home, according to the home's weight, the soil type underneath the footing, and pier locations specified by the manufacturer.

The mobile home's installation manual specifies locations for piers and footings, depending on where the weight of the home is best supported. The installation manual also specifies locations for anchors and tie-downs.

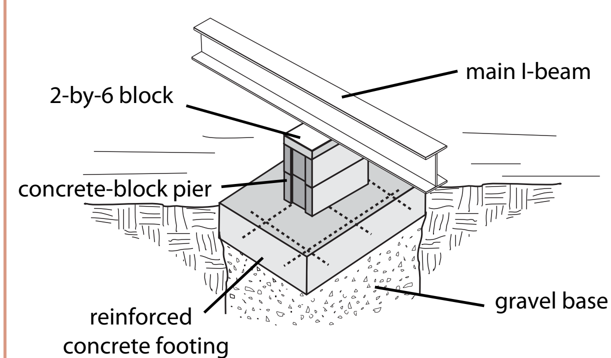
Piers and footings under the main I-beams are typically located 6-to-10 feet apart. Many homes also require perimeter support piers, particularly at the sides of doors and large windows or under the laundry or fireplace. Perimeter support piers are footings and piers installed at the home's perimeter. Double-wide homes need piers and footings under the marriage wall. The marriage wall is the common long wall shared by two sections of a double-wide home. The location of marriage-wall piers is critical, because certain piers support large sections of the roof through an interior wall. These special piers, which generally need larger-than-normal footings, are called ridge-column-support piers.

Footings

A footing is a concrete or wood pad sitting on undisturbed ground or compacted gravel that transfers the home's weight to the ground. Wood pads ($1^1/_2$-inch-thick) are used only when the footing sits on very dry, supportive soil. Solid, load-bearing concrete blocks (4-by-16-by-16 inches or 4-by-24-by-24 inches) are often used for footings. Steel-reinforced concrete is used for bigger footings. Gravel underneath the footing is often considered part of the footing, making concrete footings that extend from the frost line all the way to the ground's surface unnecessary.

The success of a foundation in supporting a home depends on the size, spacing, and depth of the footings. Footings are laid before or during the home's installation. Their area and thickness are determined by the weight they must support, the soil type, and the pier size. If footings must be buried, the region's climate and weather will determine the depth.

Figure 2-4 Large Concrete Footing with Pier

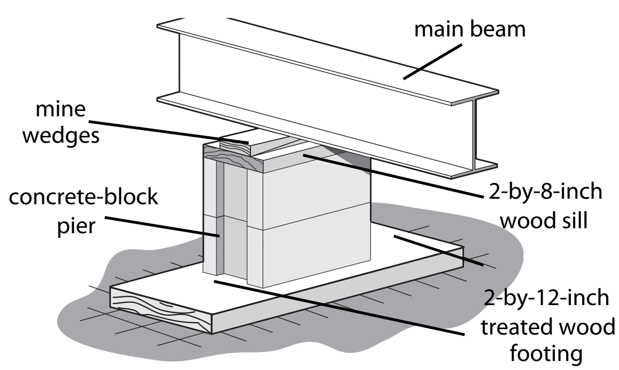


On less-supportive soils, footings must be large enough to spread the home's weight over more area. Concrete or the gravel base extends below the frost line. Here the footing's width and length exceed the dimensions of the pier by no more than twice the footing's depth.

Weaker load-bearing soils, including silt and clay, require larger footings or more footings. Design for soil-bearing capacity of 1000 pounds per square foot unless you confidently identify the soil type or test the soil with a pocket penetrometer. A concrete or wood footing—laid on compacted gravel extending below the frost line—is often used. *See "Foundation Design Reference" on page 216* for more information about frost lines and footing design.

Here's a way to design footings if you don't have an installation manual. This method uses compacted cylindrical gravel bases, 22 inches in diameter. Drill the holes for the gravel bases 6 inches below the frost line using a 22-inch auger. Compact the soil at the bottoms of the holes with a soil tamper. Pour structural gravel into these holes 8 inches at a time and then compact each gravel layer with a soil tamper. Place a standard 4-by-16-by-16-inch solid concrete block level on top of each gravel base. Each of these footings can support 2000-to-10,000 pounds, depending on the subsurface soil underneath the gravel base. This subsurface soil is often more supportive than the surface soil, and if you hit rock or compacted soil while digging, the footing will support up to 10,000 pounds. Space these footings 4-to-8 feet apart, according to the total weight of your home, including contents and snow load.

Figure 2-5 Treated Wood Footing and Pier



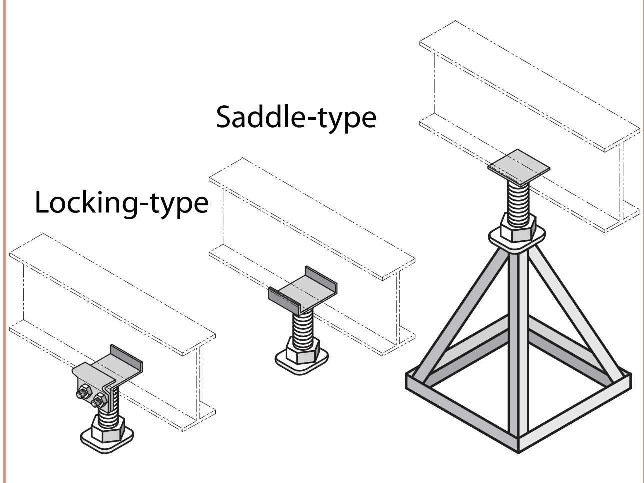
On hard soils, the footing is often blocked directly on the ground or on a gravel base using a pressure-treated wood 2-by-12-inch wood pad. The concrete blocks, 2-by-8 inch wood sill plate, and 4-inch wood wedges all are perpendicular to the main beam.

Larger footings for less supportive soils should be poured concrete. When using standard concrete-block piers, two footing sizes make sense for maximizing strength and conserving concrete—4-by-16-by-24 inches and 6-by-22-by-28 inches. The smaller of these should support 2500-to-12,000 pounds and the larger 3500-to-14,000 pounds, again depending on the subsurface soil. Footings larger than these should be reinforced with #4 rebar, one foot apart in both directions located within 2 inches of the footings bottom. Concrete requires a month to cure, but is strong enough to support the home after 3 days.

Piers

The most common type of pier is made with load-bearing, hollow-core concrete blocks. Load-bearing means that the block must be designed to bear weight. Cinder blocks and decorative masonry blocks are not acceptable. Blocks are laid on top of each other with their cores aligned vertically. The piers are capped with a 2-by-8 wood block to serve as a cushion between steel beam and concrete block. If a pier must support more than 10,000 pounds, use two 2-by-8 blocks to prevent one from being crushed. Final leveling adjustments are made with 4-inch-wide, wood wedges at each pier.

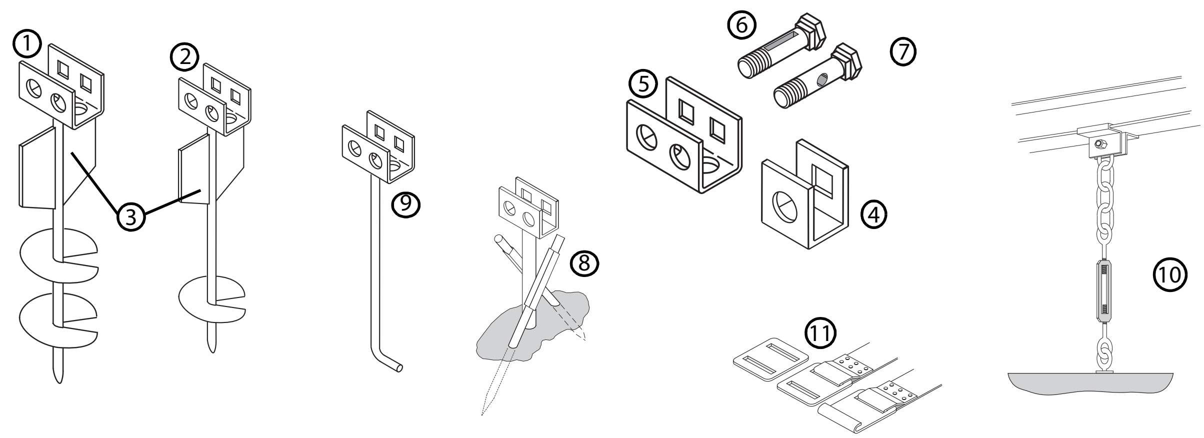
Figure 2-6 Steel Piers



Steel piers with adjustable supporting plates are popular and convenient to transport and use. They are also available with saddle-type or locking support plates.

Piers determine the minimum height between the ground and the I-beam. This height should be at least 12 inches. However, an 18-to-24 inch crawl

Figure 2-7 Devices for Anchoring



1. Soft soil anchor; 2. Hard soil anchor; 3. Anchor collar; 4. Single anchor head; 5. Double anchor head; 6. Band-tightening bolt; 7. Cable-tightening bolt; 8. Hard rock anchor; 9. Concrete anchor; 10. Chain and turnbuckle anchor (for resisting flood flotation only); and 11. Hook and buckles for fastening banding to the frame.

space is much handier for future repairs and maintenance. Keep in mind that the taller the home, the stronger the piers must be to resist tipping or crushing during an earthquake or windstorm.

A pier made of a single column of concrete blocks is strong enough to stand up to 24 inches tall. A double column of blocks (one course rotated 90° to the next) can be up to 48 inches tall. Piers over 48 inches tall should be double-column concrete blocks with cores filled with concrete or mortar and metal reinforcing steel rod running through the blocks' cores into a substantial reinforced concrete footing below.

Steel stands with saddle-shaped or locking-type tops also make good piers. These steel piers work like screw jacks, making their tops easily adjustable. The older style of steel pier has a very small bearing surface under the I-beam. The home may fall off such a pier in an earthquake. The clamping top is best for areas with any chance of an earthquake. Specialized steel piers used for preventing earthquake damage are described later. (*See "Earthquake-Resistant Bracing Systems" on page 40.*)

Anchors and Tie-Downs

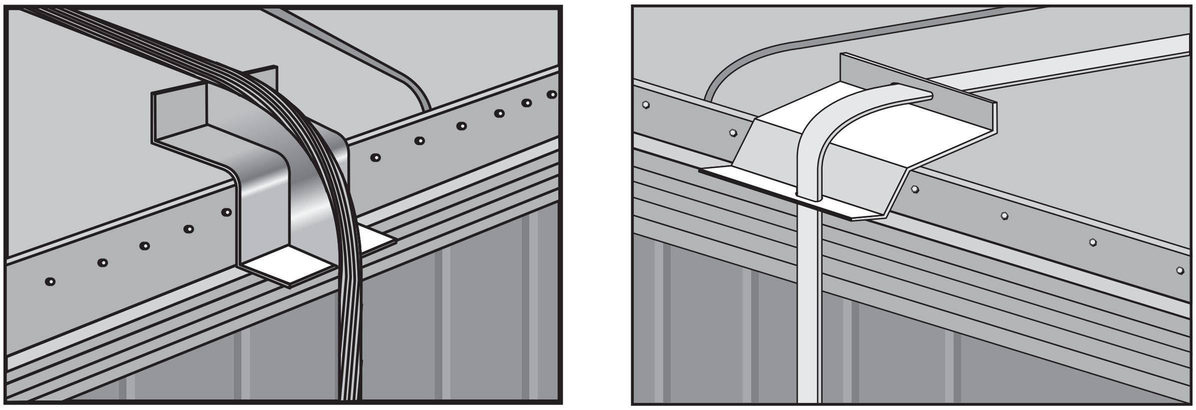
Ground anchors are steel rods that penetrate the ground, attaching the home to the ground, using tie-downs made of 1.25 inch galvanized-steel strapping or galvanized-steel cable ($^1/_4$ or $^7/_{32}$ inches in diameter). Anchors and tie-downs prevent the home from falling off its piers or rolling over during high winds or an earthquake.

Most anchors are designed to resist about 4700 pounds of pulling force. This assumes dry compact soil. If the soil is loose or is wet during a hurricane, the anchor may only resist 2000 pounds, so use more anchors if in doubt about your soil.

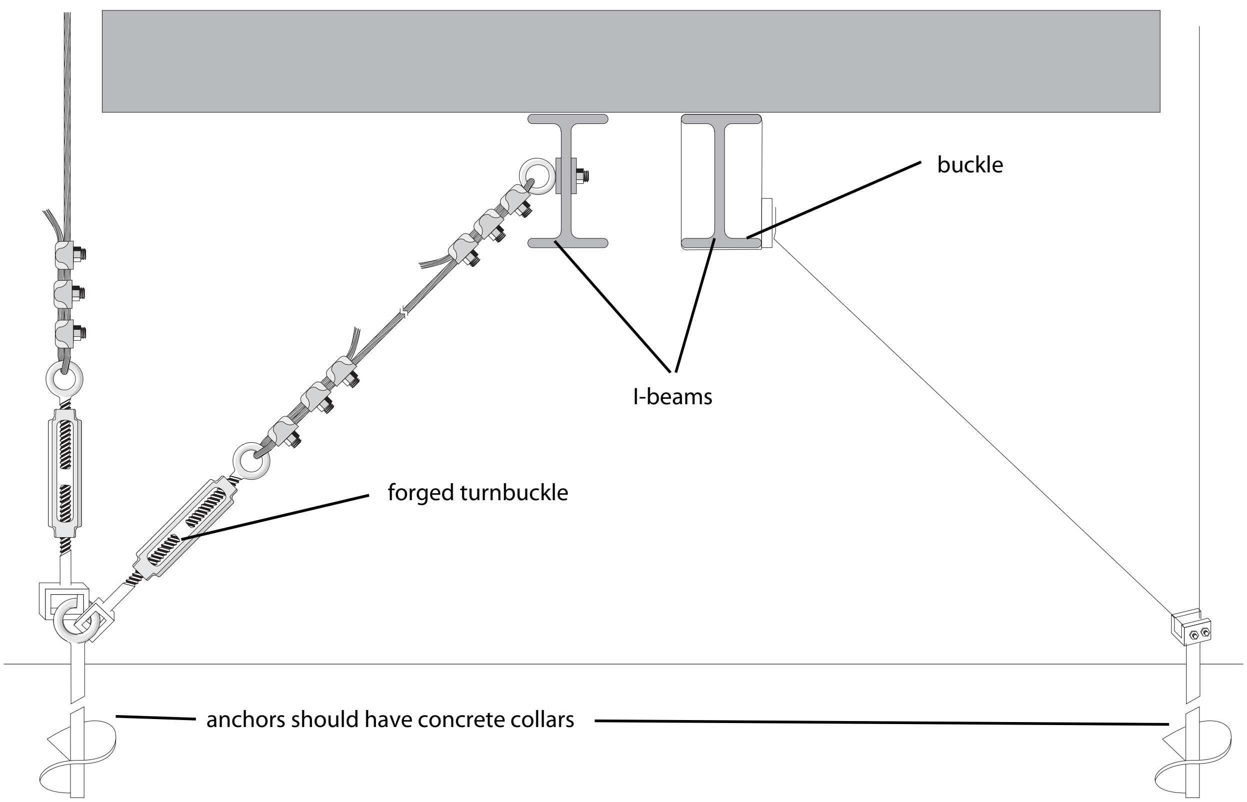
Screw-type anchors are screwed into the ground using a piece of metal rod for leverage. Electric anchor drivers make anchor installation easier. There are two types of screw-type anchors, the *soft-soil anchor* and the *hard-soil anchor.* Soft-soil anchors are longer and have one split disc; hard-soil anchors are shorter and have two split discs. The split discs are the devices at the anchors end that act as a screw.

The hard-soil anchor is installed at least 30 inches into the ground. The soft-soil anchor is installed 40 inches or more into the ground.

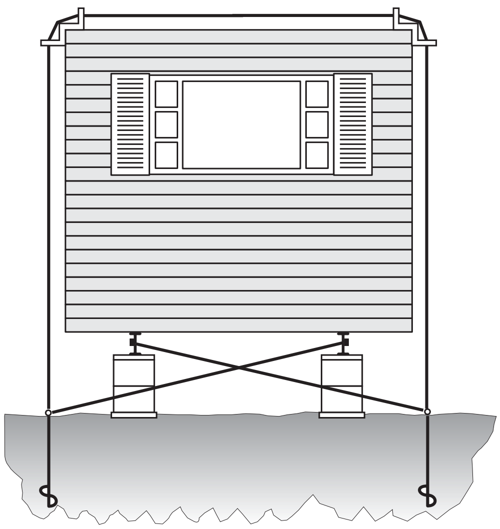
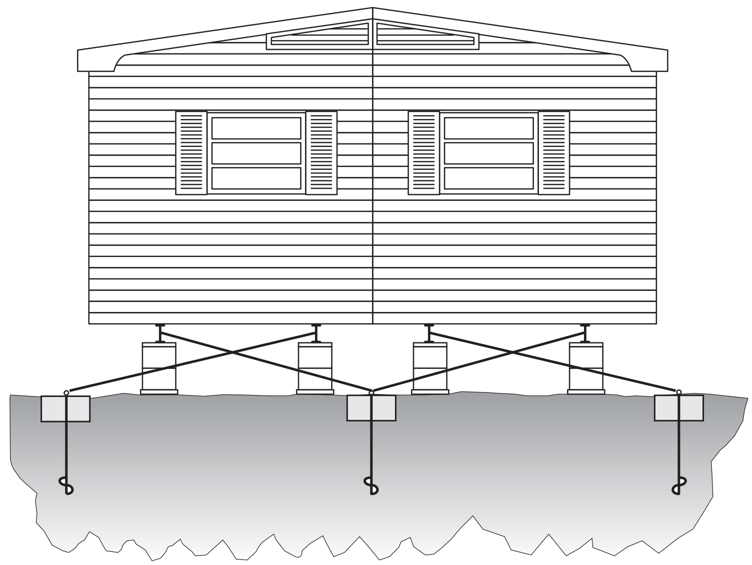
Figure 2-8 Anchor Connections to Tie-Downs



Use corner fittings like these when installing strapping or cable over the roof from anchor to anchor. Two 2-by-4 blocks or 3-foot piece of galvanized-steel angle will also serve to spread the force exerted by wind or earth-quake.



Secure connections between anchors and tie-downs are extremely important because the forces of winds and earthquakes act on all components of the anchoring system. The anchoring system will only be as strong as its weakest link. The system on the right uses 1.25-by-0.035-inch galvanized-steed strapping. The system on the left uses 1/4-inch galvanized steel cable or 7/32-inch aircraft cable. *See "Wind Speed and Anchoring Requirements" on page 218* for the recommended number of anchors and ties for your home and its design wind speed.

Figure 2-9 Single-Wide Tie-Downs	Figure 2-10 Double-Wide Tie-Downs
	
Single-wide homes need 2-to-7 vertical or over-the-roof ties and 3-to-10 horizontal or frame ties. A 90 mph wind creates enough uplift to make the lightest mobile homes hover, and the wind's horizontal force is $^{2}/_{3}$ greater.	Double wides need only frame or horizontal ties. Connecting frame ties to the far beam is an excellent way of getting the maximum holding power out of the anchor. Anchors should have a poured concrete collar to resist their slicing through the ground.

Rock anchors are pinned to the ground with steel stakes. The *drive anchor* is driven into very hard or rocky soil and works especially well in the coral soil of coastal areas. There are a variety of *concrete anchors* sold for insertion into concrete while it's being poured.

HUD requires single-wide homes to have vertical tie-downs to resist uplift and diagonal ties to resist both horizontal forces. Double-section and triple-section homes require only diagonal tie-downs. A single-section home needs 2-to-7 vertical ties and 3-to-10 diagonal ties depending on the home's length and its wind zone.

A diagonal tie-down needs a collar to prevent the anchor rod from slicing through the soil when pulled by the home. Although manufactured plates are made for this purpose, a poured-concrete collar is far superior and is an absolute necessity for hurricane, tornado, and earthquake zones. After installing the anchor, dig a round hole a foot deep and 16 inches in diameter around every anchor that has a diagonal tie. Fill this hole with concrete to the ground level.

Installing Tie-downs — Attach one end of the strap or cable to the bracket or eye on the anchor and the other end to the main I-beam or over the roof to another anchor. The I-beam may have slots or steel fittings to facilitate attaching the strapping or cable. Or, anchoring kits contain buckles or cable connectors that attach the strapping around the I-beam or anchor.

Most anchors have brackets with one or two slotted or drilled tension bolts, into which the tie-down straps or cables are inserted. These bolts are rotated to tighten the strap or cable. The two-bolt brackets can fasten one anchor both vertically and diagonally. Anchors with a forged loop at their ends, designed for cable tie-downs, are tightened by drop-forged 1/2-inch turn buckles. Tighten tie-down straps alternately on opposite sides of the home during installation and make the straps or cables as tight as you can get them.

Over-the-roof strapping is designed to prevent the home—particularly its walls and roof—from blowing off its chassis during high winds. Many manufactured homes have regularly spaced built-in anchoring straps that go over the roof and hang out underneath the siding. Modern homes use wind-resisting construction, making over-the-roof tie-downs unnecessary.

When installing external over-the-roof anchoring straps on older homes, be sure each strap lines up with a roof truss. If the strap rests on an unsupported area of roof, the wind's force could damage the roof. Use special roof protectors to cushion external straps at the roof's edge where they make a right-angle turn. Some installers use 3-foot pieces of galvanized-steel angle at the roof edge to spread the strap's force to two additional trusses, one on each side of the one chosen to line up with the strap or cable.

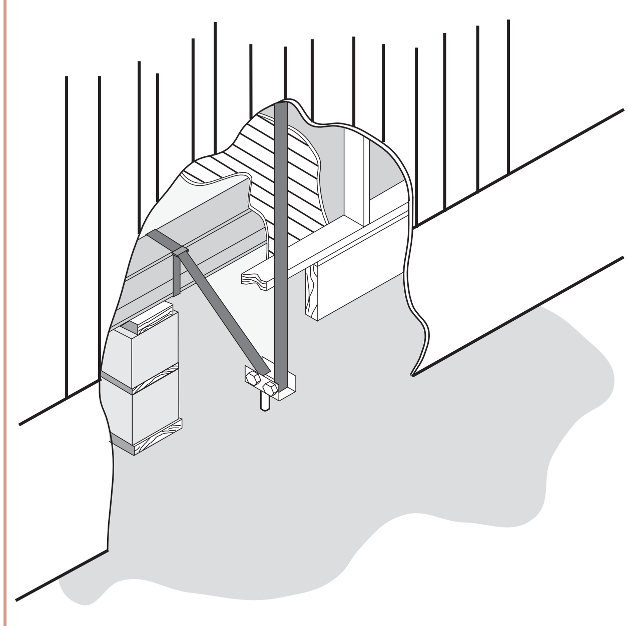
Permanent Foundations

HUD uses the term *permanent foundation* to describe a variety of foundations that don't use ground anchors. Homes are instead anchored to their permanent foundations. A permanent foundation should be designed by a structural engineer. Plans and specifications for permanent foundations can often be obtained from manufacturers or dealers.

Permanent foundations are required for real estate mortgages guaranteed by HUD and other mortgage guarantors such as the Veterans Administration, the Farmers Home Administration, Fanny Mae, and Freddie Mack.

Many manufacturers now produce homes designed to be supported by perimeter foundations. However most homes are still designed for support beneath the main beams. To many lenders and appraisers, permanent foundation means conventional or site-built foundation. This interpretation can create a problem because most manufactured homes still need support under their main beams.

Figure 2-11 Double Tie-Down

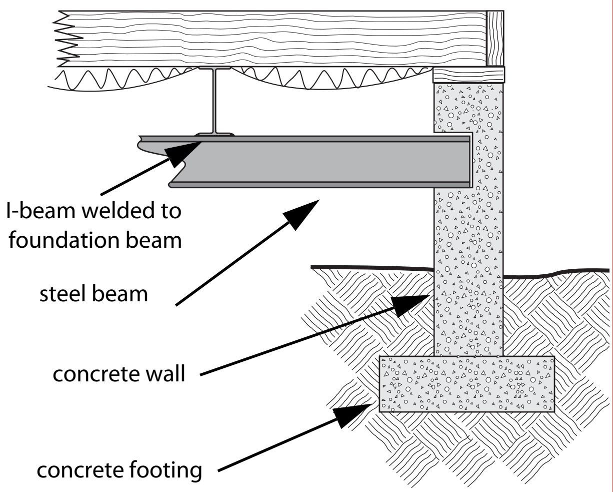


A double-headed anchor connects both a built-in over-the-roof strap and a strap tied to the main beam to the ground for stability in high winds. The over-the-roof tie prevents uplift and the diagonal tie to the frame tie prevents sliding.

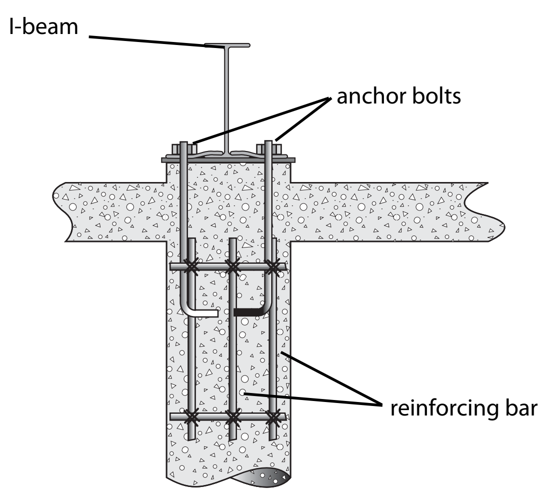
Without support under the main beams, 2-by-6 floor joists would have to span 12, 14, or even 16 feet, which is excessive. If the installers merely block the main beams off the bare earth, these footings can settle putting all the weight on the perimeter frost wall. If the interior footings instead rise from frost or expanding clay they would either deform the chassis and floor if the home were anchored to the perimeter frost wall or lift the home off the perimeter frost wall if the home weren't attached to the frost wall.

Most permanent foundations are designed to use their buried concrete footings and piers as anchoring to the ground. The homes must be attached to their piers, frost walls, or concrete slab to attain this anchoring. Unfortunately, many so-called permanent foundations don't anchor the home to the ground because no attachment was provided during installation.

Figure 2-12 Permanent Foundations



Perimeter Foundation with Beams - A popular way of supporting manufactured homes which aren't designed to be supported by a perimeter foundation alone.



Pier and Slab Foundation - The combination of piers and slabs give support below the frost line, as well as excellent horizontal and vertical wind resistance.

Types of Permanent Foundations

Permanent foundations use reinforced concrete slabs, buried concrete footings and piers, continuous concrete footings and frost walls, or treated wood pilings. A frost wall is a concrete wall with its footing buried below maximum frost penetration or frost line.

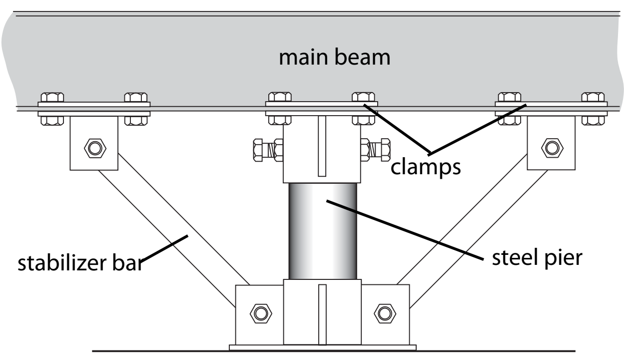
A floating slab is a good foundation for clay and silt soils because the slab simply floats atop the expanding clay or frost-heaving soil. Floating slabs are thickened to 12 inches or more and steel-reinforced under main beams, marriage lines, or other weight-bearing areas.

The most common type of permanent foundation is the perimeter frost wall with frost-proof footings and piers underneath the main beams. This type of foundation is attached by bonding its wood sill to the rim joist of the home. Steel beams embedded in the frost wall can also be used to carry the main beams, eliminating the frost-proof footings. The steel beams also provide a convenient way to attach the chassis to the foundation by welding or bolting the chassis to the foundation beams.

Strips of reinforced concrete, (at least 16 inches wide and 6 inches deep) placed either parallel or perpendicular to the main beams can also be footings for a permanent foundations. These reinforced concrete strips, poured on gravel bases are more economical than a floating slab. Each strip should contain two or more integral piers of concrete going into the ground for support below the frost line and resistance to horizontal wind forces.

There are many options for permanent foundations. A number of patented commercial foundation systems are coming to market claiming permanence and ease of installation. Make sure you choose an option that supports the home's weight adequately and ties the home down securely. Plans for permanent foundations should be stamped by a professional engineer.

Figure 2-13 Stabilized Pier System



These special steel piers may be cross-braced and anchored to concrete footings to help mobile homes resist earthquakes.

Protect Foundations from Natural Disasters

Manufactured home owners in earthquake-prone or flood-prone regions should consider specially designed earthquake-resistant and flood-resistant foundations. These special foundations are more expensive than standard ones, but are essential to preventing or limiting damage during an earthquake or flood.

Earthquake resistance is provided by an auxiliary foundation that bolsters conventional footings, piers, and ground anchors. This auxiliary foundation can even be retrofitted to an existing foundation.

Flood resistant foundations are specially constructed before the home's installation to elevate the home above a flood.

Wind-Resistant Foundations

The permanent foundations described previously resist hurricane-wind uplift and horizontal forces if the foundation has a strong connection to the home. It is also advisable to retrofit homes with effective anchors and tie-downs if the home doesn't have a permanent foundation. *See "Anchors and Tie-Downs" on page 35* and *"Wind Speed and Anchoring Requirements" on page 218* for details on installation.

Earthquake-Resistant Bracing Systems

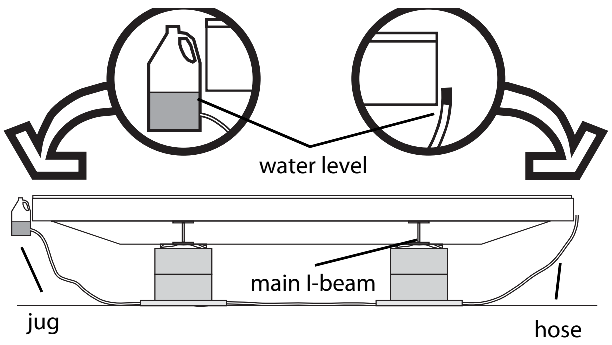
The most severe earthquake damage to manufactured homes results when the ground's movement causes them to fall off of their piers. When the home falls, the piers often break through the floor.

Figure 2-14 Elevated Foundation

Manufactured homes that have to be located on undrainable damp ground can be elevated 3 foot or more and left unskirted to prevent flooding and moisture problems.

Piers for earthquake country should be a minimum of grouted concrete block, with re-bar running through their grouted cores and into their reinforced concrete footings. Follow the specifications for diagonal tie-downs described previously in this chapter. *See "Wind Speed and Anchoring Requirements" on page 218*, and install diagonal anchors recommended for a 110 mph wind. This is a minimum recommendation and consider instead an earthquake-resistant bracing system.

Figure 2-15 Water Level



Use a water level to help you determine when a mobile home's I-beams are level. text here

Earthquake-resistant bracing systems (ERBS) have been pioneered in California. The state's Department of Housing and Community Development tests and certifies earthquake-resistant bracing systems. The department's most important standard requires the ERBS to protect the home from falling more than 2 inches during a quake.

The adjacent I-beams of the two sections of a double-wide are connected together by marriage-wall ties—actually threaded steel rods that join their I-beams. These rods hold the sections together during an earthquake.

ERBS are manufactured by a number of companies. These systems have succeeded in preventing catastrophic damage from major earthquakes. A preliminary report released after the 1989 Loma Prieta Earthquake reported no ERBS failures.

Heavy duty piers are the cornerstone of an ERBS system, because an earthquake's force often crushes ungrouted concrete-block piers. These ERBS piers are clamped onto the I-beams and cross-braced to each other. This forms a bridge-like structural system that prevents the home from falling to the ground.

Foundation Flood Protection

Floods present a number of hazards for the home and its occupants. Besides directly endangering occupants and soaking their home and its contents:

- The weight of flood water can sag the home's floor or move its walls;
- Moving flood water can move the footings and/or piers;
- Moving flood water can wash out footings' bases;
- Debris carried by moving flood waters can damage the home; and
- Rising flood water can float the home off its foundation.

In flood-prone regions, the Federal Emergency Management Agency (FEMA) recommends using compacted fill and/or an elevated foundation to raise the home above the anticipated flood level. FEMA also recommends locating footings beneath the ground's surface (below the flood's reach) and tieing the home down with ground anchors to resist flotation and wind.

Elevated foundation systems use reinforced concrete piers or a wood post-and-beam framework to raise the home 3-to-6 feet off the ground. These elevated foundations are fastened securely to the home's I-beams.

Skirting is often not installed on flood-resistant foundations. It could dam flood waters which could crush the skirting and damage the home.

Mobile Home Installation

Drainage and site preparation work should be complete before the home is to be delivered to its site. The foundation must be completed before the home is put in place for the obvious reason that it's difficult to pour gravel and concrete in a crawl space. And, water, sewer, electrical, and gas utilities must be ready for connection.

Any person experienced at measuring, digging, and pouring flat concrete pads can construct poured concrete footings. However, the installation and leveling of a manufactured home are fairly difficult and dangerous. A reputable mobile home service, often the same company that sells or moves the home, is usually best qualified to install and level it.

Installation Procedures

Professional home installers follow a procedure, with steps like those outlined below, to install the home on its site. This procedure requires skill, previous experience, and specialized tools.

Step 1: Mark where the corners of the home will be. Lay out materials for the piers and temporary blocking. Assemble: two jacks each with a steel jacking plate (to prevent slippage); and 24-to-36, 4-foot-long, wood blocks (4-by-6s or 6-by- 6s).

Step 2: Position the home over the footings, making sure the main I-beams are directly over the center of the footings. Use jacks—one under each I-beam—to raise the home to a level slightly higher than its final intended position. Jack first at the hitch, then near the axles. While jacking, use temporary blocking—stacked log cabin style—in 4 locations, 10 feet in from the corners under the main beams.

Step 3: Erect the piers and level their tops with a water level. Use the jacks to lower the home carefully. Use wedges to adjust the final level. Remove the temporary blocking.

Step 4: (For double-section homes only). Prepare the utility connections between the sections. Install the *mating gasket*—a foam gasket that completely surrounds the joint between the sections. Push the first section into position and block and level it, following Step 2. Move the second section next to the first. Follow the manufacturer's instructions for pushing the second section tightly to the first section and for fastening the sections together. Install closure materials, like siding and interior paneling, at the interior and exterior of the joint between sections. Connect the utility crossovers like piping and wiring according to manufacturer's instructions.

The home's wheels and axles can be worth $500 to $1200 in salvage. If you don't plan to move the home again, make some money by recycling them.

Leveling Mobile Homes

Mobile homes are leveled during installation and should need no further leveling unless their footings move. Unfortunately, re-leveling is a common repair practice for homes with inadequate foundations. If the foundation is moving, consider installing additional footings and piers and performing necessary drainage work to prevent the home from moving again.

You know a home needs leveling when doors and windows are difficult to open and close. Buckled siding and roofing and loose tie-downs are also signs of an out-of-level home. Inspect the piers, looking for tilting, loose wedges, and damaged blocks.

A savvy homeowner can tackle minor leveling. However, when piers are damaged or tilting and must be replaced, call the professionals.

The tools used for leveling are: two 10-ton hydraulic jacks, a water level, wedges, 2-by-8 and 1-by-8 wood leveling blocks, and large wood blocks (4-by-6s of 6-by-6s) for jacking and temporary support of the main I-beams while jacking.

Most professionals find the home's low piers and raise them to the level of the highest piers. The water level is ideal for leveling the main beams because it is easy to use over long and short distances from point to point. Set the water level of one end of the water level at the top of the pier where you want to start leveling. Then determine the level of the other piers using the level of the liquid in the water level's other end, which remains naturally level with the top of the first pier.

Mobile homes are raised by jacking underneath the two main I-beams. The best places to jack are at the hitch, the axles, and cross members where the chassis is strongest. It is important that the home be lifted slowly, jacking underneath the main I-beam. For safety, use steel jacking plates that won't allow the jack to slip. Set up a temporary pier of criss-crossed blocking to catch the home in case a jack slips, especially when building or replacing a pier. Never depend on a jack to hold the home up by itself.

When releveling, allow some time for window and door openings to return to a rectangular shape.

Installing Ground-Moisture barriers

A *ground-moisture barrier* protects the home against the effects of high crawl-space humidity. Underneath the home, water vapor rises through pores in the soil. Liquid water wicks its way upward, evaporating when it reaches the surface. A ground-moisture barrier is effective against water vapor intrusion and evaporation from the ground but not effective against pooling. Only proper drainage can prevent standing water.

Before you install your ground-moisture barrier, be sure to remove any sharp objects from the crawl space that might puncture it.

Ground-moisture barriers should be black *polyethylene* at least 6-mils thick. Black polyethylene is preferable to clear polyethylene, because it prevents plants from growing under the home.

When laying the ground-moisture barrier, all joints should overlap 12 inches. If the ground-moisture barrier is installed before the piers are constructed, place it over the footings and under the piers. If the ground-moisture barrier is laid down after the piers are constructed, cut and piece it closely around the piers. Fasten the ground-moisture barrier's edge to the base of the skirting or weight in down.

An optional topping of gravel or sand over the ground-moisture barrier holds it down and protects it.

Skirting

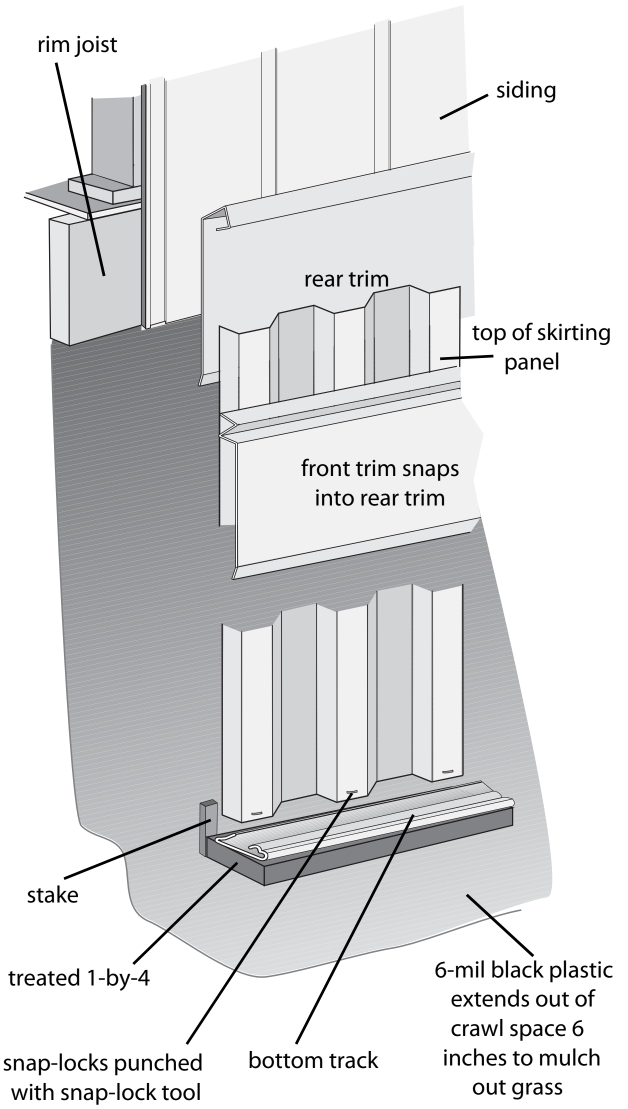
Skirting is the sheeting around the bottom perimeter of the home. Skirting protects the crawl space from snow, rain, and debris. Skirting excludes animals from the crawl space and improves the home's appearance. Skirting also provides a windbreak, reducing the likelihood of frozen pipes.

Vinyl and metal skirting kits are popular because they are waterproof and easy to install. Vinyl or metal skirting is often packaged with lightweight metal or plastic frame. A channel secures skirting to the ground and a two-piece trim system fastens skirting to the home's rim joist, while giving the skirting room to move up and down with frost heaving or clay expansion.

Vinyl skirting is recommended for cold climates and clay soil because it's more flexible than metal and regains its original shape after ground movement. Vinyl skirting also collects less condensation because it stays somewhat warmer than metal skirting. Wood skirting can wick water up from the ground into the home and is not recommended.

Where wind is a bigger threat than ground movement, as in souther coastal areas, steel skirting may be better because of its strength. In windy areas skirting is screwed to the rim joist and ground track with galvanized-steel screws.

Figure 2-16 Vinyl or Metal Skirting



This prefabricated skirting system is sold by mobile home suppliers and is easy to assemble.

Insulated skirting is usually not cost-effective or practical. Insulation materials have the same moisture-wicking problem as wood. Most manufacturers and building officials require vented skirting, and it doesn't make much sense to insulate the crawl space and to also let in cold air through vents. Adding insulation to the floor is a much better option (*See "Insulating Floors" on page 86*).

Provide one square foot of skirting vent for every 150-to-300 square feet of crawl space area, depending on how much of the crawl space is covered by a ground moisture barrier. If the whole crawl space is covered by a ground-moisture barrier, you don't usually need much ventilation. Vinyl and metal skirting kits come with vented panels. Manufacturers often recommend that one in 4 or 5 panels be a vented one. Locate the vented panels away from plumbing to prevent pipe-freezing in cold climates.

A ventilated crawl space is not a substitute for a ground-moisture barrier and the other moisture protection discussed in this book. Indeed, some experts say to forget the vents and focus on moisture prevention.

Skirting Installation **—** Be sure to read and follow the manufacturer's instructions that come with your skirting kit.

Level the ground around the home's perimeter. Remove vegetation and other debris. Install ground-moisture barrier in the crawl space and let it hang out at least 6 inches, to prevent grass and other plants from growing close to the skirting. If your ground-moisture barrier doesn't hang out 6 inches around the perimeter of the home, place asphalt-shingle starter strip, heavy roofing paper, or 6-mil black plastic underneath the bottom plate of the skirting system. Allow this material to extend into your yard at least 6 inches.

Install vents or venting panels as you go. Most vinyl skirting systems require a snap-lock tool that makes a small protrusion in the panel's bottom that holds it into the channel.

Aluminum and vinyl skirting are easiest to cut. You can cut parallel to the corrugations easily with tin snips and across the corrugations with tin snips or an electric saw. Carbide tipped fine-tooth circular saw blades are usually best for this job. Steel skirting dulls the blade quicker than vinyl or aluminum. Don't continue to cut with a dull blade because you can ruin the paint or galvanizing at the steel's cut edges. You can also cut steel with snips, but they ought to be sharp to avoid hand fatigue.

If the skirting panels are 32 inches or more, consider installing blow-out rods. These metal rods reinforce the panels and prevent their blowing out during high winds.

***Wet Ground and Skirting* —** Solid skirting should not be installed around crawl spaces with chronically wet ground or standing water. If tightly enclosed, a wet crawl space will cause moisture problems inside the home. Consider the following options for coping with chronically wet ground.

1. Install a drainage system.
2. Elevate the home on a flood-resistant foundation and forget skirting.
3. Install skirting vent panels all the way around the home.

In damp locations, avoid planting or watering closer than 2 feet from the home's edge. Dryer vents and air conditioner drains should be routed through the skirting rather than terminating in the crawl space where they can worsen moisture problems.

In warm wet climates, the outdoor air coming into the crawl space through vents may carry unwanted moisture with it. This moisture may condense in the relatively cool crawl space. Closable vents are an option to address this summer problem. These vents allow residents to ventilate crawl spaces during drier periods and close the vents during wetter periods. Another option for wet climates is vents plus a crawl-space exhaust fan to hasten drying when the outdoor air is dry. There are humidistatic controls that can run the fan automatically when outdoor air is dry.

Foundation Repair

Inadequate foundations lead to settling or rising footings, moisture problems, and damage from floods, wind, and earthquakes.

Even though mobile home foundations are less expensive than foundations for site-built homes, installation crews often skimp on materials. Many mobile homes have been damaged or destroyed for the lack of a dozen anchors and tie-downs, a hundred dollars worth of gravel, or a couple yards of concrete.

If you suspect that an inadequate foundation is causing problems with your home, you should inspect the foundation or have an expert inspect it. Major foundation repair is a job for professionals and may be expensive. However, neglecting foundation problems can result in the home's steady deterioration or even its destruction.

If ground water has caused settling or frost heaving, a drainage system using gravel and drain piping may correct the problems if designed and installed by knowledgeable people. A sump pump for pumping ground water away from the home is a last-resort solution.

If settling occurred because footing area was too small, then adding more piers and footings may correct the problem. Relevel the home and make sure that all the piers are blocked tightly beneath the I-beams and other required locations during the corrective work.

Severe drainage problems with settling or rising footings may require temporarily moving the home off the site in order to perform correct siting and foundation procedures. If ground water is unavoidable during certain times of the year, a flood-resistant foundation may provide a solution. Moving the home temporarily or elevating it, although expensive, may be the only long-term solution to moisture deterioration or destruction by flooding.

Installing ground anchors and verifying their tightness can save your home from damage during high winds. If you live in a high-wind region and your home isn't anchored, you should install anchors and tie-downs according to the instructions in *"Anchors and Tie-Downs" on page 35* and *"Wind Speed and Anchoring Requirements" on page 218*. Check anchor and tiedown tightness once a year.

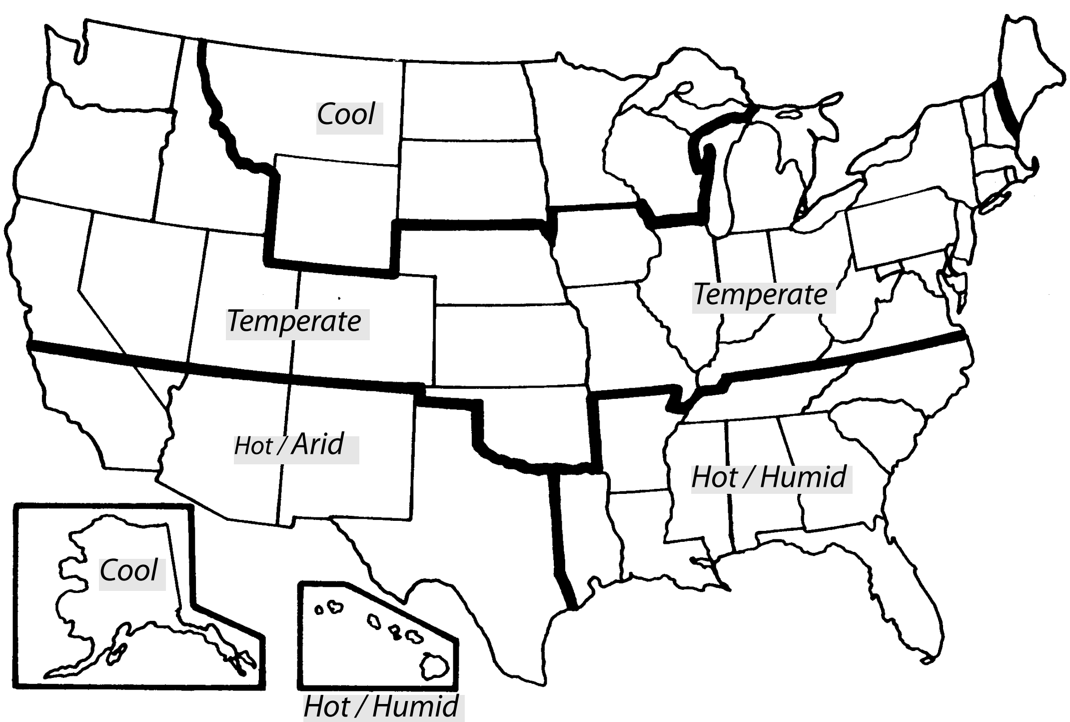
CHAPTER 3 LANDSCAPING

Trees, shrubs, vines, ground covers, and fences are all cost-effective ways to lower your energy bills. In fact, landscaping may just be your best long-term investment for reducing heating and cooling costs.

A well-designed landscaping program will:

- Protect your home from winter wind and summer sun;
- Define property boundaries and protect your family's privacy;
- Help control noise pollution and air pollution;
- Reduce your expenses for outdoor watering; and
- Enhance your yard's beauty and your family's outdoor living pleasure.

Figure 3-1 Four Climatic Regions of the United States



Cool - This region has hot summers, cold winters, and persistent winds year-round, generally out of the northwest and southeast. Northern locations receive less solar radiation than southern areas of the country.

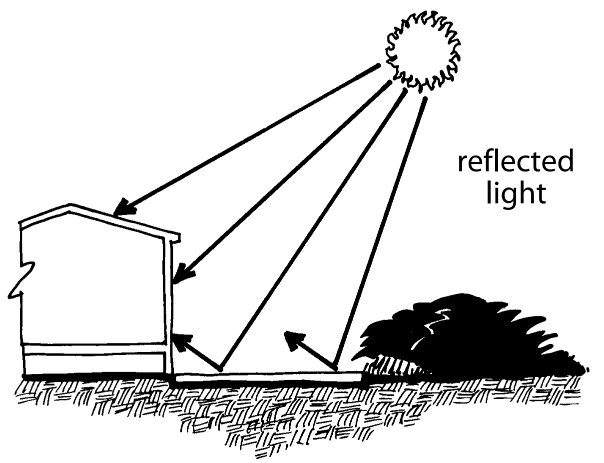
Temperate - This region has equal overheated and underheated periods, seasonal winds from the northwest and south, and periods of high humidity and high precipitation rates.

Hot-Arid - This region has clear skies, dry air, and extended periods of overheating with large daily temperature fluctuations. Wind generally is along the east-west axis, varying from day to evening.

Hot-Humid - This region has high temperatures and consistent high humidity. Wind speed and direction vary throughout the year and daily. Wind speeds of up to 120 m.p.h. may accompany hurricanes, which generally come from the east-southeast direction.

Use the landscaping methods discussed in this section for a single manufactured home or for a group of homes located together. If you are setting up a new mobile home park, follow these siting and landscaping guidelines for all the sites.

Figure 3-2 Reflected Heat and Light



Paved areas reflect the sun's heat and light toward the home.

Figure 3-3 Natural Cooling With Vegetation

To cool south and west sides of home: 1. Reduce paved areas; 2. Plant shade trees; or 3. Add a trellis.

Landscaping = Money Saved

Carefully positioned trees save 20% to 25% of a household's total energy consumption, according to the U.S. Department of Agriculture. Computer models devised by the U.S. Department of Energy project that the proper placement of only three trees will save an average household between $100 and $250 annually in reduced summer air-conditioning and winter heating costs.

A well-designed landscape can provide enough energy savings to return your initial investment in less than eight years.

Well-planned landscaping reduces a previously unshaded home's summer air-conditioning costs by 15% to 50%. In fact, one Pennsylvania study reported air-conditioning savings of up to 75% for small mobile homes!

During winter, windbreaks to their north, west, and east cut site-built homes' fuel consumption by an average of 40%, according to a study in South Dakota. With a windbreak on only the windward side, the homes still consumed 25% less fuel than similar unprotected homes. An Oklahoma study found that a tall evergreen hedge on a home's north side reduced that household's fuel consumption by 10% during light winds and by 34% during high winds.

Climate

In order to landscape properly, mobile home owners must first secure basic knowledge about the climate and microclimate in which they live.

For landscaping purposes, the United States can be divided into four climatic regions: temperate, hot-arid, hot-humid, and cool.

The energy-conserving landscape strategies you employ will be different for each of these regions. Here are some general guidelines:

1. **Temperate.** Landscaping should:

- Maximize the sun's warming effects in winter
- Maximize shade during summer
- Reduce winter winds near buildings, but allow air circulation in summer

2. **Hot-Arid.** Landscaping should:

- Provide shade to walls and windows while cooling air around the home by evaporation of water from leaves
- Allow cooling summer breezes access to the home while blocking winter winds
- Use drought-resistant trees to maximize shade

3. **Hot-Humid.** Landscaping should:

- Allow summer winds full access to the home
- Avoid locating planting beds that require frequent watering close to the home
- Maximize shade from tall trees which overhang the roof

4. **Cool.** Landscaping should:

- Use dense windbreaks to protect the home from cold winter winds
- Shade south, east, and, especially, west windows from direct summer sun
- Allow winter sun to reach south-facing windows

Microclimate

The climate in close proximity to your home is called its ***microclimate***. If your home is located on a sunny southern slope, it may have a warm microclimate, even though you live in a cool region. Or, even though you live in a hot-humid region, your home may be situated in a comfortable microclimate, due to cool dry summer breezes, channeled your way by a forested area.

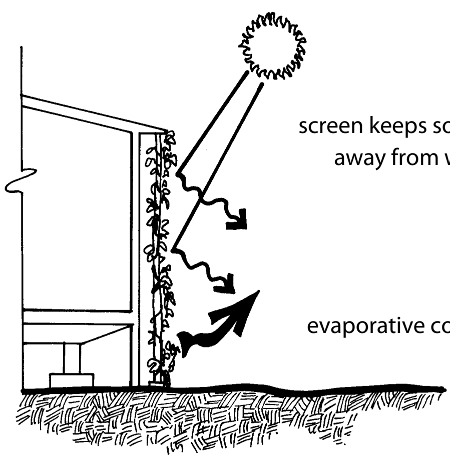
Certain plants may or may not grow in your climate and microclimate, depending on the following factors. See if you can answer these questions about your home, its site, and local weather patterns:

- What is the sun's daily path over your home? How does this path vary with seasons?
- Where are your site's sunny spots and shaded areas? How are they affected by the sun's seasonal position?
- Where does the wind usually come from in the summer? In the winter?
- Are trees and shrubs already growing on your property? Are they evergreen or deciduous (leaf-shedding)? How tall, wide, and dense are they?
- How do current vegetation, fences, garages, or outbuildings block the wind or sun?
- Do you have nearby water bodies that increase humidity or moderate air temperature?
- Does the ground slope away from your home or toward it? Does this sloping create any drainage problems?
- What types of soils does your property have? Do these soils shed moisture? Do they retain moisture?
- Which paved surfaces reflect or radiate the most solar heat to your home?

Shade

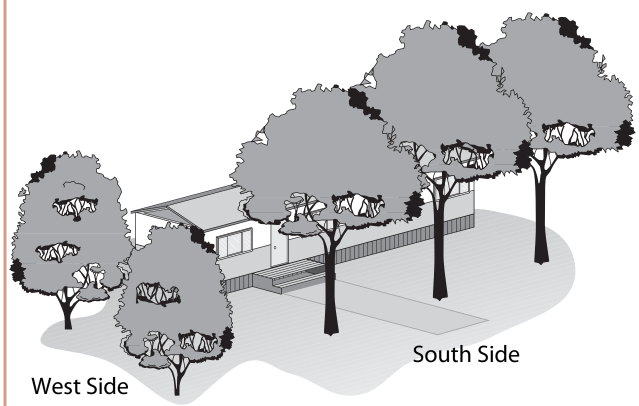
Heat from the sun shining through windows and on the roof is a major reason for using air conditioners. Shading is the most cost-effective way to reduce solar heat gain and to cut air conditioning costs.

Figure 3-4 Plants and Vines Used for Sunscreen



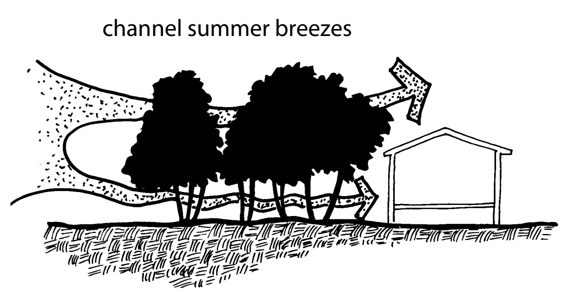
A lattice with vines shades the walls and cools the air by evaporation.

Figure 3-5 Shade Trees



A well-shaded home uses far less energy for cooling than one that is fully exposed to the sun. In some climates, shade can actually eliminate the need for mechanical cooling.

Figure 3-6 Natural Ventilation



Deciduous trees can channel and cool summer breezes.

Trees grow to different sizes, densities, and shapes fitting almost any shading need. Deciduous trees or shrubs block solar heat in summer and shed their leaves in winter to allow partial passage of the sun's warm winter rays.

A tree can reduce solar radiation from 25% to 60%, depending on the density of its foliage. Tall deciduous trees with a spreading canopy can be planted to the south and east of your home to provide maximum shading of summer sun. Shorter, round-headed trees are more appropriate to the west, where shade is needed from lower afternoon sun angles.

A single tree, located to provide shade during the afternoon, may reduce wall and roof temperatures as much as 20°F to 40°F. Shading your air conditioner could increase its efficiency up to 10%.

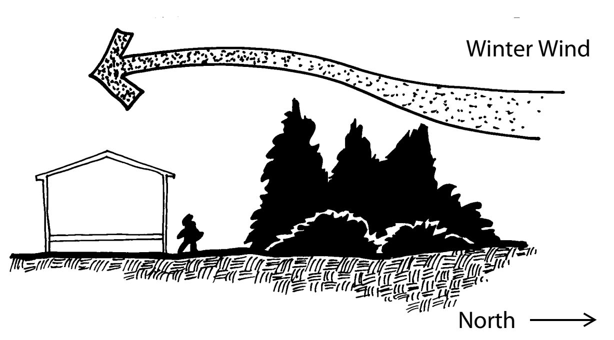
A 6-to-8 foot deciduous tree planted near your home will begin shading windows the first year. Depending on the species and the home, the tree will shade the roof in 5-to-10 years.

Trees, shrubs, and ground covers shade the walls, ground, and paved areas around the home. This shade reduces heat absorption and radiation and also cools air before it reaches your home's walls and windows. Shade the home and surroundings with a single large shade tree with wide limbs or with a row of narrow trees planted relatively close together.

Use a large bush to shade a patio or driveway. Plant a hedge to shade a sidewalk. Shrubs planted close to the house will fill in rapidly and begin shading walls and windows within a few years. However, allowing dense foliage to grow immediately adjacent to a home where soil wetness is a problem can inhibit the drying action of the wind and sun. Well-landscaped homes in wet areas allow wind to flow around the home, keeping the soil reasonably dry.

A lattice, a trellis with climbing vines, or a planter box with trailing vines all form plant screens that block the sun, yet allow cooling breezes. You may choose annual vines (such as runner beans, sweet peas, and morning glories) or perennial vines (such as Virginia creepers or honeysuckles). (See *Chapter 12* ***Cooling Systems***, for more information about shade.)

Figure 3-7 North Side Winter Windbreak



Properly selected and placed evergreen trees and shrubs can shelter homes and reduce heating costs.

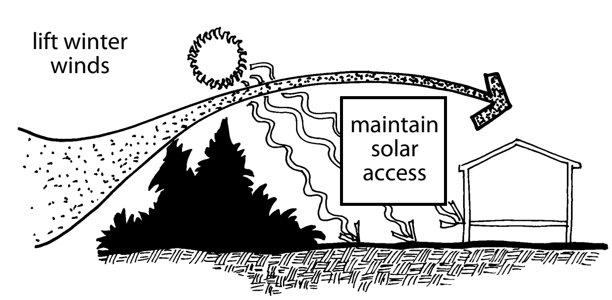
Wind Protection

Windbreaks, if properly selected and placed, will reduce heating expenses considerably as trees and shrubs mature. Evergreens, which keep their dense foliage all year around, help block winter winds when planted to the north and northwest of the home. During summer, these evergreens cool air and screen afternoon sun.

Although a windbreak will reduce wind speed for a distance of up to 30 times the windbreak's height, for maximum protection plant your windbreak two-to-five times the height of the trees away from the home. For example, if the trees will be 30 feet tall when mature, plant them 60-to-150 feet away from the home.

If snow accumulates in your area, plant low shrubs on the windward side of your windbreak. This will help trap snow in the windbreak before it piles up near your home.

Figure 3-8 South Side Winter Windbreak



If south winds are a problem in the winter, plant evergreens far enough away to lift winds without shading the home from winter sun.

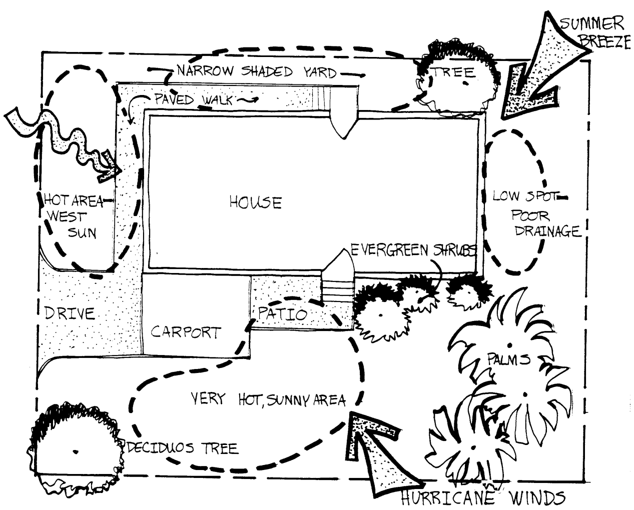
In addition to windbreaks, shrubs and vines next to the house create dead air spaces that insulate your home in the winter and cool it in the summer. Be sure to plant so there will be at least a foot of space between the full-grown shrub and the house wall.

Consider planting evergreen shrubs around your home's entry way, if it faces cold winter winds. Be careful not to plant evergreens too close to the house's south side, since evergreens would shade the house from winter sun.

Planning Your Landscape

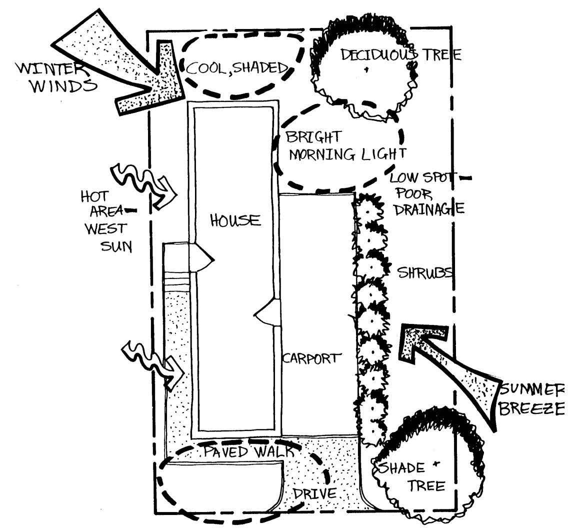
To begin designing your landscape, first draw a simple sketch of your yard—an aerial view. Locate its buildings, walks, driveways, and utilities (water, sewer, electric, gas, telephone, etc.). Then,

Figure 3-9 Sample Site Analysis for Hot and Humid Regions



This example shows a double-wide mobile home facing south. Dotted lines indicate potential problem areas. This home is exposed to hurricane winds.

Figure 3-10 Sample Site Analysis for Temperate Region



This example shows a single-wide mobile home with problem areas on the west and the south where the home is exposed to the sun.

identify how you plan to use different areas of your yard: vegetable gardens, flower beds, patios, play areas, and so on.

Draw arrows to show sun angles and prevailing winds, for both summer and winter. Using different colored pencils or felt-tipped markers may help. As you sketch, circle the areas of your yard that need shade and/or protection from wind.

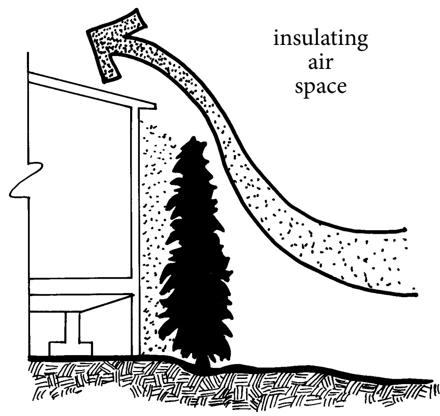
Paving near your home reflects or radiates solar heat onto the walls and windows. Note the location of all paved surfaces near your home, such as streets, driveways, patios, or sidewalks.

You may want to screen a nearby house or street light, yet maintain your view of distant mountains. Draw arrows to show how you want views to be maintained, screened, or framed. Mark sources of noise pollution you wish to block. Also, highlight areas where landscaping height or width may be restricted, such as under utility lines or along street corners.

Note yard areas that suffer from poor drainage and standing water. Some trees and shrubs won't grow well in poorly drained areas, others will.

The more you identify your goals and familiarize yourself with your yard's features—current and proposed—the more your landscaping projects will succeed.

Figure 3-11 Insulating Walls With Plants and Shrubs



Create a dead air space next to the wall by planting a dense row of shrubs.

As you develop your landscaping plans, remember:

1. To decrease summer energy demands, landscaping should maximize cooling shade and the circulation of air.
2. To decrease winter energy demands, landscaping should maximize the sun's warming effects and minimize winter winds.

Large expanses of lawn are not necessary for a pleasing landscape. Lawn areas not intensively used by people can be converted. After you remove the sod and plant trees, shrubs, and perennials, cover the bed's remaining area with an attractive organic mulch, such as bark chips. This conversion from lawn to planting bed will save energy and reduce your household's water consumption.

If you live in a manufactured housing community, consult the manager to discover what landscaping incentives or restrictions may apply. Discuss plans with your neighbors to insure that your proposed landscaping benefits them and that their landscaping benefits you. In many instances, it is likely you and your neighbors can cooperate on purchasing and planting windbreaks, shade trees, or landscaping for property boundaries.

To better define property boundaries or shield your home from traffic noise, consider a living fence of dense trees and/or shrubs. Depending on its location and application, you can customize your fence to be tall, short, wide, narrow, open, or dense.

A living fence creates acoustic barriers, visual screening, windbreaks, food for your family, or wildlife habitat. And, once established, many living fences require less maintenance than conventional fences.

Planting Your Landscape

Don't plant without careful planning. Trees and shrubs have a life span of many years. Ideally, landscape improvements become more attractive and functional with age. Poorly landscaping can create problems.

Figure 3-12 Shaded Community

A shaded mobile home community uses a fraction of the air conditioning energy as one with little shade.

Insure proper plant placement and minimal landscaping maintenance **before** you plant. Learn about plant usage and mature sizes. Know what maintenance tasks plants require, like raking and disposing of flowers, seed pods, and leaves. Talk to local nursery and landscape professionals who understand climates, micro-climates, sun angles, shade, wind, tree types, tree growth, soil preparation, planting, watering, water conservation, mulching, wrapping, staking, and pruning.

Show your drawings and ideas to your local nursery or landscape specialist. As long as you've defined intended uses and allowable spaces, a competent nursery or landscape specialist can provide specific planting and maintenance instructions as well as help you evaluate options and choose appropriate plants.

Local nurseries know local growing conditions from experience. They'll often escort you through their lots for visual comparisons of different plant stock. For major purchases, a nursery representative may even visit your property to discuss your planting options.

Many landscape professionals are happy to provide references or locations of some of their landscaping work. Their field experience is often valuable for answering specific questions about site planning and micro-climate. Landscapers may be knowledgeable about plant growth, landscape maintenance, and disease prevention. These specialists can also offer advice about efficient and convenient watering systems, such as drip irrigation.

What about chain stores or temporary nurseries in hardware or grocery store parking lots? Although there are exceptions, these stores are generally not your best source for hardy plant stock and accurate information. Chain store clerks are frequently ill-prepared to accurately answer your questions. And, their plant stock may not even come from a local climate.

Getting More Information

For further information about landscaping and plant selection, contact your public libraries, county extension agents, local nurseries, landscape architects, or landscape contractors.

Chapter 4 Healthy Homes

In order to live in a safe indoor environment, residents of mobile or manufactured homes need to be aware of possible health and safety hazards.

Fire, moisture, windstorms, toxic substances, and accidents are the main threats to your health and safety, and also to the longevity of your home. Fire is a leading cause of accidental death and injury. Moisture-aided fungus and dust mites cause allergies and asthma. Exposure to toxic substances in the home is probably the greatest long-term health hazard we face. And, accidents are the fourth leading cause of death in the United States and constitute the greatest short-term hazard in our lives.

Renovation and energy conservation can create health and safety hazards in any building, if workers and occupants are not aware of potential problems. Recognizing hazards and knowing how to avoid them will reduce accidents and exposure to toxic substances.

The information in this chapter will help you recognize possible hazards and take all the necessary steps to protect yourself and your home.

Windstorms

Manufactured homes are more susceptible to windstorms than site-built homes because of their lightweight foundations, lack of structural sheathing, and lightweight framing.

Surviving a Tornado

One of the most important things you can do to prevent being injured in a tornado is to know the signs of a tornado. Most deaths and injuries happen to people who are unaware and uninformed. Plan your escape before severe weather strikes. A safe shelter near your home is the best option for evacuation. In an emergency, lie in a ditch or some other low-lying area outdoors. Don't remain in your home.

If strange clouds start moving in and the weather begins to look stormy, turn to the local radio or television station to get the weather forecast. If a tornado watch is issued for your area, it means that a tornado is possible and that you should watch for these signs.

- A green or greenish black sky color.
- A strange quiet period shortly after the thunderstorm.
- Debris dropping from the sky.
- Clouds moving by rapidly in a rotating pattern or converging toward one area of the sky.
- Debris being pulled upwards, even if no funnel cloud is visible.
- A sound like a waterfall or rushing air at first, but turning into a roar as it comes closer. The roar of a tornado is similar to railroad trains and jets.
- With a tornado watch posted, consider hail as a real danger sign.

If a tornado warning is issued, it means that a tornado has actually been seen or identified on radar, and it is time to seek safe shelter immediately.

Weathering a Hurricane

Mobile homeowners must evacuate when the order is given. Secure your home before evacuating.

- Pack breakables in cartons and place them on the floor.
- Tape window glass and mirrors.

- Shutter windows if you have time. Tape offers minimal protection.
- Turn off the water at the main shutoff.
- Shut off fuel lines and propane tanks.
- Tie down garbage cans, lawn furniture, etc.

Improving Your Home's Wind Resistance

The reasons why hurricanes damage or destroy manufactured homes is well-known and well-documented in technical studies by engineers. Of the manufactured homes destroyed when Hurricane Andrew hit Louisiana, 55% of the structural failures were caused by anchor and tie-down failure; 34% failed because either the roof or the roof and walls blew off; and 11% failed because of large missiles (building materials flying through the air) or falling trees.

Figure 4-1 Sliding Storm Shutters

Sliding corrugated-steel storm shutters offer effective protection from windstorms for windows and they are easy to install.

Hurricane damage and destruction is caused by the following structural problems, occurring in high winds.

- Connection of the home to the ground is insufficient to prevent movement, allowing the home to fall off its piers, roll over, or actually fly through the air, destructing on impact.
- Failure of joints between floor and walls and walls and roof allows the roof to separate from the wall or the roof and walls to separate from the floor.
- No structural wall sheathing,
- Siding not adequately attached so that when siding blows off the lightweight interior sheeting is exposed to winds and heavy rains. If the wind pops the interior sheathing off after blowing the siding off, the home could be further damaged from high wind pressure.
- A large window breaking could also cause high interior wind pressure.
- Roofing and siding not adequately attached blows off.

Preventing damage or destruction from high winds involves carefully inspecting and improving anchors and tie-downs, reinforcing the wall joints at the floor and ceiling, strengthening wall sheeting, and reinforcing the fastening of siding and roofing.

Consider the following specific retrofit measures to make your home more hurricane resistant. Success depends on strengthening all the weak areas because the wind will damage the home at the point of weakness.

- *See "Anchors and Tie-Downs" on page 35* for instructions on retrofitting a foundation to be more wind-resistant.
- *See "Permanent Foundations" on page 38* for options on constructing a permanent foundation.
- *See "Wall Structural Problems" on page 91* for instructions on retrofitting a wall to be more wind-resistant. *See page 103* for a wall-roof retrofit designed to increase windstorm resistance.
- Install sliding storm shutters on all windows.

Fires

Fires in residential buildings cause about 4000 deaths, 20,000 injuries, and $10 billion in property damage each year. The National Fire Protection Association and the National Safety Council research these fires and publish information on their causes. They have found the following:

The leading cause of death by fire is careless smoking.

The fastest growing cause of death by fire is children playing with matches.

The leading cause of injury by fire is cooking.

The three leading causes of fires are: 1. Heating equipment; 2. Cooking; and 3. Electrical failures.

Electrical overloads and short circuits from unsafe extension cords, improper electric space heating, and faulty heat tape cause many fires.

Fire Prevention and Fire Extinguishers

Residents should minimize the risk of fires. Don't use lightweight extension cords for irons or electric heaters. Discard concentrations of waste paper, cloth, or flammable liquids or, at the very least, store them outside the home. Eliminate or limit indoor smoking. Restrict children's access to matches. And, safety-check heating appliances regularly to make sure there is no sign of heat or flame damage. Also, never store combustible material near the furnace or water heater.

Repair damaged extension cords immediately and don't use extension cords with electric space heaters. Remove old brittle heat tape and install new safe heat tape if pipe freezing is a problem in your region. Flat heat tape with its own thermostat that looks like antenna wire is the least safe. Don't overload circuits by plugging too many appliances into one receptacle.

Since cooking fires are so common, every kitchen should have a container of baking soda clearly marked and accessible for use in extinguishing fires. To put out fires outside the kitchen, a pressurized 2.5-gallon fire extinguisher is probably best for fires involving wood and other building materials. A 5-pound ABC fire extinguisher is a good all-purpose fire extinguisher for grease, wood, and electrical fires. Locate fire extinguishers near an outside door so the person using them will not be caught between the fire and an exit.

Fire Escape

Families should discuss and practice fire escape plans. Each bedroom should have two exit routes, one through the bedroom door and one through a window. Some mobile home window units are hinged in their frames to facilitate fire escape. Other windows have enough area, when opened, to let a person out during a fire. Teach all family members how to operate the exit windows. Practice escaping through the windows to ensure escape during a fire. Make sure windows open easily. Do not block your home's window exits.

Some windows, like awning windows, may require breaking out the window to provide a large enough opening to escape. In this case, identify a large heavy object that can be used to break out the window. Objects like wooden chairs and baseball bats work well.

Your fire escape plan should establish a place outside the home where occupants gather after escape. This meeting place helps account for everyone and avoid panic.

If you ever have to travel through a fire to escape, remember it is cooler and safer to crawl along the floor. This keeps you away from the smoke, which generally concentrates higher in the room. Remember that smoke from most home fires is so toxic that only a few inhalations can produce serious injury or death.

Smoke Alarms

All mobile homes should be equipped with smoke alarms. Smoke alarms are designed to wake sleeping occupants in the event of a fire. Mobile homes should have at least one smoke detector in a common area adjacent to the bedrooms. If the bedrooms are not close together, there should be smoke detectors near each bedroom or group of bedrooms. Keep smoke detectors as far from the kitchen as possible, so residents are not tempted to tamper with them in order to prevent sounding during routine cooking.

A smoke detector consists of a smoke-sensing device, an alarm, and a power source—either a battery or a connection to house power. Fire alarm systems that use house power have the potential advantage of sounding all the alarm after one of the sensing units senses a fire. As many as 50% of existing smoke detectors are useless because they have been disabled or their batteries are worn out.

Test all smoke alarms with smoke once a year to make sure the alarm sounds.

Moisture in Homes

All necessary steps should be taken to prevent or mitigate moisture condensation, water leakage, and water seepage during repair projects and energy conservation retrofits.

Moisture in homes causes millions of cases of respiratory disease each year and billions of dollars in property damage. Moisture condensation—a leading cause of the disease and damage—is common during both heating and cooling seasons.

Moisture is important to residents of mobile homes because:

- Water allows dust mites, fungus, mildew, and mold to thrive. This creates a threat to human respiratory health.
- Water leads to the deterioration of building materials by termites, mold, mildew, and dry rot.
- Water reduces insulation's thermal resistance and may permanently damage it.

Moisture Movement

Water's intrusion into a building can determine how long that building will survive. Moisture enters and moves through buildings as liquid water and as water vapor. The four categories of water movement are:

1. Liquid flow. Driven by gravity or wind, water flows into and through holes and cracks in houses. Leaks in roofs and plumbing can deposit large amounts of water in a home.
2. Seepage. Liquid water creates its own suction as it moves through tiny spaces within and between building materials. This suction draws in ground water and also redistributes water from leaks, spills, and condensation.
3. Air movement. Air movement carries water, in the form of vapor, into and out of the home and its cavities.
4. Vapor diffusion. Responding to differences in the amount of water vapor between indoor and outdoor air, water vapor moves slowly through apparently solid materials like masonry and wood.

Liquid flow is the most serious water threat since it moves large amounts of water rapidly. Seepage can also move liquid water rapidly into a home through damp soil and porous skirting materials.

Water vapor movement by air leakage occurs mainly when heating or cooling systems are operating. Winter air leakage tends to carry moist indoor air outdoors—drying the indoor air. However, winter air leakage going through the home's shell can deposit moisture in building materials through condensation. Summer air leakage tends to bring moist, hotter air from outside into the home—increasing the humidity of indoor air and again possibly causing condensation within the home's wall, floor, and ceiling cavities.

Vapor diffusion is the slowest form of moisture movement, creating less problems than the others. However, vapor diffusion can cause condensation inside building cavities during both heating and cooling seasons.

Water Leakage and Seepage

The home's exterior walls and roof should be watertight. As stated above, problems with water intrusion will likely determine how long your manufactured home survives. Leaks in the roof, walls, and foundation that admit rain water are important causes of moisture problems. Ice dams, formed by snow melting and refreezing on the edge of the roof, can force water underneath shingles and into the attic and upper walls.

Many mobile homes have no eaves and so the walls are exposed to rainwater from the roof. The seam around windows' perimeters and their screw holes can leak water. Roof leaks most often occur at penetrations and the roof's edge. (*See "Repairing Roof Leaks" on page 126.*) Leaks through the roof and walls can be difficult to find because wetness can result from either roof or wall leakage or from condensation inside the roof or wall cavity. Condensation, in fact, is often mistaken for roof leakage.

Plumbing leaks are also important sources of water leakage. Leaks in water supply and drain pipes are relatively easy to find and should be fixed as soon as they are discovered.

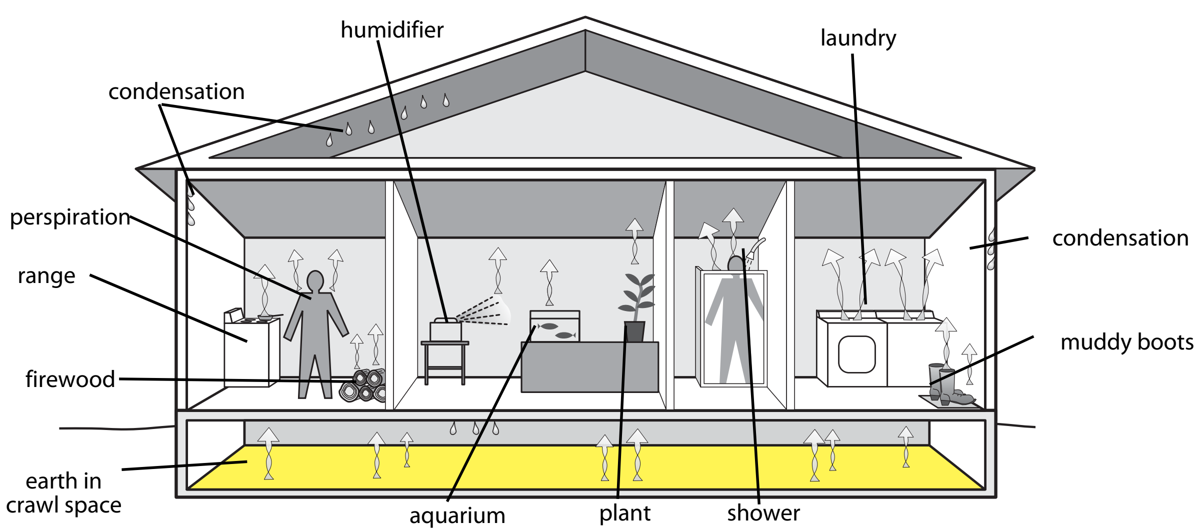
Poor site drainage encourages seepage through skirting. Reduce water seepage with drainage ditches, gravel, perimeter water barriers, and foundation waterproofing.

The home site should be planned to keep rain water, ground water, and irrigation water away from the skirting and crawl space. The ground near the home should slope to drain away water. Employ rain gutters and regrade the site, if necessary, to carry water off the roof and away from the foundation. In areas where surface water must flow near a building, cap the ground next to the home with impermeable clay or concrete. (*See "Site Drainage" on page 30.*)

Flood Recovery

Recovering from a flood involves drying and decontaminating the home as quickly as possible after the flood recedes. Materials like carpet, sheetrock, ceiling tile, insulation, and fiberglass

Figure 4-2 Sources of Water Vapor



A variety of household sources release water vapor into the air. When the relative humidity rises and outdoor temperatures fall, the water vapor changes to liquid water—a process called condensation. Condensation occurs near the sources of water vapor and on the home's colder surfaces.

ducts are almost never salvageable because they can't be decontaminated. Therefore, the first job is to rip out these wet materials and get them out of the home. If interior sheetrock was submerged, cut a horizontal line at least 12 inches above the flood level and remove it with the wall insulation.

The home's wood framing must dry out if the home is to be saved. Removing exterior siding may be necessary or desirable for drying if the walls were several feet under water (*See "Removing Exterior Siding to Insulate" on page 99.*) Remove the skirting to maximize ventilation to the crawl space. The underbelly and floor insulation will also need removal and disposal if they were under water. Remove all ceiling tile, if it was wetted.

The home's ducts along with its furnace and air conditioner must be cleaned and decontaminated or replaced. The furnace and air conditioner controls are particularly sensitive to water and may be damaged beyond repair. The exception is that many outdoor air conditioning and heat pump units are sealed and may just need a good cleaning. Find out as much as you can about the extent of damage yourself with the counsel of an electrician or heating-and-cooling specialist, before deciding between repair and replacement.

Decontaminating the home requires washing all its surfaces contacted by flood waters or mud. Use a 5% to 10% chlorine bleach solution. A 5% solution is sufficient for lighter contamination when you can decontaminate quickly after flood waters recede. Use 10% for heavier contamination when the microbe community has had a few days or more to incubate. To insure success, wash the surfaces twice within 30 minutes with the bleach solution.

If the weather is warm, move as much air as possible through the home's open windows with large fans. Window fans work better for exhausting air than for pushing air into the home. Locate the fans to work with, not against, any prevailing winds. If the weather is colder, use heaters, electric dehumidifiers, and partially open windows to dry the home. After the initial drying period, strive to keep the humidity below 60% with dehumidifiers and heaters or with your air conditioner, depending on the season.

After a flood, appliances like dehumidifiers and window fans may be in short supply. Home owners living in areas with any flood history would be wise to buy one or two fans and dehumidifiers and store them near the ceiling when not in use. They can save your home after a flood.

The flood's aftermath may be your best opportunity for making your home energy efficient. During the renovation, carefully seal all interior seams on the ceiling, floor, and exterior walls to prevent air leakage. Use the insulation methods described in this book's chapters on floors, walls, and roofs to optimize the home's thermal resistance. Replace furnaces, water heaters, dishwashers, and other damaged appliances with the most efficient models available. (*See "Foundation Flood Protection" on page 41.*)

Water Vapor and Humidity

The average person emits four pints of water daily into the air through breathing and perspiration. Showers, housecleaning, and cooking can add up to another three pints per person. Moist firewood and house plants generate additional moisture. Water brought into the home on shoes or clothing also adds moisture to the home.

Relative humidity measures how saturated with moisture the air is. Relative humidity is 100% when indoor air is completely saturated with moisture. Air at 50% relative humidity could hold twice as much moisture as it currently holds. Unsaturated air can become completely saturated either by absorbing more moisture or by cooling off. When air at 100% relative humidity absorbs more moisture or cools off, droplets begin to form on the coolest objects in the environment. These droplets are called condensation. Condensation happens most frequently and plentifully on the coldest surfaces.

High relative humidity in indoor air can cause:

1. Comfort problems in summer;
2. Condensation problems in both summer and winter.

Experts on cooling say that indoor air should be less than 60% relative humidity for adequate indoor comfort during the summer. During cold weather, indoor relative humidity should be less than 40% to avoid moisture condensation problems.

Un-vented gas or kerosene space heaters add unwanted moisture and other more dangerous pollutants to the indoor air. (*See "Gas, Propane, and Kerosene Space Heaters" on page 161.*) Therefore, they should never be used. Gas ranges and ovens also emit moisture and combustion by-products. Open a window slightly and use your kitchen exhaust fan when cooking with gas.

Vent dryers outdoors—not into living spaces, crawl spaces, basements, or attics. And, avoid using humidifiers, unless they are medically prescribed.

Moisture Condensation Problems

The moisture leading to high relative humidity comes from well-known sources in the home. The strategies for reducing humidity involve reducing sources, diluting it, restricting its travel, and raising surface temperatures to reduce condensation. Consider the following effective strategies for reducing high indoor relative humidity and moisture condensation:

Reduce moisture at the source. Install a ground moisture barrier. Cook with lids on your pots. Build a mud room for wet clothing and boots.

Since the ground under the home can be a major source of water vapor which can condense on cool surfaces, install a ground moisture barrier. This will stop water vapor from rising through the soil under the home or from evaporating from damp ground underneath the home (*See "Installing Ground-Moisture barriers" on page 43.*)

Air-seal interior surfaces of exterior walls, ceilings, and floors. This will prevent air leakage from moving water vapor into building cavities where water can condense. (*See "Sealing Cracks and Holes Ceilings" on page 125.*)

Dilute humid air by ventilating it with drier air. This drier air will encourage evaporation from the home's damp surfaces.

Use air conditioning systems and dehumidifiers to remove moisture from indoor air.

Add insulation to the walls, floor, and ceiling. This will keep the home's indoor surfaces warmer and less likely to condense water out of nearby air.

Indoor Air Quality

Air pollution is the most serious long-term health hazard of the indoor environment. By-products from combustion appliances and environmental tobacco smoke are the biggest contributors to indoor air pollution. Both of these sources contain multiple toxins including carbon monoxide (CO), nitrogen oxides, volatile organic compounds (VOCs), and fine dust particles which are inhaled deeply into the lungs.

Another source of VOCs are the building materials and furnishings used in many homes. Curtains, carpets, furniture finishes, and many other building components are bound together with synthetic resins that emit VOCs.

Moisture condensation encourages the growth of microscopic organisms such as fungi and dust mites. Mold and mildew are common forms of fungi. Their spores and dust-mite fecal matter frequently cause allergies, asthma, and other respiratory ailments.

Dust contains a wide variety of particles that can affect health. Smaller and lighter dust particles are more dangerous than larger and heavier particles because the smaller ones remain airborne for longer periods of time and they penetrate more deeply in the lungs. The sharpness and chemical activity of dust particles also affects the danger they present. In many areas of the country, radon is a significant indoor air pollutant carried by dust particles.

The combination of gases and dust inhaled can make a person environmentally sensitive. Environmental sensitivity creates severe respiratory and immune system reactions to environmental gases and dust.

Combustion By-Products

Combustion appliances may cause the most serious indoor air quality problems if the combustion by-products are allowed into the home. Under certain conditions, gas, propane, kerosene, and oil-fired appliances can produce carbon monoxide, a poisonous gas. If they are left open to the living space, combustion appliances can also deplete the oxygen that we breathe.

Combustion appliances all produce water vapor. They also produce nitrogen oxides and sulfur oxides, which are respiratory irritants, especially to children. Mobile homes are smaller and often more airtight than site-built homes. For these reasons, HUD requires space-heating and water-heating appliances, located within the home, to be sealed-combustion units.

The most important sources of combustion by-products in indoor air are: un-vented combustion space heaters, wood stoves, gas and propane ranges, and tobacco smoke. Un-vented space heaters should never be used in manufactured homes. Wood stoves should draw combustion air from outdoors and have airtight doors.

Environmental Tobacco Smoke

More than 1,000 Americans die each day from smoking-related diseases such as: lung cancer, emphysema, bronchitis, and heart disease. Smoking is responsible for 20% of all deaths, more than any other single cause. The EPA estimates an additional 3,000 nonsmokers die each year from cancer brought about by secondhand smoke. The American Heart Association estimates that 37,000 people die annually from heart disease related to secondhand smoke. Cigarettes are also the leading cause of fire-related deaths.

Tobacco smoke contains more than 3,800 chemicals, including: carbon monoxide, ammonia, formaldehyde, and nicotine. Tobacco smoke is responsible for 39% of all indoor air pollution, according to the EPA.

Volatile Organic Compounds

Wood stoves, un-vented kerosene space heaters, building materials, and cigarette smoke release volatile organic compounds (VOCs) and other pollutants into the indoor air. Other sources of VOCs include: solvents, glues, synthetic resins, cleaners, paints, varnishes, furniture, carpeting, and draperies.

Formaldehyde, a VOC, is particularly prevalent in new homes because so many new home components—from plywood and sheetrock to cabinets and carpet—contain formaldehyde. In its 1985 revisions to the HUD Code, HUD limited the amount of formaldehyde contained in a mobile or manufactured home's building materials.

Symptoms of overexposure to formaldehyde include watery eyes and persistent respiratory distress. Formaldehyde levels in new homes fall significantly after the first few years of occupancy.

Radon

Many experts at the EPA believe that radon is the most dangerous indoor air pollutant. Radon is a naturally occurring radioactive gas whose decay particles cling to dust. Once inhaled, these particles can mutate lung tissue. Radon normally comes from the ground underneath a home. The concentration of radon in the ground varies widely both regionally and within regions.

Radon is less of a problem in manufactured homes than in site-built homes because manufactured homes usually have ventilated crawl spaces.

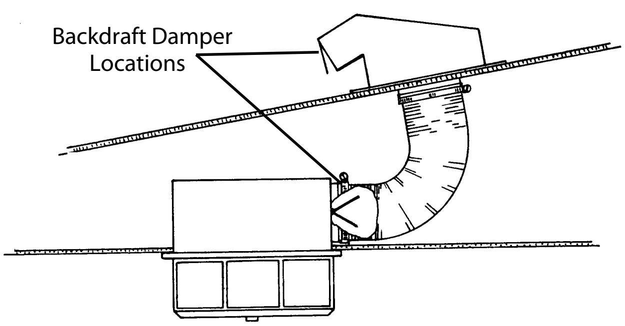
Also, the mobile home's underbelly and ground cover serve as barriers against radon from the ground.

Biological Particles

Dust mites, cats, fungi, and cockroaches put biological dust particles into the air; these particles are leading causes allergy and asthma. High relative humidity and the moisture condensation it causes encourage the growth of dust mites, cockroaches, and fungi.

These biological particles often go unrecognized as the major causes of allergy, asthma, and other respiratory ailments. People who are especially sensitive to biological dust are called environmentally sensitive.

Figure 4-3 Exhaust Fan with Backdraft Damper



Backdraft dampers may be located in the fan housing, in the duct, or in the termination fitting on the exterior wall or roof. Only one backdraft damper is needed.

Environmentally sensitive persons must keep biological dust in check. This requires controlling humidity. Relative humidity below 40% in winter and below 60% or less in summer helps minimize condensation, fungi growth, and dust mite populations. If problems persist after humidity is controlled, environmentally sensitive people need to keep their pets outdoors.

Controlling Moisture and Air Pollutants

Inadequate ventilation contributes significantly to indoor air contamination. Lack of ventilation is a relatively new phenomena, due to the rapid increases in energy prices during the 1970s that drove up indoor heating and cooling costs. In the last 20 years, home owners tried to keep utility bills in line by caulking, insulating, and fitting their homes with storm windows.

These weatherization measures reduce the amount of fresh air that ventilates the home. Pollutants and moisture tend to be more concentrated indoors than outdoors. The more pollutants that are released into the indoor air, the more ventilation is needed to keep that indoor air healthy.

Mobile homes may have a smaller volume of air than site-built homes. If they are properly weatherized and insulated, mobile homes also will likely have lower natural ventilation rates than site-built homes. Thus, it is important to ventilate mobile homes regularly by opening windows, as weather permits, to allow the entrance of fresh air.

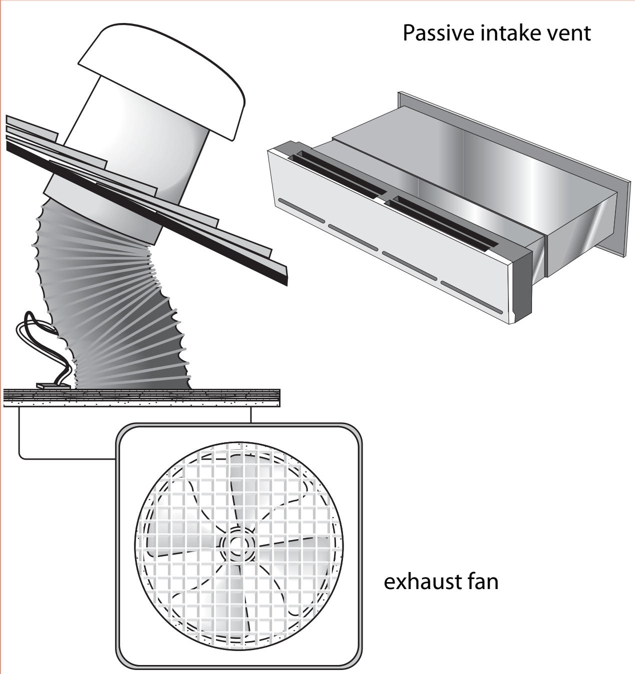
If polluted indoor air is allowed to remain in the home, breathing that contaminated air can cause respiratory problems or aggravate existing ones. Every individual has a different tolerance for pollutants. After that tolerance limit is exceeded, health may be noticeably degraded and the individual may become environmentally sensitive.

If odors linger in your home or if you have had persistent respiratory problems, take steps to improve your indoor air quality. Listed below are recommendations for reducing indoor air pollution and keeping the air in your home healthy:

1. Never use un-vented combustion space heaters.
2. Use an exhaust fan in the kitchen when cooking.

3. Use an exhaust fan in the bathroom when showering.
4. Keep relative humidity between 30% and 50%.
5. Ventilate continuously when the smell of smoke, cleaners, paint, or other pollutants is noticeable.

Figure 4-4 Exhaust Fan with Passive Intake Vent



A common way to ventilate the home is with a central or bathroom exhaust fan and passive vents through the wall.

To avoid severe reactions to pollutants, environmentally sensitive persons may need to reduce indoor air contaminants at the source by enacting the following measures:

1. Prohibit smoking indoors.
2. Eliminate the use of gas or propane ranges.
3. Restrict or eliminate the use and storage of paints, solvents, strong cleaners, and other chemicals indoors.
4. Eliminate wood heating.
5. Keep pets outside.
6. Reduce or eliminate the use of cosmetics.

Ventilating the Indoors

Adequate ventilation is essential to avoid health problems related to moisture and air pollutants. Ventilation also fights building material deterioration caused by excess humidity.

Indoor ventilation uses two strategies: spot ventilation and whole-house ventilation. Exhaust fans accomplish spot ventilation by sucking moisture and pollutants out of kitchens and bathrooms where pollutants are produced. Whole-house ventilation in mobile homes uses the same exhaust fans or a roof-mounted fan with small intake vents to ventilate the whole home.

The success of spot ventilation or of whole-house ventilation often depends on how much noise that fans make. If fans are too noisy, occupants may decide not to use them or may disconnect their automatic controls.

All homes allow some air leakage between indoors and outdoors. This unintentional ventilation helps keep the home's air fresh and relatively dry. The problem with using air leakage for ventilation is that the rate of air leakage may be too high, wasting energy. Or, the rate of air leakage may be too low, fostering indoor air pollution. Also, air leakage doesn't ventilate all areas of the building equally. This unequal ventilation leaves some areas drafty and fresh, and others stagnant and polluted.

Effective ventilation is vitally important in homes with large volumes of pollutants: smoking, new furniture, new carpet, new cabinets, use of aerosols and paint, etc.

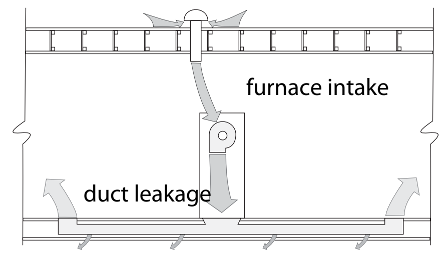
Spot-Ventilation and Exhaust Fans — Spot-ventilation in the kitchen and bathroom is the most effective way to remove moisture and odors where they are generated. Exhaust fans should operate during cooking, bathing, and washing. Ventilating windows are also considered by HUD as part of the spot-ventilation system.

Exhaust fans should have backdraft dampers. Backdraft dampers are little doors located: in the fan housing, in the vent duct, or in the termination fitting in the roof or wall. Backdraft dampers close preventing air leakage when the fan is off.

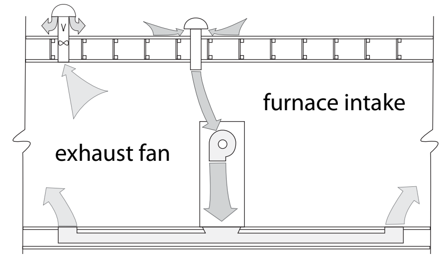
Every mobile home should have a properly operating bathroom exhaust fan and ducted kitchen range hood or wall exhaust. Kitchen and bath fans were not required until the 1994 revisions to the HUD code. However, most manufacturers were already installing these fans to satisfy customer demand. The kitchen fan is required to move 100 cfm of air and the bathroom 50 cfm. If you are installing or replacing a spot-ventilation fan, select a larger one than recommended above. Research shows that the measured airflow through an exhaust fan is typically about a third less than its rating.

Bathroom exhaust fans usually have their own switches. However, when moisture is a chronic problem, the fan is often wired to the same switch as the bathroom light to ensure frequent use. Timers are also used to control exhaust fans for this spot ventilation. Special controls, called humidistats, cycle the fan on and off by sensing the relative humidity of the air.

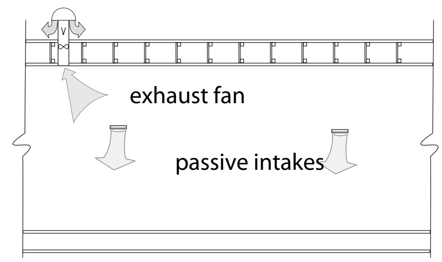
Figure 4-5 Exhaust fan ventilation



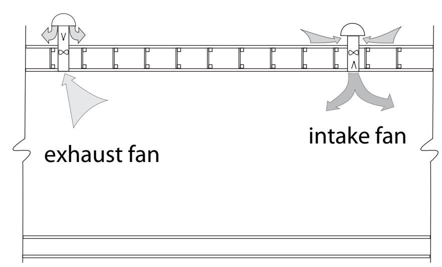
Furnace Intake with Duct-Leakage Exhaust - The factory-installed passive intake vent brings air in from the roof and leaky ducts exhaust air through the belly. The duct leakage is accidental and often excessive.



Furnace Intake with Exhaust Fan - If ducts are airtight as they should be, a bathroom exhaust fan can be used to balance the furnace intake. The bathroom fan is wired to run when the furnace is running.



Exhaust Fan with Passive Intake - Passive intake vents through the wall provide intake air to balance air being exhausted through the exhaust fan.



Exhaust Fan with Intake Fan - Recommended by experts to ventilate very tight homes. Fans run at the same time, either intermittently or continuously.

Whole-House Ventilation — Ventilation is an important health and safety concern in all manufactured homes, especially newer ones. New homes are fairly airtight—probably averaging an air change every 4 hours (0.25 air change per hour). Since the American Society of Heating Refrigeration and Air Conditioning Engineers (ASHRAE) recommends 0.35 air changes per hour (ACH), HUD now requires the manufacturers to provide 0.10 ACH (0.35 minus 0.25) in whole-hose ventilation for these newer homes. To reach 0.35 ACH, HUD specifies that the average continuous ventilation rate should be 0.035 cubic feet per minute (cfm) for each square foot of floor area. For example, a home having 1000 square feet of floor area needs continuous mechanical ventilation of 35 cfm, according to HUD.

Ventilation systems often combine exhaust fans with passive vents through walls and windows to provide makeup air. These passive vents are little more than rain-shielded and insect-screened holes that penetrate walls and provide a slow steady inflow of fresh air. They help prevent the exhaust fan from creating a vacuum inside the home. Timers are often used to control exhaust fans to provide whole-house ventilation for manufactured homes. The timer keeps the fan running two-to-twelve hours a day, depending on the home's ventilation needs. Many other ventilation systems operate continuously.

Many furnaces include outdoor air ventilation that provide outside air directly into the furnace blowers through ducts connected to the roof or crawl space. Air from outside is heated or cooled and then distributed when the furnace fan goes on. (*See "Downflow Furnace Air Circulation" on page 150.*) Although these furnaces drew ventilation from the crawl space in the past, HUD now prohibits manufacturers from drawing outside air from the crawl space, because of the questionable air quality there.

Ventilation fans can create positive or negative pressures inside the home as a by-product of moving air. A positive pressure in the home during winter may drive moist air into building cavities through cracks in the interior surfaces. This can cause condensation inside wall, floor, and ceiling cavities. Likewise, a negative pressure during the summer cooling season could draw hot, humid outdoor air into building cavities. This causes condensation near the cooler interior surfaces. For these reasons, HUD has prohibited positive ventilation-induced pressures in middle and northern areas of the US and negative ventilation-induced pressures in the very southern US in their 1994 revisions to the HUD Code.

The 1994 HUD Code also forbids venting house air into ventilated attics, a practice which was previously common in some mobile homes.

Retrofitting a mechanical whole-house ventilation into an existing home goes hand in glove with thorough air sealing. In fact, mechanical whole-house ventilation systems may not be necessary or reliable in leaky homes. Air leakage greater than 0.25 ACHn can interfere with the mechanical ventilation system, making the fan's contribution to the overall ventilation rate smaller than expected. Ideally the ACHn provided by the fans should be twice the natural ventilation rate in ACHn. For example, a 0.12 ACHn natural ventilation rate plus 0.24 ACHn of fan-powered mechanical ventilation would yield an almost perfect 0.36 ACHn total ventilation rate. For very airtight homes, fan-powered intake combined with fan-powered exhaust is the preferred ventilation strategy.

Ventilating Attics and Crawl Spaces

Relatively dry outdoor air can be used to ventilate and remove accumulated moisture from attics and crawl spaces. Attic and crawl-space ventilation is a last resort for removing condensed moisture, ground water, or leaked rain water. It's much preferable to prevent moisture's intrusion into the attic or crawl space with vapor barriers and ground moisture barriers, and by sealing floor air leaks and ceiling air leaks.

The 1994 revisions to the HUD Code require vapor barriers in the middle and northern US (Required in zones 2 and 3, vapor barriers are optional in Zone 1). HUD also now requires attic ventilation except for metal-roofed mobile homes that have no roof sheathing. To meet this new requirement, homes with roof sheathing must have at least 50% of the vent area high on the roof, and at least 40% must be located low on the roof (soffit vents or low roof vents).

Building codes usually recommend 1 square foot of vent for every 150 square feet of attic or crawl space floor, if there is no vapor barrier in the ceiling or no ground moisture barrier. If there is a vapor barrier or ground moisture barrier, the codes recommend 1 square foot of vents for 300 square feet of attic or crawl space area.

Attic and crawl space ventilation has become a controversial issue in recent years. Many building inspectors, manufactured housing specialists, and builders will tell you that attic and crawl-space ventilation is absolutely essential. However, many of North America's leading building scientists doubt that attic and crawl space ventilation does any good. In fact, some experts assert this ventilation can actually carry moisture into attics and crawl spaces when the attic or crawl space is cooler than the outdoors. Building scientists believe that crawl-space ventilation causes moisture problems in humid regions, especially during the summer when hot humid air is introduced into a cool crawl space. Attic ventilation could lead to condensation any time the attic is cooler than humid outdoor air.

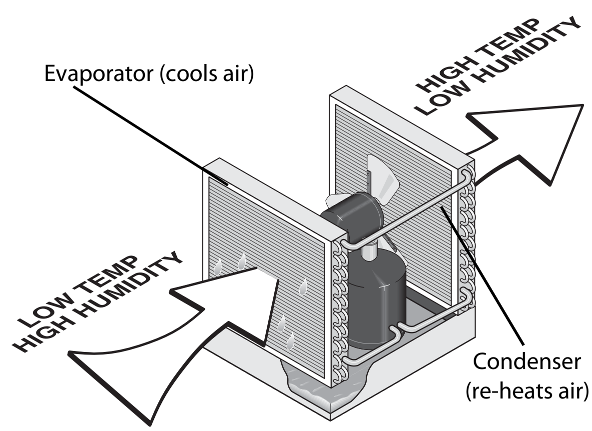
In general, attic and crawl-space ventilation seem to work well in the cooler and drier North American climates. In wetter, milder climates especially coastal regions, attic and crawl space ventilation are less effective at removing moisture. Ventilation can actually carry moisture into attics and crawl spaces. Specially designed ventilation-control humidistats are available from ventilating companies like Tamarack Technologies. These humidistats can operate attic and crawl-space vent fans when outdoor air is relatively dry and keep them off when outdoor air is humid.

Mechanical ventilation with humidistatic control can be an effective way to remove attic and crawl space moisture.

Combination Ventilation Systems

Several companies make mobile home ventilation systems that ventilate both the attic and the home's interior. These combination ventilators have two roof fittings, one for the roof ventilation fan and one for the fresh-air inlet. Combination ventilation systems use roof-mounted fans that blow air into the attic or suck air out to ventilate the roof cavity. The fresh-air inlet allows outdoor air into the furnace when the blower comes on. Ask your mobile home dealer or mobile home parts dealer for details about the different combination ventilation systems.

Figure 4-6 Dehumidifier



A dehumidifier removes moisture and raises the air temperature. It can be an efficient space heater for areas of buildings that need both dehumidification and space heating.

Air Conditioners and Dehumidifiers

Air conditioners and electric dehumidifiers remove water vapor by refrigerating the air and forcing it to relinquish some of its water vapor. This drying process also removes heat from the air. The air conditioner releases this heat outdoors through its outdoor condenser coil.

A dehumidifier reheats the indoor air after refrigerating it. The dehumidifier is essentially a space heater since all of its electrical consumption ends up as heat inside the home. If moisture removal and space heat are needed in the same part of the home, the dehumidifier is an excellent way to both heat and dry the home.

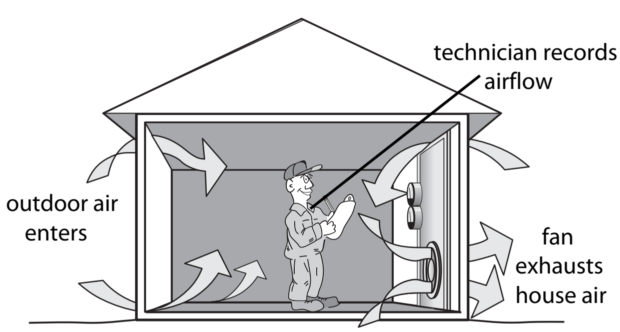
Avoid using dehumidifiers with air conditioning. Air conditioning systems should be designed to remove enough moisture to keep the home dry and comfortable during hot, humid weather. The air conditioner and the dehumidifier work in opposition—the dehumidifier heats the space, while the air conditioner cools it. That's why you don't want to use the two together.

Chapter 5 Air Leakage

Reducing air leakage saves energy and money by reducing the rate of heat flow through the building shell—a mobile home's walls, floor, ceiling, and ducts. Air sealing is equally important for heating and air-conditioning energy savings. Curbing air leakage is also crucial to stopping condensation problems in the shell's cavities caused by air migration between these cavities and the home's interior.

There are two common approaches to air sealing: the ***prescriptive method*** and the ***guided method***. The prescriptive method uses a list of leakage locations. The guided method uses a ***blower door***, an instrument that measures air leaks and helps locate them.

Figure 5-1 Blower Door



The blower door is an instrument that measures a home's leakiness and helps locate the leaks. Blower door testing also helps access the need for mechanical whole-house ventilation.

Air Sealing - Prescriptive Method

When people complain about drafts and air leakage, they often blame windows and doors for most of the problem. However, research and field experience indicate that major air leaks in mobile homes are not usually concentrated around windows and doors. The following list, used in the prescriptive method of air sealing, details where air leaks are most commonly found:

1. Return air plenums in the floor and ceiling associated with heating and cooling systems in older homes. (*See "Ceiling and Floor Return-Air Systems" on page 156.*)
2. Joints and holes in ***forced air supply ducts;*** and cracks around ***registers*** where these ducts penetrate the floor. (*See "Leaky Supply Ducts" on page 151.*)
3. Packaged air conditioners installed without proper backdraft dampers. (*See "Packaged Air Conditioners" on page 174.*)
4. Torn or missing underbelly. The underbelly is the protective covering underneath the floor. (*See "Improving Energy-Efficiency of Floors" on page 84.*)
5. Plumbing areas under bathtubs, behind washing machines, under sinks, and, especially, in interior walls adjoining external water-heater closets.
6. Joints between the halves of double-wide homes completely around the perimeter of each section—floor, walls, and ceiling.
7. Joints between the main structure and building additions.
8. Gaps around light fixtures, electrical receptacles, flue pipes, and exhaust fans.
9. Hidden openings through closets and cabinets into building cavities.
10. Loose siding, paneling, and trim.
11. Electrical service panel boxes.
12. Room air conditioners and evaporative coolers during winter when they're idle.
13. Older jalousie and awning windows, especially those with malfunctioning mechanisms

for closing. (*See "Repairing Windows" on page 116.*)

14. Damaged, malfunctioning, and poorly fitting doors. (*See "Weatherstripping Doors" on page 108.*)

If you inspect and carefully seal all these areas, you will probably have a very tight home. However, you could be missing a major leak like a hidden hole in a duct or other hard-to-reach area. The guided method of air sealing is much more likely to find these hidden problems.

Air Sealing - Guided Method

The guided method of air sealing uses a blower door to measure and locate air leaks.

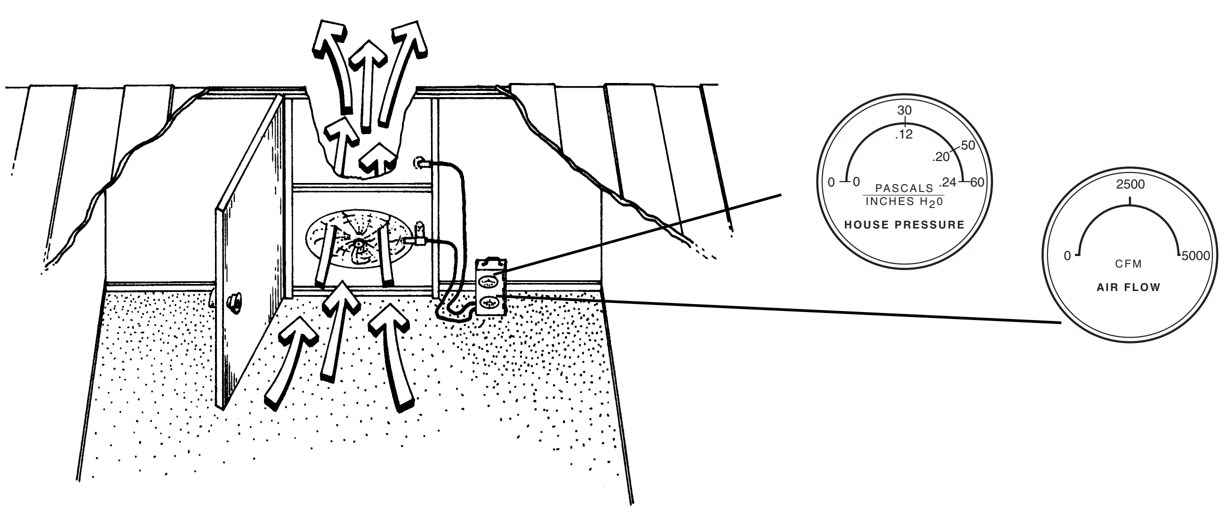
Blower door testing is a practical and effective technique for estimating air leakage. The main challenge in controlling air leakage in homes is in determining how large a problem air leakage presents to each particular home. Some homes are very leaky, while others are very tight. It's difficult to know without measuring.

A blower door is a large fan installed in a sealed doorway. The fan blows air out of the home, drawing air from outdoors through holes and cracks in the home. The air moving through the blower door's fan housing is measured by gauges and used to tell whether the home is leaky or tight.

Blower Door Testing

Most of what is known about the effectiveness of air sealing methods comes from the use of blower door testing. Blower door tests produce approximate air-leakage estimates by measuring how much airflow is required to produce a specific pressure—usually 50 pascals (or 0.2 inches of water)—between the house and the outdoors. A wind of approximately 20 miles per hour blowing against all sides of a home would produce about 50 pascals of pressure difference between indoors and outdoors, similar to a house pressure of 50 pascals produced by a blower door.

Figure 5-2 Blower Door Testing



Blower doors estimate air leakage by measuring how much air flow (cfm) is required to produce a particular pressure difference between indoors and outdoors—called "house pressure." The most common house pressure for judging the home's airtightness is 50 pascals.

Figure 5-3 Natural and 50 Pascal Air Flow Rates

Natural Air Changes Per Hour (ACHn)

0 – .50	.50 – 1.00	1.00 – 1.50	1.50 – 2.00
Newer more energy-efficient homes	**Average older homes and less efficient newer homes**	**Older homes with large air leaks**	**Older homes with very large air leaks**
Mechanical whole-house ventilation required / Mechanical ventilation recommended	Well-ventilated homes. Air leakage a small to moderate energy problem.	Excessive air leakage. Thorough air sealing effort will produce significant energy savings	Air leakage is the major energy problem. Thorough air sealing will produce impressive energy savings
0 – 1200	1200 – 2400	2400 – 3600	3600 – 4800

Cubic Feet Per Minute @ 50 Pascals Blower Door Measurement

The natural air change rate is calculated from the 50-Pascal air flow, measured by the blower door. This chart shows how ACHn and CFM_{50} compare for a 14 x 65-foot mobile home.

Blower door tests determine how much air leakage a home has. The test results help you decide if air-sealing work is necessary. A high airflow reading at 50 ***pascals*** house pressure would point out the need to seal air leaks. A low reading would mean the home is allowing only enough air leakage to keep the air fresh and relatively dry. In the latter case, air-sealing procedures may not be cost-effective and could create a health hazard if the home doesn't have a whole-house ventilation system.

Figure 5-4 CFM50 Reduction for Air-Sealing

Air-Sealing Procedure	Typical CFM_{50} Reduction
Windows and doors: caulking/weatherstripping	50-150
Installing tight interior storm windows	100-250
Caulking interior cracks	50-150
Sealing leaky supply ducts	100-600
Sealing leaky water-heater closet	200-600
Sealing floor return-air plenum	300-900
Patching large air leaks in floor, walls, and ceiling	200-900

The blower door's fan exaggerates air leakage so that it can be felt and measured. You can feel air coming in through the various leaks around the home during a test. You can seal a leak and then measure the reduction in airflow. The use of blower door testing is the only practical and accurate way to determine whether or not you need to seal air leaks.

The blower door measures two factors:

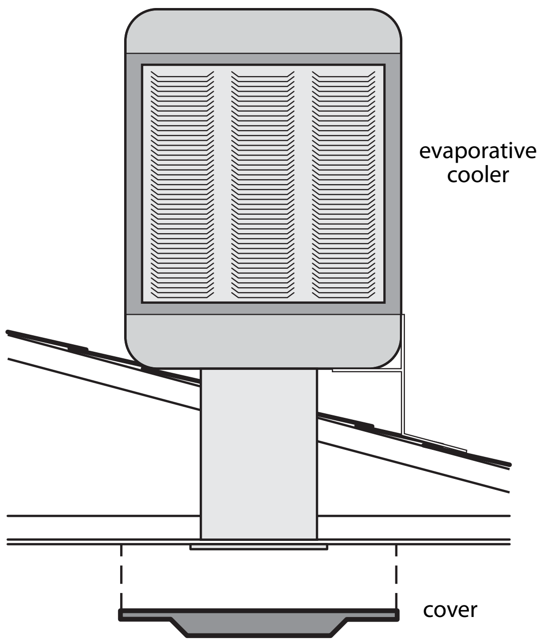
1. The pressure difference—measured in pascals—between indoors and outdoors, referred to as the *house pressure*; and
2. The ***airflow rate*** —measured in cubic feet per minute (cfm)—required to maintain a specific house pressure. Calculations are applied to the exaggerated airflow, produced and measured by the blower door, to estimate the natural airflow under typical wind and barometric conditions.

There is one common airflow factor measured by a blower door and two others that are calculated from it. These factors are as follows:

1. **The 50-Pascal Airflow Rate (CFM50)** is expressed in cubic feet per minute and is the actual flow rate measured at 50 pascals of house pressure by the blower door. CFM50 is the simplest and most direct measurement of the airtightness of a building.
2. **The 50-Pascal Air Change Rate (ACH50)** is expressed in air changes per hour at 50 pascals and is calculated by dividing the CFM50 by the house volume in cubic feet, and then multiplying by 60 minutes per hour.

3. **Natural Air Change Rate (ACHn)** is expressed in air changes per hour and is roughly estimated by dividing the 50-Pascal Air Change Rate by a number between 10 and 20, depending on geographic location, wind, and shielding by nearby objects.

Figure 5-5 Evaporative Cooler Cover



The evaporative cooler inlet is another major source of air leakage. During the heating season, a cover eliminates most of this leakage.

Ventilation and Air Leakage

To protect indoor air quality, the American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) and the EPA have established guidelines for minimum natural airflow rates in buildings of 0.35 air changes per hour (ACHn), which HUD adopted into its 1994 standard on ventilation.

To ensure healthy indoor air, a home must either have enough air leakage to remove moisture and pollutants, or it must have a mechanical whole-house ventilation system. A well-designed mechanical ventilation system is superior to air leakage for providing fresh air, because it controls ventilation to a safe minimum and ventilates the home's rooms more consistently than air leakage. Mechanical ventilation systems are required for new manufactured homes. (*See "Ventilating the Indoors" on page 64.*)

A very airtight house with a continuous mechanical ventilation system produces clean, healthy air for the lowest energy cost. Air leakage greater than 0.25 ACHn can interfere with the mechanical ventilation system, making the fan's contribution to the overall ventilation rate smaller than expected. Ideally the ACHn provided by the fans should be twice the natural ventilation rate in ACHn. For example, a 0.12 ACHn natural ventilation rate plus 0.24 ACHn of fan-powered mechanical ventilation would yield an almost perfect 0.36 ACHn total ventilation rate.

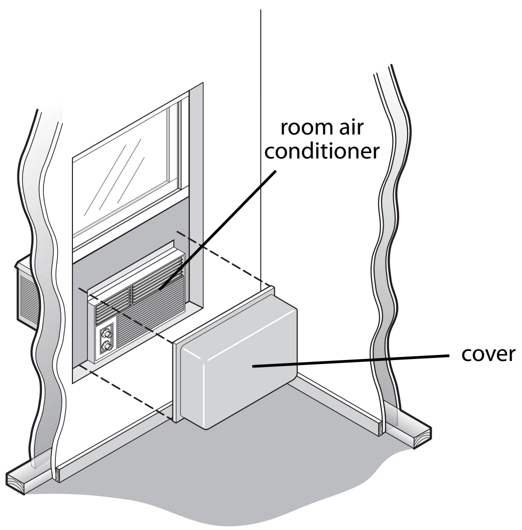
Figure 5-6 Laundry Faucets

Anywhere supply or drain pipes penetrate the building shell, they often provide a large air-leakage pathway.

Air Sealing

The most important idea for air sealing homes is to seal the biggest leaks first. Caulking or weatherstripping small cracks around doors and windows, while at the same time ignoring large air leaks in hidden locations, won't measurably reduce energy consumption.

Figure 5-7 Room Air Conditioner Cover



Room air conditioners leak air through their cabinets and around their perimeters. An interior air conditioner cover greatly reduces this leakage during the heating season.

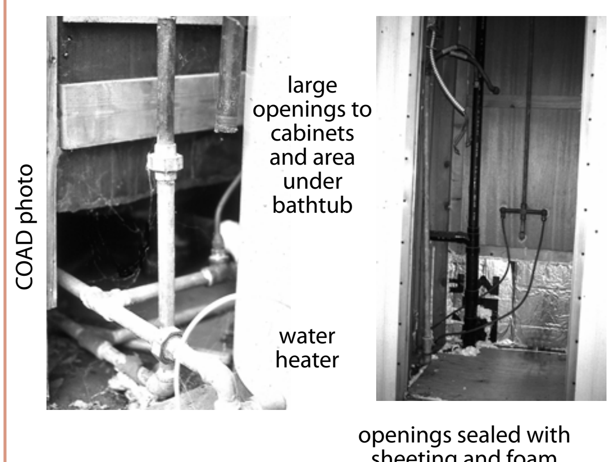
The largest and most predictable air leakage reductions come from sealing up ducts; patching underbellies; plugging major leaks around plumbing, wiring, flues, and joints in the building sections; and sealing return air plenums in the floor and ceiling (in older units). Adding insulation to wall, floor, and ceiling cavities reduces air leakage to a surprising extent, also.

There is a large selection of materials available for patching large leaks in walls, floors, and ceilings. In most cases these materials are similar in structure and appearance to the existing materials. Adhesives packaged in caulking tubes, used with screws or staples, work well for attaching patches. Don't forget to refasten loose trim and paneling on both the interior and exterior of the home.

Figure 5-8 Electrical Breaker Box

The breaker box often provides large air-leakage pathways where holes are cut for wires and conduit.

Figure 5-9 Water-Heater Closets



Pipes connecting the water-heater closet with the adjacent bathroom create very large air-leakage pathways. Often the water heater must be removed to do a thorough job, as shown at right.

Cracks and small holes more than $^1/_4$-inch wide should be stuffed with foam rubber or another compressible material before caulking is applied. Use caulking and foam rubber to fill small and medium-sized cracks on the interior side of walls, floors, and ceilings. Foam sealant applied from a can is also effective for gaps $^1/_4$-inch or larger. Since some people are sensitive to the odor from caulking and adhesives, ventilate the home regularly for a day or so after application to remove odors.

Apply caulking to exterior wall joints only to seal out water—not to block air leakage. A little air leakage between the outdoors and wall cavities usually helps to keep them dry. Joints at the bottom of the wall let any water condensing in the wall escape.

Water leaks occur at the tops and sides of window and door frames and at the joints between walls and the roof.

Other sections of this book dealing with repairs to walls, floors, ceilings, roofs, windows, doors, and ducts also describe specific ways to reduce air leakage.

Figure 5-10 Gap Around Chimney

Large gaps around chimneys, pipes, and vents are common where they aren't visible from indoors.

Chapter 6 Insulation

Insulation is added to cavities in the building envelope to slow heat loss in the winter and heat gain in the summer. Insulation materials reduce heat flow by creating millions of tiny air pockets—air is a poor heat conductor.

This section describes types of insulation that can be added to mobile or manufactured homes and general methods for installing it. For particulars about insulation installation, refer to succeeding chapters on floors, walls, doors and windows, and roofs and ceilings.

Figure 6-1 R-Values of Insulation Materials Per Inch of Thickness

Fiberglass Batts	2.5-3.5
Fiberglass Blowing Wool	3.0-4.5
Mineral (Rock) Blowing Wool	2.5-3.5
Cellulose Blowing Insulation	3.0-4.0
Polystyrene Beads	2.0-2.5
Polystyrene Beadboard	3.5-4.0
Urethane Foamboard	5.5-6.5

About Insulation

Many mobile homes, especially those built before 1976, are not well-insulated. Walls, floors, and roofs typically have from one inch to four inches of insulation. Existing insulation was applied erratically in many cases, leaving voids and edge gaps that reduce the insulation's effectiveness. If the voids occur between the interior of the home and the insulation, the insulation loses much of its effectiveness because air convection carries heat right around it. Most floor cavities suffer from this problem—insulation is fastened to the bottom of the floor joists. When wall cavities aren't completely filled with insulation, air convects around the insulation reducing its ***R-value*** (thermal resistance) by 15% to 50% according to reliable research.

Adding insulation can bring the home up to modern standards of energy efficiency. However, adding insulation to closed building cavities—with sheeting on both sides—can be difficult and requires experience and specialized equipment.

In cold climates, it makes good economic sense to add insulation to wall, floor, and ceiling cavities where there is room for more insulation. Insulating roof cavities, with their high solar heat ***absorptance***, greatly reduces summer cooling costs, too. However, adding wall and floor insulation are not very cost-effective in warm climates.

R-Values

The R-value of a material is its resistance to heat flow. The higher the R-value of a material, the longer it takes heat to travel through the material. Single-pane glass has an R-value of approximately R-1; solid wood doors are roughly R-2; and uninsulated walls are about R-4. Insulating materials range from R-2 to R-7 per inch of thickness.

Adding insulation to a wall, floor, or ceiling increases its R-value. Achieving the maximum R-value from insulation requires installing the new insulation with uniform coverage and density. Uniform coverage means that all areas of the building cavity are evenly blanketed with insulation and there are no voids. Uniform density means that the insulation is uniformly compacted throughout the cavity.

Moisture and Insulation

When insulation is wet, it loses much of its R-value, and it holds moisture that could rot building materials. With existing moisture problems, adding more insulation merely provides more material to get soaked. Therefore, it is very important to find and eliminate moisture problems before adding any insulation.

Experience indicates that re-insulation doesn't increase dampness as long as moisture problems are fixed before re-insulating. Adding insulation can actually prevent moisture problems by allowing less moisture-laden air into building cavities.

Types of Insulation

Insulation is made of fibrous or cellular material that traps air in tiny cavities. Glass (fiberglass) and wood fibers (cellulose) are packaged in plastic bags for blowing using an insulation blowing machine. Fiberglass is also manufactured in batts, 1-to-10 inches thick. Plastic resins are foamed with air or other gases to form sheets of insulation, $^1/_4$-to-4 inches thick.

Fiberglass Insulation

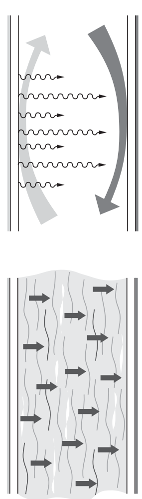
Fiberglass is a versatile insulation for insulating or re-insulating mobile and manufactured homes. Fiberglass doesn't burn, doesn't absorb much water, and doesn't rot or physically deteriorate with wetness.

Fiberglass insulation does irritate the skin and lungs. Always wear a respirator when working with fiberglass. Powdering exposed parts of the body before handling fiberglass will reduce itching and skin irritation.

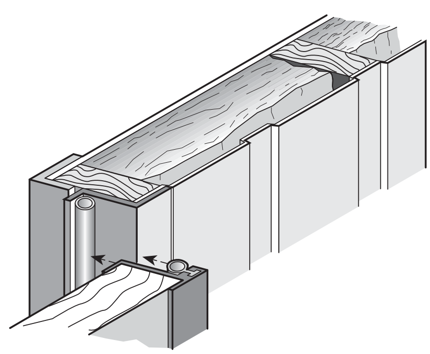
The R-value of fiberglass starts at about R-2.9 per inch at a density of 0.65 pounds per cubic foot (pcf) and increases to about R-4.5 per inch at 2.5 pcf. The R-value per inch begins decreasing when fiberglass is packed beyond 3.0 pcf.

Fiberglass batt insulation or fiberglass blanket insulation was factory-installed in most manufactured homes in service today. The batt insula-

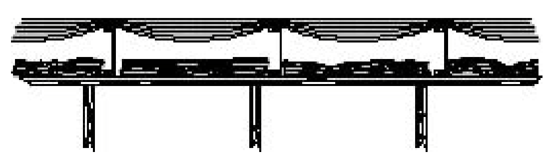
Figure 6-2 Insulation Flaws



Wall Insulation Versus None - Heat travels quickly by radiation and convection in the uninsulated wall. Heat travels slowly through the wall cavity filled entirely with insulation.



Unfilled Wall Cavity - A space like that shown at left can significantly reduce the R-value of wall insulation.



Flaws in Roof Insulation - Voids and edge gaps in roof cavities result in R-values significantly lower than predicted.

tion was either installed between studs, trusses, and floor joists; or it was installed over the outside of studs, trusses, or floor joists in large blankets.

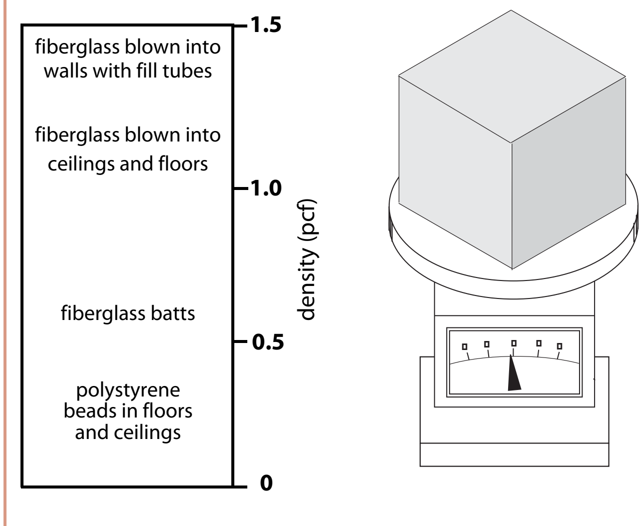
Fiberglass batts are inexpensive, readily available, and require no special tools to install (other than a respirator). The best type of fiberglass batt for re-insulating a mobile home is the un-faced batt. Most facings make the batts harder to install and can trap moisture within the insulation. The purpose of facings is to resist moisture and to make fastening easier in new homes, but the facings are usually a hindrance for re-insulating older mobile homes. Facings are flammable too, unlike fiberglass itself.

Blown fiberglass generally gives better R-values in closed cavities than fiberglass batts. To achieve good R-value and convection resistance, blown fiberglass insulation should be 1.0-to-1.5 pcf density in floors and ceilings and about 2.0 pcf in walls. Blowing fiberglass at these densities generally won't cause damage to the siding or interior sheeting.

Blown fiberglass is the best type of insulation for metal-skinned mobile homes because it is non-corrosive and moisture resistant. It installs inside roof and floor cavities at a lower density than cellulose blowing insulation and therefore puts less pressure on the wall, ceiling, or underbelly during installation, reducing the possibility of damage. The disadvantages of fiberglass blowing wool are that it requires more experience, a better blowing machine, and more installation time than cellulose.

Fiberglass for blowing is packed in very compressed 24-to-40 pound bales. The compressed fiberglass requires a blowing machine with an agitator that tears it up into small pieces that fly fluidly through the blower hose without plugging up. Some smaller blowing machines are not suitable for blowing fiberglass.

Figure 6-3 Density of Insulation



Density of insulation affects its R-value and resistance to air flow. Wall insulation should be denser than floor and ceiling insulation—walls are vertical and can act like chimneys, if filled with only loosely packed insulation. This chart presents each insulation's density in pounds per cubic foot.

Polystyrene Bead Insulation

Polystyrene beads are lightweight, moisture-resistant, plastic foam beads that can be blown into cavities for insulation. Beads used for blowing are made by shredding polystyrene foam board waste. The largest particles of shredded foam board should be no more than $^1/_2$ inch in diameter.

Polystyrene beads are the most moisture-resistant blown insulation. Beads don't produce much respirable dust and are less likely to plug the hose on a blowing machine than cellulose or fiberglass.

Beads are easy to install in floors and ceilings because they can flow past barriers that would stop fiberglass or cellulose. The beads, flowing into a ceiling or floor cavity, put very little pressure on the interior ceiling or underbelly. Since beads will flow freely out of any small opening in a cavity, use special care to seal all interior openings.

However, beads have a relatively low R-value of about R-2.3 per inch. They are not compressed in their bags, so they are very bulky to store and transport compared to other blowing insulations.

Beads are not appropriate for roof cavities of homes in hot and sunny climates, because polystyrene starts to soften and shrink at temperatures above 130°F.

Beads should also not be used in wall cavities with interior wood paneling, because they are combustible and produce toxic smoke when they burn. The Department of Housing and Urban Development requires all plastic foam insulation to be separated from indoors by: $^{5}/_{16}$-inch gypsum board, or two inches of mineral fiber insulation, or some equally fire-resistant material.

Rigid Foam Insulation

Foam board $^{1}/_{4}$-to-$^{1}/_{2}$ inches thick, some faced with cardboard or foil, is a common exterior insulating sheathing for many manufactured homes. You can buy foam board at lumber yards and manufactured housing suppliers in sheets, 4 foot by 8 foot or larger.

Building codes do not allow the interior application of plastic foam board, because it produces toxic smoke during a fire. The HUD Code requires that foam board be separated from the interior by: $^{5}/_{16}$-inch sheetrock, or 2-inch mineral fiber insulation, or some equally fire-resistant material.

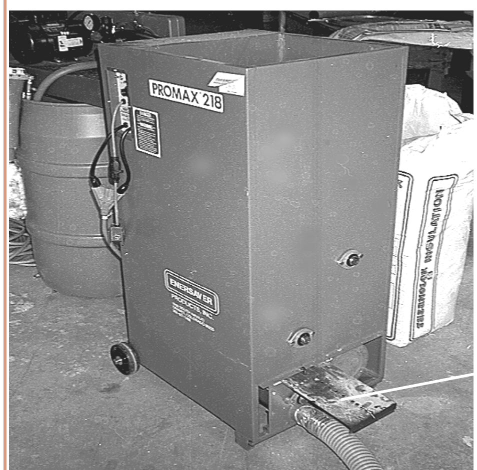
Foamcore, a $^{1}/_{4}$-inch-thick foam board used primarily on manufactured homes, is excellent for underbelly repair and sealing air leaks in areas that do not face a living space. Thicker sheets of polystyrene foam and polyurethane foam are useful for patching underbellies below pipes and ducts in order to enclose ducts within the insulated shell.

White polystyrene bead-board is the least expensive of the foam boards. It is installed over metal roofs and capped with rubber or metal roofing.

Since polystyrene softens and shrinks at temperatures above 130°F, it is **not** recommended for installation directly under a dark-colored roof.

When installing new interior sheetrock, first install foam board $^{1}/_{4}$-to-$^{1}/_{2}$ inches thick if you live in a cool or cold climate. Foil-faced foam gives the added benefit of being a vapor barrier.

Figure 6-4 Small Insulation Blower



Some small electric-powered insulation blowers, like this one, will blow insulation slowly but steadily into mobile home building cavities. Rental businesses and lumber yards often rent these blowers. If they are poorly maintained, they will blow very slowly.

Cellulose Blowing Insulation

Cellulose blowing insulation is inexpensive and easy to install. Cellulose is easier for a do-it-yourselfer with a rented blowing machine to use than blown fiberglass. However, unlike fiberglass or polystyrene beads, cellulose absorbs lots of water and deteriorates with wetness. Fire retardants in the cellulose may corrode metal siding and roofing. And, since cellulose packs tighter and puts more pressure on the siding, roofing, and underbelly during installation than fiberglass or beads, the likelihood of damage increases.

Because of the above disadvantages, cellulose is only recommended for manufactured homes in very dry climates and multiple-section homes with enough attic space for good ventilation. If the insulation will be in contact with metal siding or roofing, make sure to use cellulose with fire retardants that are noncorrosive to metal.

Installing Blown Insulation

Insulation blowing machines break up the bundled insulation and capture the insulation in a sealed chamber at the bottom of the machine's hopper. Air pressure, created by a compressor or blower, blows the insulation out of this chamber and through the hose.

There are two common types of insulation-blowing machines, electric-powered and gasoline-engine-powered. Most professional insulation companies use gas-powered machines. They blow insulation more quickly and conveniently than electric-powered machines. But, gas-powered insulation blowers are much more expensive.

Smaller electric machines with rotating metal tines do a good job of blowing fiberglass if they're in good repair. Blowing fiberglass challenges some smaller electric machines, however, and the job can be very slow if the machine you're using is not designed for fiberglass or if it is in poor repair.

Controls on the blowing machine adjust the air pressure and insulation flow rate. The operator starts with medium-to-high air pressure and a low delivery rate. If the delivery rate is too fast, the hose may clog, which you want to avoid at all costs. If the delivery rate is too slow, the cavity takes too long to fill, and the insulation packs too tightly. This could bulge interior or exterior paneling. Adjust the delivery rate and pressure to fill the cavity quickly and steadily without bulging the cavity's sheeting or clogging the hose.

Graphite powder is an excellent lubricant for insulation blowers and hoses. Mix about a cup of powder with half a hopper-full of insulation. For larger hoppers, proportionately add more graphite. Blow this mixture through the blower and hoses, then back into the hopper. After a few minutes of circulating this mixture, blow it into a bag for future use.

Hoses, Fittings and Fill Tubes

Hoses and fittings are important to effective insulation blowing. Hoses, connections, and fill tubes should be as airtight as possible to avoid weakening the pressure needed to blow the insulation.

When filling closed building cavities, it's necessary to reduce the diameter of the hose from 3-or-4 inches down to $1^1/_2$-or-2 inches. Use metal or rubber reducers to reduce the hose's diameter $^1/_2$ inch at a time. A one-inch reduction may be too sudden and can cause the hose to plug. It's best to use two reducers to go from 3-inch-diameter hose to a 2-inch-diameter hose and to install several feet of $2^1/_2$-inch hose between the two reducers.

Insulation might travel several feet from the end of the hose into a floor cavity or a double-section home's attic. But, in more narrow cavities, blown insulation won't reliably travel much more than one foot. If you assume the insulation will travel more than one foot from the end of the tube, voids and low-density insulation may result. The fill-tube, inserted into the farthest corners, fills the cavity evenly and completely.

A flexible fill tube is flexible yet still considerably more rigid than standard blower hose. Its flexibility allows it to bend around corners and snake its way past obstacles. The fill-tube's rigidity allows the technician to push the fill tube 6 feet or more into a closed cavity without its crimping or doubling back. Fill tubes are usually made of corrugated or smooth plastic hose used in farms and factories.

Cut the end of the fill-tube at a 45° angle so the tip is on the inside of the curve and the heel of the angle is on the outside of the curve. Mark the fill tube in one-foot intervals to show how much of the tube remains in the cavity when you are pulling the tube out.

Use the biggest tube diameter that will fit comfortably into the cavity. Common diameters are $1^1/_2$ inch, 2 inches, and $2^1/_2$ inches. Some technicians flatten the tube slightly into an oval because flattened tubes fit into narrow cavities easily. In this case, the technician knows which way the tip of the flattened tube is pointing to avoid snagging existing insulation because one flattened side of the curved tube or the other is laying against the sheeting.

Use rigid fill tubes for filling roofs and floors from the side or end of the home. Metal conduit, copper drain pipe, steel muffler pipe, or polyvinyl chloride (PVC) pipe all work well. Technicians prefer 2-inch and, sometimes, $2^1/_2$-inch diameters for the rigid fill-tube.

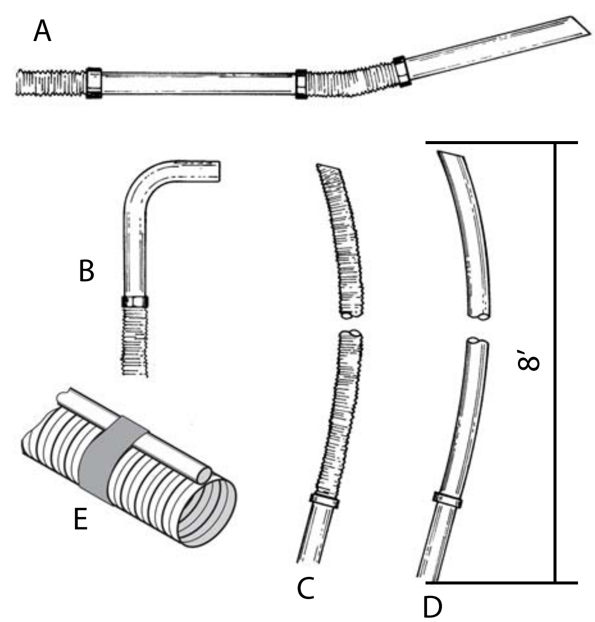
Insulation Blowing Safety

Blowing insulation creates dust that irritates the lungs, eyes, and skin. Always wear a respirator when you blow insulation. Protect your skin with gloves and coveralls. And, shield your eyes with goggles.

Static electricity sometimes builds up in fill-tubes and shocks technicians. Fill-tubes made of lightweight electrical conduit, muffler pipe, and copper drain pipe are more static-free than PVC. Fill-tubes made of PVC plastic pipe are most likely to shock.

Clamping a piece of bare copper wire to a metal connector between the hose and the PVC tube and dragging the wire on the ground discharges the static electricity. Spraying small amounts of water into the hopper of the blowing machine also reduces static electricity.

Figure 6-5 Fill Tubes for Blowing Insulation



A. Long 1 1/2" to 2" rigid pipe used for floor and roof insulation; B. 1 1/2" to 2" muffler pipe fitting for blowing through ceilings, roofs, and bellies; C. Wall insulation fill tube made of flexible spa tubing; D. Wall insulation fill tube using flexible heavy-duty agricultural tubing; E. PVC water pipe is taped to the blower hose to stiffen the last 4' to 8' of hose.

Chapter 7 Floors

This chapter discusses floor construction, floor damage, and floor energy problems. Specific techniques detail how to reduce heat flow through the floor by insulating, air-sealing, and making associated repairs. These improvements will save energy costs, improve comfort, and extend the useful life of a manufactured home.

Floor Design and Construction

The floor system of a manufactured home is like a sandwich. On the bottom is the underbelly. On the top, is a single layer of particle board flooring. Inside the floor's sandwich is the floor cavity with the floor joists, insulation, and ducts.

The floor's 2-by-6 floor joists (2-by-4s on some very old models) are spaced at 16 inches, 18 inches, or 24 inches on center and supported underneath by the metal chassis. Floor joists either run lengthwise along the home's length or crosswise across the width of the home. The floor joists are fastened to the steel chassis with lag screws.

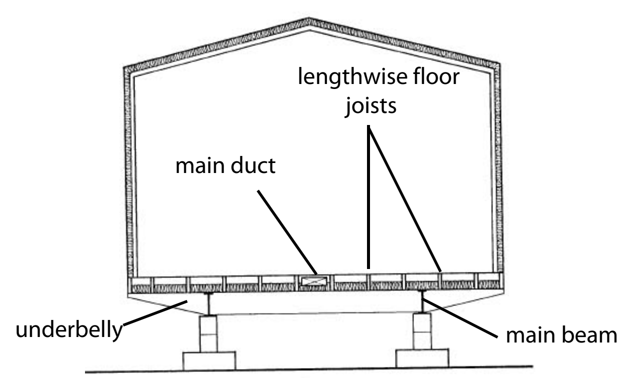
Floors with crosswise joists have underbellies that are dropped 4-to-10 inches below the bottom of the floor joists in the center of the home's width. The insulation and underbelly attach to the floor at its edges and sag in the middle to enclose the duct within the heated shell of the home.

Floors with lengthwise floor joists have ducts that lie up against the flooring and between the floor joists. These homes have insulation and underbellies flatly attached to the bottom of floor joists.

In older mobile homes, large blankets of fiberglass insulation are usually fastened to the bottom of the floor joists. Many newer homes have the fiberglass batt insulation installed between the floor joists—a better insulation practice.

The underbelly is flexible or rigid sheeting protecting the floor's underside from dirt and water in transit and from rodents and other pests once the home is sited. Older mobile homes have underbellies of asphalt-impregnated fiberboard or heavy tar paper. Newer homes use an asphalt-impregnated fiberglass cloth or fiber-reinforced polyethylene. You can often buy these mate rials at mobile-home suppliers.

Figure 7-1 Lengthwise Floor Joists

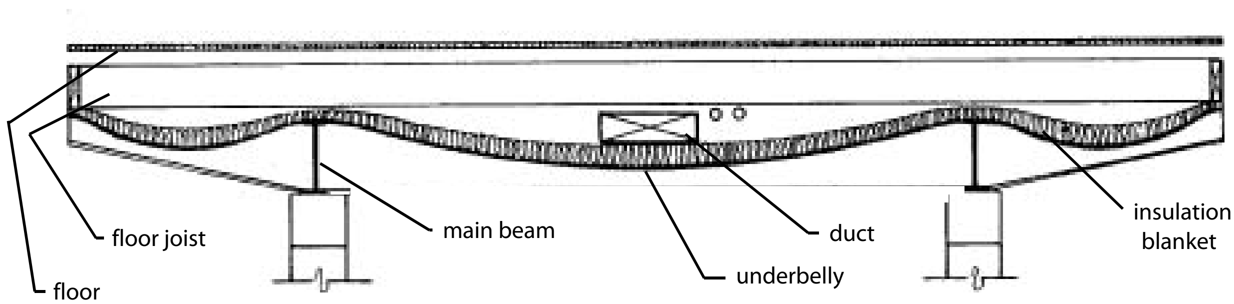


The underbelly is level and the main duct is up against the flooring in mobile homes with lengthwise joists.

Inspecting Floors

Inspecting the entire area underneath the home will help you decide what repair and weatherization projects might be needed. Look for the following conditions when you inspect the floor:

Figure 7-2 Crosswise Floor Joists



In a manufactured home with crosswise joists, the underbelly drops down in the center to provide room for the duct and an insulating blanket installed below the duct.

- The floor should feel solid, with no soft spots, when you walk around on it. Persistent wetness can make an area of the flooring soft and mushy-feeling due to soggy particle board. Repair water-damaged and weak areas.
- The underbelly should be nearly airtight. Seal holes, cracks, and plumbing and wiring penetrations through the floor and underbelly, using the methods described below.
- A plastic ground-moisture barrier should cover the ground underneath the entire home to protect it from moisture.
- The heating supply duct should be enclosed within the homes insulated shell. If not contained inside the insulation, the duct should be insulated to R-4.
- In cold climates, drain pipes and supply pipes should be protected from freezing by being enclosed within the insulated floor cavity, or being insulated.
- Skirting should protect the underbelly from damage by excluding plants, animals, and insects.

Repairing Floors

The floor is a key structural part of a manufactured home. If you repair flaws in the floor, the home will last longer and give its occupants better service.

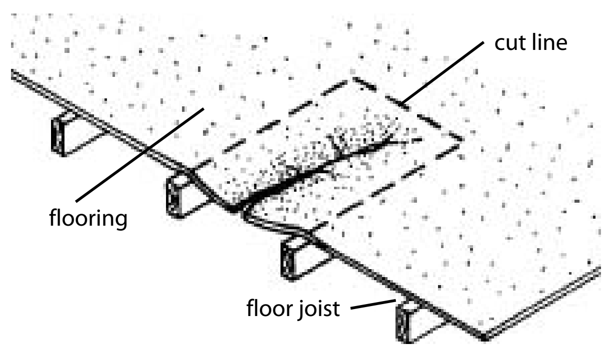
Underbelly Repairs

The underbelly can be damaged by transportation, plumbing repairs, moisture, animals, and other causes. There are a variety of effective methods to patch the underbelly.

Keep in mind that the underbelly material is wedged between the metal chassis and the wood floor, making it a little tricky to patch. You can't always fasten a patch to a floor joist, because the metal frame under the floor may obstruct you.

Paper and fabric underbellies are the easiest to patch using a combination of adhesives and mechanical fasteners. Staple patches into the floor joists whenever possible. When there is no wood backing for the patch, use construction adhesive to adhere fabric or paper patches to the existing underbelly. Many technicians use adhesive along with outward clinching staplers (also called stitch staplers) that stitch paper to paper. Large fabric patches may be stapled into available floor joists and reinforced underneath with wood lath, so that the process of blowing insulation doesn't loosen the patches.

Figure 7-3 Floor Patch



Cut damaged sections of flooring out between joists where you can re-attach a plywood patch.

Solid fiberboard underbellies can be patched using a variety of materials including plywood, paneling, reinforced polyethylene, and rigid insulation. Use floor joists for backing if you can. If there isn't a floor joist nearby, use this technique.

Step 1: Cut a rectangular hole removing the damaged fiberboard. Insert one or more wood or plywood backer boards.

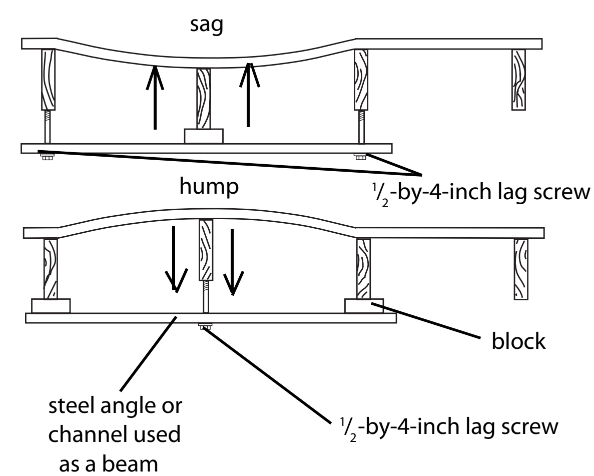
Step 2: Drive screws through the fiberboard into the backer with a reversible drill/driver. With your free hand, pull the backer board down, so the screws penetrate and hold.

Step 3: Cut fiberboard, plywood, or other suitable material to fill the hole. Subtract at least $^{1}/_{8}$-inch each way so the patch will fit.

Step 4: Fasten the patch into the backer board with screws and caulk the seams.

Power staplers are a good alternative and they make this repair job easy.

Figure 7-4 Repairing Humps and Sags in Floors



Illustrates how to level floors if the floor joists are bowed, causing the floor to hump or sag. Hydraulic jacks can also help by pushing on low floor joists.

Floor Repairs

Damaged areas in the particle board flooring can be repaired using plywood or particle board—preferably plywood because it's stronger and more waterproof. To repair the hole, first locate the centers of two floor joists at or beyond the borders of the damaged area. Cut out a rectangular piece of the floor including its damaged area. Remove the nails or staples along the joist's line where you'll be cutting. To avoid damaging the floor joist, set your circular saw blade to a depth of $^{5}/_{8}$-to-$^{7}/_{8}$ inch, depending on the thickness of the existing floor.

Figure 7-5 Underbelly Patch

A technician puts caulking around the perimeter of a patch. The patch is made of an air leakage barrier which is permeable to water vapor.

Cut out a rectangular piece of the floor including its damaged area. Patch the hole with plywood or particle board of the same thickness. Cut the patch about $^1/_4$-inch short in both length and width to allow for its fit and expansion. Fasten the new patch to the joists with flathead screws, countersunk to make the screw heads even with the floor.

Some technicians use an alternate method of cutting the flooring on the edge of the joist and attach a 2-by-4 wood nailer to the side of each floor joist to support the patch.

Squeaky floors can usually be fixed by driving flathead screws into the squeaky area. Sometimes, a small wedge inserted from underneath between the floor joist and the particle board floor is needed to stop the squeak.

Humps and sagging areas in the floor are sometimes caused by floor joists that hump or sag. The joists can be repaired using a 4-by-4 wood beam or a steel beam. Lag screws provide the force to pull the floor joists into the level plane established by this beam. A small hydraulic jack can provide lift for the sagging floor joists.

If a bent chassis is pushing the floor up, the bent section may need to be cut off and the floor re-supported from piers, footings, and beams underneath. If a bent chassis is causing the floor to sag slightly, wedges between the frame and underside of the floor joists will re-support the joists.

If the repaired floor section seems weak, add another footing and pier underneath that section for additional support.

Figure 7-6 Outward Clinch Stapler

This stapler, sometimes called a stitch stapler, fastens paper and fabric underbelly to patches made of a similar flexible material.

Improving Energy-Efficiency of Floors

Floors are an important source of heat loss in cool climates, due to their relatively low R-value. The low R-value is such a big problem in warm climates.

Floors are also a major source of air leakage—an energy problem in both cool and warm climates. Air flow between indoors and the crawl space wastes energy, reduces the insulation's effectiveness, and can cause condensation in the floor. In addition to floor's air leakage, the main duct—usually housed in the floor assembly—is often a source of severe air leakage.

There are 5 main energy problems related to mobile home floor assemblies:

1. Inadequate floor insulation (3 inches or less, attached to the bottom of floor joists, is common);
2. Air leakage into the home caused by holes in the underbelly and floor;
3. Movement of outdoor air around and through the insulation, decreasing the insulation's R-value;
4. Space between flooring and insulation, allows heat loss by convecting air moving around the insulation; and
5. Leaks in the heating/cooling ducts and in floor cavities used as return plenums. These leaks can cause: 1. Heated or cooled air to escape the heating or cooling system, or 2. Outdoor air to enter the heating or cooling system.

Floor insulation and the associated repairs to the underbelly can effectively solve the first four problems. The fifth problem is addressed in this book's *Chapter 11 Heating*, and *Chapter 12 Cooling Systems*.

Preparing the Floor for Insulation

Before beginning to install insulation into the floor cavity, follow the five preparatory steps listed below.

Step 1: From above, tightly seal all openings in the floor to prevent loose insulation from entering the living space.

Step 2: Inspect and seal the ducts thoroughly, to prevent blown insulation from entering the ducts. (*See "Leaky Supply Ducts" on page 151.*)

Step 3: Install a plastic, ground-moisture barrier to protect the new insulation from moisture damage.

Step 4: Repair the underbelly as necessary using the techniques described earlier this chapter. Consider blowing insulation through damaged sections of the underbelly before you patch any holes. Using a flexible fill tube, you may be able to fill several cavities through one large tear in the belly.

Step 5: Water supply pipes, separated from the warmth of the home by new insulation, could freeze in very cold climates. Locate the plumbing supply pipes from underneath and note their locations. Check the pipes for leaks. Repair any leaks before adding insulation. If these pipes are installed close to the floor or next to the heating duct, they won't need added protection. But if the pipes are below the floor joists and away from the heating duct, find a way to strap them up closer to the floor. An alternative is to insulate underneath the pipes with rigid foam or a fiberglass batt with a facing to facilitate fastening.

Step 6: In floors with crosswise joists and a dropped underbelly, you can push the dropped belly up and brace it. This will reduce the volume of insulation that the floor cavity will consume. The floor doesn't need insulation two feet thick. With dropped fabric underbellies, you can pin the fabric up to the floor joists with wood strips. If you use this procedure, be extremely careful not to damage the duct. Leave a 2-to-3-inch space between the underbelly and pipes and ducts to avoid freezing pipes or damaging ducts.

Figure 7-7 Blowing Floors from Underneath

The advantage of blowing the floor from underneath is that you can use a large flexible fill tube (2 inch diameter) for rapid insulation flow.

Insulating Floors

Installing additional floor insulation saves up to 10% of the mobile home's annual heating cost. Blowing fiberglass insulation is the easiest and fastest way to insulate the floor cavity.

The crawl space area underneath the mobile home is the best access point for insulation. Installing the ground moisture barrier before starting to insulate makes the lying on the ground more comfortable. (*See "Installing Ground-Moisture barriers" on page 43.*)

To install insulation safely, wear a respirator, safety glasses, and coveralls.

The most effective insulating materials for floor cavities include un-faced fiberglass batts, rigid foam insulation, blown fiberglass, and polystyrene beads.

Floors vary in construction, accessibility, and state of repair. Because of this variation, use more than one insulation technique if necessary.

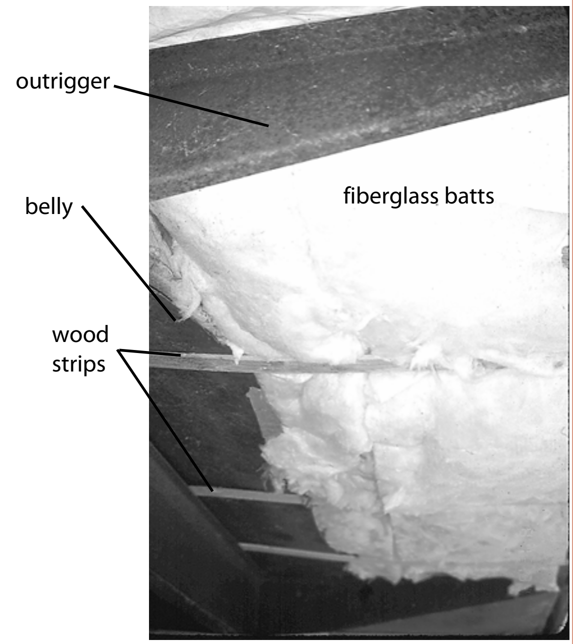
Damaged or Missing Underbelly — When large sections of the underbelly are damaged or missing, you can stuff fiberglass batts into the floor cavity. Install the fiberglass batts directly against the underside of the floor to prevent air from convecting between the floor and the new insulation.

Using batts designed for a thicker cavity and compressing them gives a slightly higher R-value per inch and inhibits air convection.

Use lightweight wood strips to hold the batts up to the floor; these strips serve as backers for stapling large fabric or polyethylene patches needed to repair the underbelly.

Sheeting Over the Underbelly — Sheeting over the underbelly with insulation is also a good option, either by itself or combined with stuffing fiberglass batts into the floor cavity. Installing insulation under sections of the floor with ducts or piping is a good option when you won't be blowing insulation into those areas

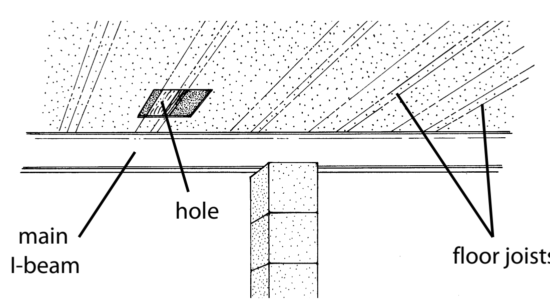
Figure 7-8 Stuffing Fiberglass Batts



Fiberglass batts are stuffed into a floor cavity where the belly had been torn away and the insulation removed. Wood strips hold the batts up and act as a backer for staples, holding a building-paper patch, to be applied next.

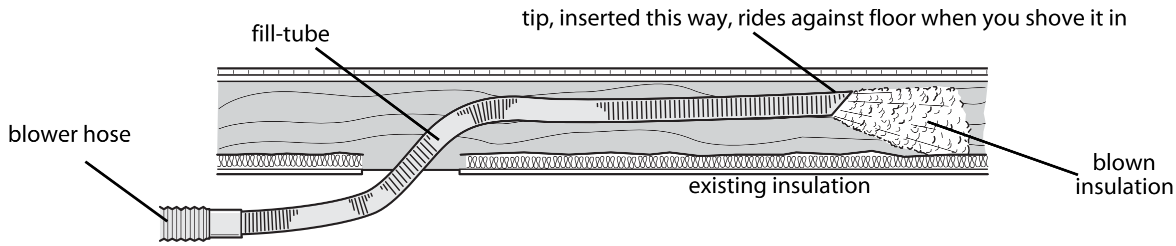
The insulation used for sheeting over the underbelly should have a strong foil, paper, or vinyl facing. Use $^{1}/_{4}$-inch foam board (called Foamcore), thicker rigid foam board, fiberglass batts, or fiberglass blankets. Fasten the insulation using screws or nails with large washers to prevent the fastener from tearing through the soft insulation material.

Figure 7-9 Cutting a Hole at a Floor Joist



A hole directly beneath a floor joist gives the technician access to two joist spaces for blowing insulation.

Figure 7-10 Flexible Fill-tube



Flexible fill-tubes blow insulation quickly into the floor cavity. The technician works from underneath the floor in the crawl space.

Blowing Insulation into the Floor Cavity —

Following are four practical options for blowing insulation into floor cavities. Before you begin, observe the floor's construction characteristics and the condition of the underbelly. Locate the main duct and plan your fill holes and fill-tube insertions to avoid damaging the main duct.

Remember: You can blow insulation into nearby areas through existing holes and tears in the underbelly before you patch them.

During the insulation process, inspect any areas where you doubt insulation has filled. Cut the underbelly for inspection to make sure that insulation fills the cavity.

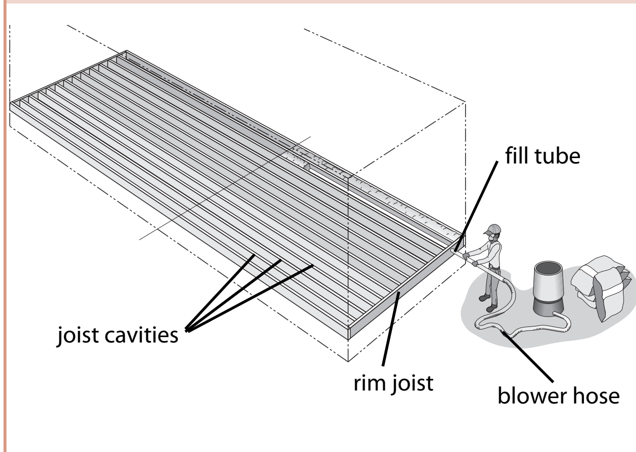
You can add insulation to almost any floor using one or more of these methods:

Option 1: Flexible fill-tube through underbelly for crosswise floor joists: For joists running the width of the home, cut a hole or slit near the center of the width of the underbelly. Insert a flexible fill tube through the underbelly over top of the I-beam and towards the rim joist. Insert the fill tube so that its curvature causes the tip to ride against the floor's smooth underside as it goes in. This avoids snagging existing insulation. Fill the cavity from the floor's edge towards the hole at its center; then insert the tube in the other direction and repeat the procedure. Try to fill the entire cavity without allowing any voids.

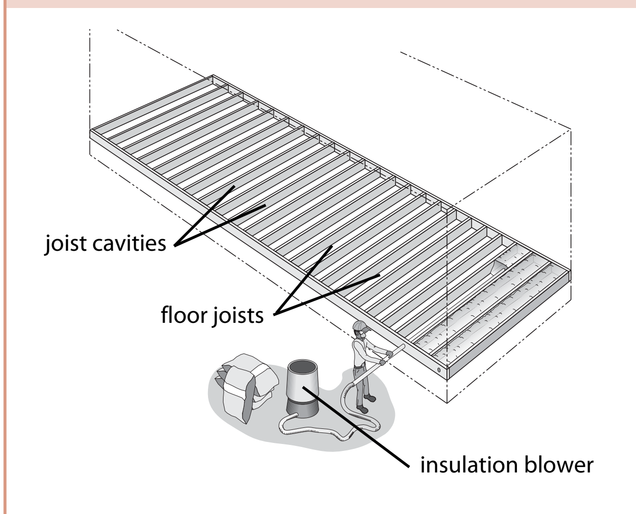
Option 2: Flexible fill-tube through underbelly for lengthwise floor joists: Starting 8 feet from one end (assuming your fill tube is 8 feet long), cut a row of holes or slits into each joist cavity through the underbelly across the width of the belly. Or, cutting larger holes (10-by-10 inches) directly under alternating floor joists results in half as many holes to patch, because each hole gives access to two cavities. Insert the fill tube so that its curvature causes the tip to ride against the floor's underside as it goes in. This avoids snagging the existing insulation. Fill the cavity first blowing in one direction, then the other. Cut the next row of holes 16 feet away or twice the length of the fill-tube.

Option 3: Rigid fill-tube through rim joist: Loosen or remove the metal trim piece at the bottom of the wall on the ends or sides of the home. Drill a hole 2-to-$2^3/_4$ inches in diameter through the rim joist into each joist cavity. Attach a long plastic or metal tube to the end of the blowing hose and insert it into the cavity extending to the opposite rim joist. This method is favored by many technicians who prefer to avoid climbing underneath the home. A disadvantage of this method is that these holes may weaken the rim joist excessively—a problem if the home is ever moved. To prevent excessively weakening

Figure 7-11 Blowing Floor-Joist Cavities



Lengthwise - The technician uses a 20-to-30-foot rigid fill-tube to fill cavities between lengthwise joists from holes in the rim joist.

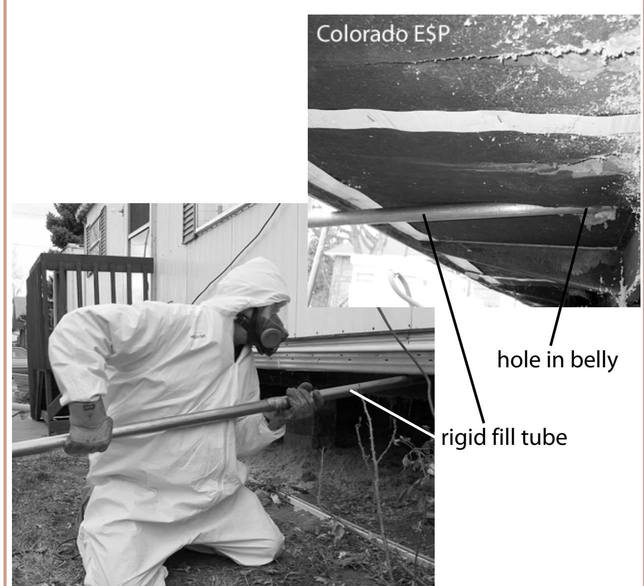


Crosswise - Technician uses a 16-foot rigid fill-tube to insulate joist cavities of crosswise floor joists.

one rim joist, drill holes into adjacent cavities from opposite sides of the home. Avoid locating holes below the sides of large windows and doors. You can add extra piers and footings under the rim joist for added support after drilling. Drilling rim joists on homes with lengthwise joist cavities isn't a structural problem. However, you may not be able to blow half of the home's length from each end. In this case, finish the job by blowing through the underbelly as described above or below.

Option 4: Insert a metal pipe into the floor through a hole in the edge of the belly. The pipe should be bent into a very gentle arc. If the tube is bent right, you can often fill the whole joist cavity from one side of the home without crawling underneath and without drilling a hole in the rim joist. This method is often the best option. Copper drain pipe $1^1/_2$ inches in diameter is a good choice for the rigid fill tube, used to blow the insulation.

Figure 7-12 Blowing Floor Insulation



Blowing the floor through the edge is often the easiest and least destructive.

Chapter 8 Walls

This chapter discusses how to repair walls and how to reduce heat flows through the home's exterior walls. The wall improvements discussed in this chapter will help you reduce energy costs, increase comfort, and protect the home from moisture and high winds.

Design and Construction

Most walls in homes built after 1976 are built with 2-by-4 ***studs*** (vertical framing boards) that measure $1^1/_2$ inch in width and $3^1/_2$ inches in depth. Other common types of wall studs include:

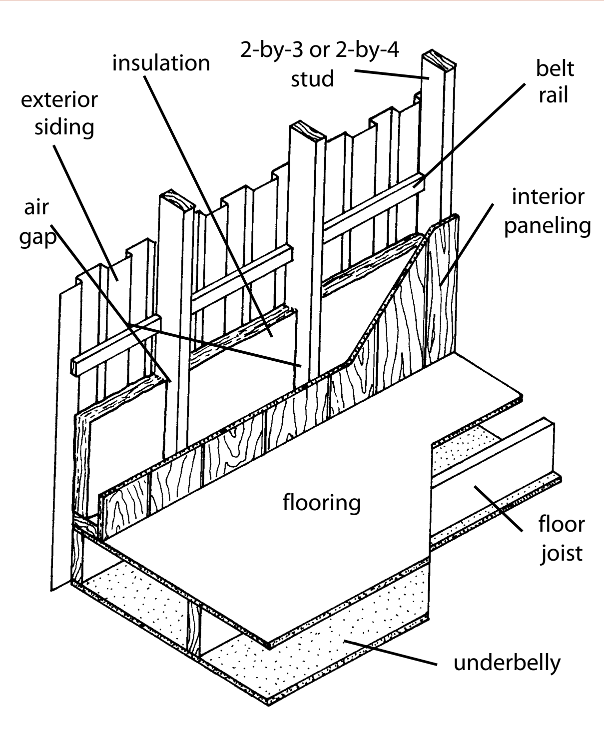
1. Very old mobile homes that have 2-by-2 studs (which measure $1^1/_2$ inches by $1^1/_2$ inches).
2. Many moderately old mobile homes that have 2-by-3 studs (which measure $1^1/_2$ inches by $2^1/_2$ inches); and
3. Some newer mobile homes—particularly those in cold climates—that have 2-by-6 studs (which measure $1^1/_2$ inches by $5^1/_2$ inches). In addition to the studs, walls also contain interior sheeting, vapor barriers, and exterior siding.

The HUD Code looked establishes three specific wall types for manufactured homes: 1. ***Vapor-barrier walls***; 2. ***Pressure-envelope walls***; and 3. ***Ventilated walls***. Vapor-barrier walls have a vapor barrier of plastic under the interior paneling. Pressure-envelope walls have some type of air barrier on the exterior. And ventilated walls have corrugated metal siding that isn't airtight, letting air ventilate the wall to remove accumulated moisture.

Many walls have ***belt rails*** of $^3/_4$-inch-thick lumber applied horizontally across the studs to provide a nailing strip for the siding. The belt rails are either fastened on outside of the stud or laid into rectangular slots cut in the edge of studs. The framing lumber is usually not doubled-up around windows and doors as in site-built homes.

The top and bottom plates of most walls are a single 1-by-3 or 1-by-4 ($^3/_4$-inch-thick lumber). The siding is usually attached directly to studs or belt rails, without structural sheathing. Regardless of the stud sizes used, many mobile home wall cavities are only partially insulated, as described in detail below.

Figure 8-1 2-by-3 or 2-by-4 Wall Section



This type of partially insulated wall is a good candidate for wall insulation in cold and temperate climates.

Inspecting Walls

Many mobile homes have only 1-or-2 inches of fiberglass insulation inside the wall cavity or their insulation has settled, due to vibration in transit. A good indication of settled or missing insulation is when a particular wall section is colder than other wall sections during winter. This un-insulated wall section may feel colder to the touch or be more likely to show water condensation or frost during very cold weather.

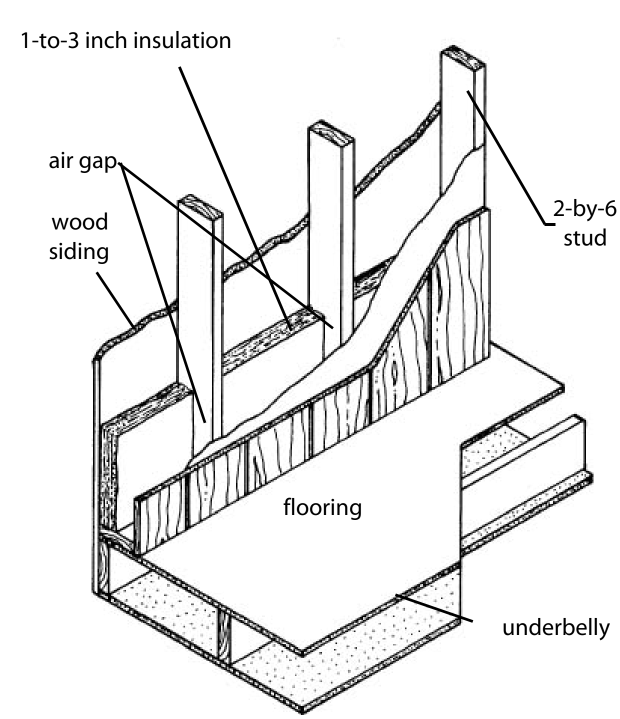
Don't assume that the thickness of the wall insulation is the same as the wall cavity's thickness. A 2-by-4 cavity may only have 2 inches of insulation, and a 2-by-6 wall cavity may only have 2-or-3 inches of insulation.

Inspecting a wall cavity is usually easy, taking only a few minutes. Use a tape measure and flashlight, if necessary, to measure the thickness of the insulation and the depth of wall cavity. The goal is to compare the thickness of the insulation with the thickness of the wall cavity and to notice moisture and structural problems. The minimum size of inspection hole is 2-by-3-inch rectangle or a 4-inch-diameter circle, to allow your hand into the wall cavity. If you suspect that insulation may vary in different parts of the home, inspect several walls.

Try seeing into the wall first from the water heater closet or indoors. If you want a better look, partially or completely remove some interior or exterior siding. Siding removal gives a better picture of insulation, moisture problems, and structural problems inside the wall.

First, look in the water heater closet which may be partially unfinished. You may be able to see into the exterior wall there. If not, look indoors for a hole in an exterior wall. Or, find an electric outlet or switch and remove the cover. If the electrical box is surface mounted with screws, remove it and examine the insulation behind it. Or, cut a 4-inch hole through an exterior wall's interior paneling—in a closet or cabinet where it won't be seen. You can readily patch this hole after inspection.

Figure 8-2 2-by-6 Wall Section



Sometimes 2-by-6 walls in manufactured homes are only partially filled with insulation.

Wall Moisture Problems

Don't consider insulating a wet wall cavity until you've solved the moisture problem that made it wet. Check the exterior closely for areas where rain water can penetrate. It doesn't take a very big hole or crack especially on homes without eaves. Insulating a rain-soaked wall just provides more material to soak up water.

Condensation in walls is also a common problem in mobile homes. Water condenses on the cool exterior siding in winter and on the cool interior sheeting in summer (if the home is air conditioned). The condensed water drains to the bottom of the cavity where water damage is often observed. Under windows, condensed water running off the glass leaks into the walls damaging framing below the window.

While there is the slight possibility that wall insulation could aggravate existing moisture problems by reducing the flow of dry air through a ventilated wall cavity, it is far more likely that wall insulation will reduce moisture problems. By completely filling the cavity, insulation stops most of the air convection within the wall cavity, along with much of the air leakage into the cavity from indoors and outdoors. Stopping convection and infiltration reduces the mixing of warm moist air with cool dry air within the cavity and the condensation that can result from that mixing. If the new insulation lays evenly against the interior paneling and exterior siding, it inhibits condensation by restricting moist air's movement against these potentially cold surfaces. Moisture will still move into and out of the wall after adding insulation, but at a slower rate.

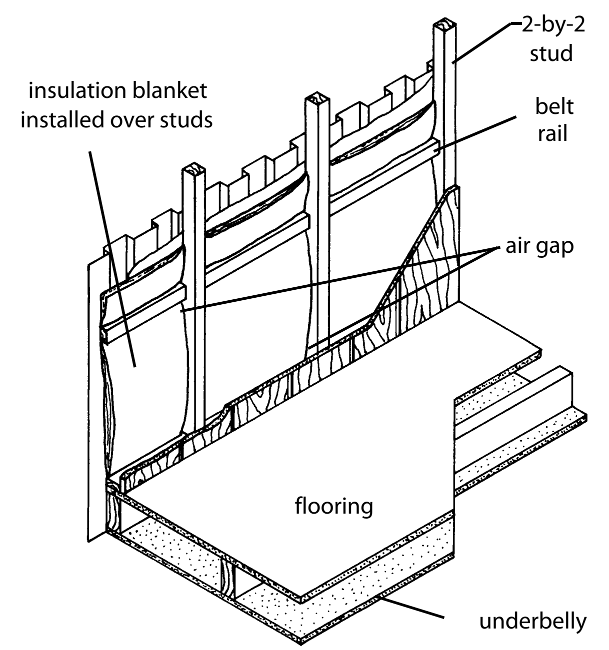
Some pressure-envelope walls actually have a vapor barrier directly underneath the wall's exterior siding—not a good place for a vapor barrier except in hot, humid climates. These walls are the most likely to have moisture problems. Other pressure-envelope walls have Foamcore™ sheeting ($^{1}/_{4}$-inch polystyrene foam). Both varieties of pressure-envelope wall may show moisture damage at the wall cavity's bottom. During a re-insulation project, the insulators break the vapor barrier or Foamcore's seal at the wall's bottom. This may allow any water which gathers there in the future a path to drain out.

Follow these recommendations to avoid causing or aggravating moisture problems when you insulate your walls:

1. Before you insulate, identify existing moisture problems and their causes. Condensation from indoors and rain leakage from outdoors are the most common problems. Suggestions in this chapter will help you solve these problems. Condensation is caused by excess humidity which can be reduced by controlling sources of water vapor, ventilating the home with outdoor air, or using an electric dehumidifier. These topics are covered in *Chapter 5* ***Air Leakage***.
2. Avoid sealing a metal-sided mobile homes' exterior siding at horizontal joints at the wall's bottom. When left unsealed, these bottom joints allow water to escape. Seal only horizontal joints that might leak rain—such as joints around windows and doors, or joints at the roof edge that face the weather.

Before installing new siding, understand and solve your existing moisture problems or the new siding could make these problems worse.

Figure 8-3 2-by-2 Wall Section



This older type of wall is a good candidate for wall insulation in cold and temperate climates; however installation can be a tight squeeze.

Wall Structural Problems

Walls in mobile homes often lack the strength to resist very high winds. The walls sometimes separate from the floor or roof in hurricanes. Most manufactured-home walls don't have structural sheathing on their exterior under the siding. And, siding often blows off due to insufficient fastening.

Residents living in high-wind regions may want to retrofit walls to be more resistant to high winds. Consider the following options for improving wall structure.

Option 1: Remove windows, doors, metal siding and improve insulation as detailed on *page 99*, Also remove siding starter strips on top and bottom. Install insulation to completely fill wall cavities. Fasten $^3/_8$-inch OSB sheathing to rim joist, studs, plates and the roof's fascia board 6d galvanized nails spaced 4-inches apart. The sheathing should bond the rim joist to the wall to the roof edge. The bond at the roof edge is very important should be made with galvanized-steel screws and a layer of construction adhesive that covers the entire fascia board. Finally re-install metal siding, windows, and doors.

Option 2: Remove windows, doors, and siding, then insulate as in option 1. Discard or recycle siding and re-side with 4-by-8 sheets of vertically grooved hardboard siding. Siding should be nailed with 6d galvanized nails spaced 4-inches apart. The siding should bond floor to wall to roof. The bottom and top edges of each 4-by-8 sheet should be primed and painted. Protect the siding's top edge with a new custom-bent, galvanized-steel roof edge. Screw this heavy-duty roof edge to every truss on top with pan-head sheet-metal screws

Option 3: Remove interior paneling and drive screws through diagonal countersunk holes in the stud's bottom through the bottom plate, and into the flooring. Also drive screws down through the edge of the bottom plate, through the flooring and into the rim joist. Drill and screw through the top plate, through the ceiling material above the top plate and into the trusses, two screws per truss. Fill all voids in the wall with insulation. Then glue and screw the paneling back on. Only remove 4 sheets on paneling at a time because it is structural support in many homes. As a option, screw and glue $^3/_8$-inch sheetrock to the paneling for added strength and a now, smooth interior finish.

These measures alone will not guarantee that your home is safe during a hurricane. The home must be anchored securely to the ground. (*See "Anchors and Tie-Downs" on page 35.*)

Wall Energy Problems

Many manufactured homes have wall insulation filling all the wall cavities without many major flaws in installation.

However, many other homes have only 1-to-3 inches of fiberglass insulation installed inside wall cavities that are deeper than the insulation's thickness. Reasons for inadequate insulation may vary. The original HUD Code didn't require much insulation. Wall insulation sometimes settles down several inches during transit. Very old mobile homes have insulation installed over the outside of the wall studs—leaving the cavity between the studs empty.

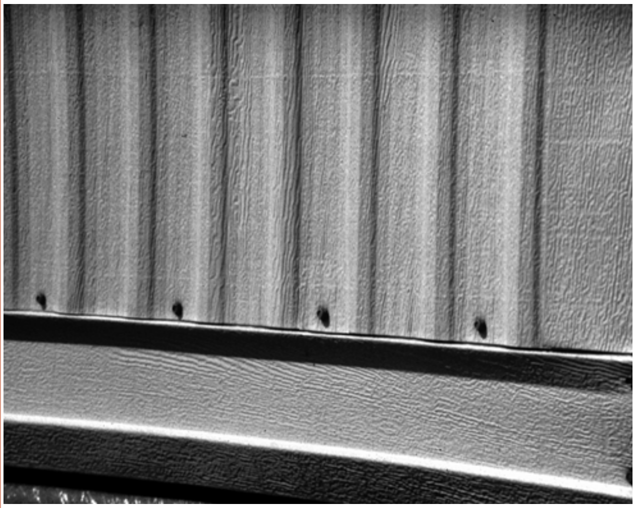
Wall cavities can act like chimneys, only air moves both up and down. Air movement within walls can carry heat around wall insulation, reducing the wall insulation's R-value.

Laboratory tests of wall cavities with voids and air channels adjacent to the insulation, show that the actual R-value is 15% to 45% less than predicted. Therefore, the home's occupants don't receive the benefit of the insulation's predicted R-value when wall cavities are only partially filled.

Partially filled cavities are good candidates for added wall insulation in cold climates. Re-insulating walls in warm climates is less cost effective.

Installing new siding is *not* an energy-saving measure. Be sure to re-insulate partially filled walls with batts or blown-in insulation before installing siding—there will never be a better time.

Figure 8-4 Vertical Corrugated Siding



This ventilated wall system was designed to ventilate the wall through bottom of corrugations. The ventilation wasn't too effective at preventing moisture condensation. However, water that condenses on the interior of the siding can flow out through these corrugations. There is usually no structural sheathing underneath this siding.

Wall Repair and Renovation

If wall framing or siding has been damaged (by moisture, a collision in transit, on-site accident, etc.), remove and replace the damaged sections.

Since a mobile home is designed to be lightweight, every piece is important to its structure. New pieces of the framework should be the exact same size as the damaged pieces you remove.

Make sure that replacement framing lumber is fairly straight, so it won't create bulges in the wall.

Fastening the framing pieces to existing framing is the key to wall frame repair. Construction adhesive and all-purpose screws work better than nails, because nails can easily split the wood reducing its strength. Drilling holes in lumber before driving the screws prevents splitting.

Interior paneling and indoor trim should be re-nailed to studs if loose. Construction adhesive can help to permanently fasten paneling and trim. When re-nailing paneling and trim, don't use the existing nail holes—the nails will come loose again. Hide nail holes with colored putty, available at most lumber and hardware stores.

If you remove interior paneling to remodel or insulate, remember that the paneling is very important to the structural strength of the wall. Remove only a few sheets of paneling at a time. Replace them as soon as possible, and before removing other sheets of paneling.

Just a reminder: Completely residing the home is primarily to improve the home's appearance. Don't expect dramatic energy savings unless you add insulation, as described in this chapter.

Siding Repair and Replacement

This section gives general information about siding materials and installation. Most manufactured homes have metal, vinyl, or wood composition siding. Deciding whether to repair or replace siding is a common choice facing homeowners. Most manufactured-home siding is either installed vertically as rectangular sheets or horizontally as long strips.

If your siding is damaged or faded, you can repair it, replace just the damaged sections, or replace all the siding. The best choice depends on your budget, materials availability, and how you want your home to look.

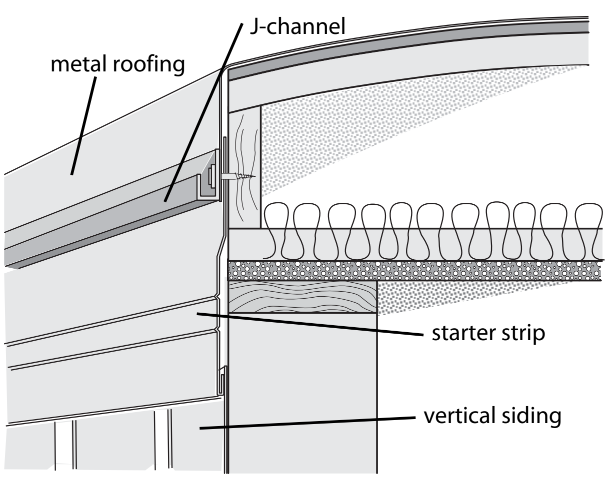
If you live in an area where a hurricane may strike, think seriously about removing your old siding and installing structural sheathing or hardboard siding as discussed in *"Wall Structural Problems" on page 91*.

You can only see two sides of a house at a time. Think what vantage points people can view your home. You may be able to salvage siding from one side of a home to use on another, then re-side just part of the home. Be sure to make appropriate improvements to insulation during your siding repair or replacement project.

If you're considering residing your home:

1. Do not count on new vinyl or metal siding with a thin insulation backing to save much energy;
2. Do not assume that your walls are completely filled with insulation;
3. Plan to inspect your wall insulation and to re-insulate when you reside if necessary;
4. Inspect the cavity carefully and blow in more insulation, if there's room; and
5. If you live in a cold climate and your home has a roof overhang, consider adding 1 inch of foam insulation under the new siding, in addition to retrofit wall-cavity insulation.
6. If you live in a hurricane zone, consider taking steps to improve the bonding between the wall and the floor and roof. Consider installing plywood siding or sheathing underneath metal or vinyl siding to strengthen the walls.

Figure 8-5 Siding Details at Roof Edge



Vertical metal siding terminates underneath a starter strip at the top of the wall that sits underneath the roofing and j-channel.

Metal **—** Metal siding is the most common siding used on older homes. Of the metal sidings, aluminum is more common than steel. To tell them apart, use a magnet. Metal siding is the most waterproof and rot-proof type of siding, although aluminum is easily dented by hail and other forces.

Most metal siding is corrugated sheets, installed vertically. There are a variety of colors and styles used by home manufacturers. These colors and styles are difficult and sometimes impossible to match. Be creative in planning repairs or partial replacement. Corrugated aluminum siding is only available in a few common colors and patterns.

Metal vertical siding is fastened to belt rails, which are either notched into the vertical studs or attached to their outer surface. The siding usually sits on top of a metal starter strip on the bottom and underneath another starter strip at the top. Doors and windows are installed over top of the siding, so you'll have to pull them out before removing the siding.

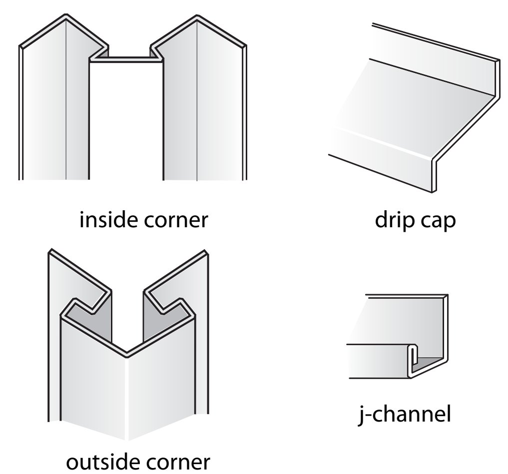
Older mobile homes have vertical sheets of metal siding. Metal lap siding is also found on some newer homes. Metal lap siding has roughly the same accessories and installation procedures as vinyl lap siding, described next.

Vinyl **—** Vinyl siding is lightweight, durable, and inexpensive. Vinyl is sold as lap siding and installed horizontally. Specially designed vinyl or metal corner and trim pieces, installed before the siding itself, give the installation a finished appearance. The bottom of one siding panel locks to the top of another; only the panel's slotted top is nailed. Panels are nailed in the center of slotted holes with nailheads protruding slightly to allow for vinyl's expansion and contraction with temperature change. Windows and doors don't usually need to be removed to repair or replace vinyl siding.

Fading and cracking can be a problem, especially in sunny climates with extreme hot and cold temperatures. Vinyl siding, made brittle by weather, may chip and break in hailstorms. Avoid using dark-colored siding because it soaks up more solar energy and is therefore less durable. Vinyl can't be easily patched or repainted so you have to replace pieces. You can cut a straight line across a damage piece with a utility knife, to replace only that damaged section.

Replacing a damaged piece of vinyl siding requires unhooking the piece from the piece above it and below it, using a zip tool. (You can buy a zip tool from your local siding distributor.) Then pull the nails in the top of that piece and remove it. Install the new piece, remembering not to drive the nails completely flush.

Figure 8-6 Vinyl Siding Trim



Vinyl siding is trimmed by vinyl or metal trim. Drip cap installs above windows and doors and j-channel installs on sides and bottoms of wall openings.

Wood Composite **—** Wood composite siding is installed vertically in 4-by-8-foot sheets like plywood. Wood composite siding is initially strong and gives the wall good structural strength if it is nailed into the rim joist. However, wood composite siding is the least durable type of siding because it is porous to moisture. Wood composite siding failure has generated many consumer complaints. Manufacturers have responded by improving the weatherability of their products.

Water-damaged sections should be repaired before installing new siding. If the water damage is confined to a strip at the bottom, you can cut a straight horizontal line with a power saw around the home just above the damaged areas. Remove the damaged siding. While this continuous gap in the bottom of the wall cavity is open, you can stuff or blow more insulation into the cavity. Then, replace the siding with more moisture-resistant material (plywood or fiberboard treated on all sides and edges with a sealer and paint; vinyl siding; or metal siding). To allow the wall to shed water, install metal or plastic flashing at the joint between existing siding and new siding. This flashing should go under the existing siding and over the new siding.

Wall Air Barriers

Air barriers stop air from moving between indoors and outdoors through the building shell. When they're new, manufactured homes have fairly effective air barriers compared to site-built homes, many of which don't have an effective air barrier. Air barriers stop energy-wasting air leakage which also carries water vapor into building cavities where the water can condense.

It's important to stop the air, because the warm, moist air from the home can carry moisture rapidly from a source into the building cavities. Sealing all penetrations in the interior membrane of the home creates an air barrier. This air-sealing would include: installing gaskets on all outlets and switches; sealing window and door frames; patching holes and cracks in ceilings and walls; sealing the floor/wall junction; and identifying and plugging air conduits—like plumbing chases, chimney enclosures, and wire holes.

The air barrier may be separate from the vapor barrier—achieved with caulking, gaskets, and tight joints between building materials. Many new homes employ a woven polyethylene air barrier on the outside of the exterior sheathing. This type of air barrier is permeable to water vapor, allowing water vapor to escape. If a material like polyethylene, installed as a vapor barrier, is attached in an airtight manner to framing lumber, the result is an air/vapor barrier. Vapor-barrier paints are often the only practical way to achieve a vapor barrier in an existing home.

Wall Vapor Barriers

Vapor barriers are most important in climates where there is a large difference in humidity between outdoor air and indoor air. Vapor barriers should be installed on the warm side of the wall. The vapor barrier in cold climates should be on the indoor side of the wall. The vapor barrier in hot, humid climates should be on the outdoor side of the wall.

Vapor barriers stop moisture from diffusing through building materials like sheetrock and wood-composite siding. Vinyl and metal siding are vapor barriers. Metal siding collects condensation during very cold weather because it's a vapor barrier on the cold side of the wall.

In moderate climates, with air conditioning and heating, moisture is coming from outside to inside during the summer and from inside to outside during the winter. It may be best to avoid vapor barriers by letting the cavities be porous to drying from either side of the wall in warm climates.

The ground under the home can be a major source of water vapor, which then condenses on cool surfaces. Ground moisture barriers stop water vapor rising through the soil under the home, and also prevent evaporation of water seepage from damp ground. Ground moisture barriers should be installed on dirt floors in all crawl spaces. Heavy polyethylene plastic (at least 6 mils thick) makes a good ground moisture barrier.

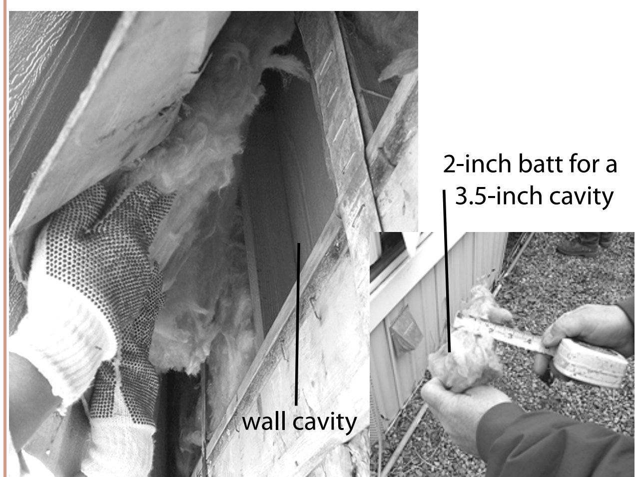
Wall Insulation

Although installing wall insulation is a difficult energy retrofit, it can be cost-effective in cold climates with moderate to high fuel costs.

Mobile home walls are often partially void of insulation because of insufficient insulation thickness, settling, or poor installation.

Adding more wall insulation will save around 10% of existing heating costs in cold-climate homes that have 2 inches or less of wall insulation. In warmer climates, it is generally not as cost-effective to re-insulate partially insulated walls.

Figure 8-7 Inspecting Wall Cavities



Many wall cavities have insulation that doesn't completely fill the cavity, rendering the insulation far less effective than when insulation packs the cavity.

Remember: Working with insulation creates dust that can irritate your lungs, eyes, and skin. For your safety, wear a respirator, safety glasses, gloves, and coveralls.

Comparing Wall Insulation Methods

Compacted fiberglass insulation produces a slightly higher R-value per inch of thickness than un-compacted fiberglass. Compacted fiberglass also stops air more effectively than looser fiberglass. Compacting insulation is important for re-insulating wall cavities in order to achieve maximum R-value and to stop air movement.

Three different methods of wall insulation are discussed below: 1. Blowing insulation; 2. Stuffing fiberglass batts; and 3. Removing exterior siding to install batts. Each has advantages and disadvantages when compared to the others. On some homes, because of variations in the wall, the three methods might even be combined.

1. **Blowing insulation into wall cavities** works well in most applications. Generally, blowing insulation is slower than stuffing insulation and faster than removing siding.
2. **Stuffing batts into wall cavities** with a flexible stuffing tool is usually the fastest way to insulate walls. With stuffing, however, it is difficult to fill corners, narrow cavities, and areas around doors and windows. The stuffing method can work well, when combined with blowing or removing siding. However, stuffing doesn't work on every home.
3. **Removing exterior siding to allow for batt insulation** is the most time-consuming method, but it does facilitate wall repair (if needed) and it doesn't require a blowing machine. Insulating the open cavity is easy with exterior siding removal or interior paneling removal during major renovations.

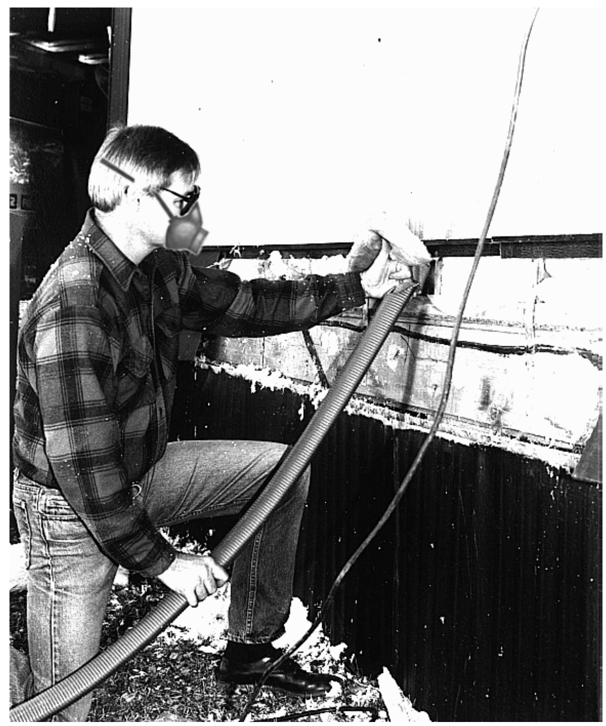
All of the above wall insulation methods should be accompanied by the repair and refastening of any damaged or loose interior and exterior wall panels.

Blowing Insulation into Wall Cavities

Fiberglass insulation can be blown into walls using a blowing machine, hoses, and a flexible fill-tube. The best fill tubes for mobile home walls are stiff but flexible plastic pipes about 8-feet long and 1-to-2 inches in diameter. Corrugated plastic tubing used with agricultural or spa pumps works well. You can take the 2-inch size and drive over it with a car to flatten the round shape of the tube into an oval. This oval-shaped tube fits in most 21$^1/_2$-to-5$^1/_2$-inch-deep wall cavities. A flattened 1$^1/_2$-inch-diameter tube will fit into a partially insulated 1$^1/_2$-to-3$^1/_2$-inch-deep cavity. Marking these fill tubes in one-foot intervals helps you know how much of the tube remains in the wall when you are pulling the tube out.

The blowing machine's delivery rate and its air pressure determine the insulation's density and the time required to fill a cavity. If the delivery rate is too fast, the hose may clog. If the delivery rate is too slow, the cavity takes too long to fill, and the insulation packs excessively, possibly bulging interior or exterior paneling. Choose a delivery rate and pressure that fills the wall quickly and steadily without bulging the wall or clogging the hose.

Figure 8-8 Inserting the Fill-tube



The technician inserts the fill-tube into a wall cavity. text here

The areas above many windows are small and may not be worth the considerable effort required to fill them with insulation. Removing siding or interior panels or drilling holes in interior or exterior sheeting is difficult but will work.

Blowing insulation – metal-sided homes

For mobile homes with metal siding, a simple and straightforward fiberglass insulation blowing procedure is described below:

Step 1: Check the interior paneling and trim to make sure they are securely fastened to the wall. Repair holes in interior paneling and caulk cracks at seams to prevent indoor air from entering the wall. Note the location of electrical boxes and wire to avoid hitting them when you push the fill tube up the wall.

Step 2: Remove the bottom horizontal row of screws from the exterior siding. If the vertical joints in the siding interlock, fasten the bottom of the joints together with $^1/_2$-inch sheet metal screws to prevent the joints from coming apart. Pull the siding and existing insulation away from the studs, and insert the fill tube into the cavity with the point of its tip against the interior paneling.

Step 3: Push the fill tube up into the wall cavity until it hits the top plate of the wall. The tube should go in to the wall cavity 7-to-8 feet. It is important to insert the tube so that its natural curvature presses its tip against the interior paneling. When the tip of the fill tube, cut at an angle, is pressed against the smooth paneling, it is least likely to snag the existing insulation on its way up the wall. If the fill tube hits a belt rail or other obstruction, twisting the tube will help its tip get past the obstruction.

Step 4: Stuff a piece of fiberglass batt into the bottom of the wall cavity around the tube to prevent insulation from blowing out of the wall cavity. Leave the batt in-place at the bottom of the wall, when you pull the fill tube out of the cavity. This piece of batt acts as temporary gasket for the hose and insulates the very bottom of the cavity after the hose is removed. This batt also eliminates the need to blow insulation all the way to the bottom, preventing possible spillage and overfilling. If you happen to overfill the bottom of the cavity, reach up inside the wall to pack or remove some insulation, particularly any that lies between the loose siding and studs.

Step 5: Draw the tube down and out of the cavity about 6 inches at a time. Listen for the blower fan to indicate strain from back-pressure in the wall. Watch for the insulation to slow its flow rate through the blower hose at the same time. Also watch for slight bulging of the exterior siding. These signs tell the installer when to pull the tube down.

Step 6: Carefully refasten the siding using the same holes. Use screws that are slightly longer and thicker than the original screws.

Blowing Insulation—Wood-Sided Homes — For homes with wood siding, drill holes ($2^1/_2$ inches to $3^1/_2$ inches in diameter) into each cavity a foot or two from the bottom of the wall. Insert the fill tube up into the wall, following procedures outlined above to avoid snagging the existing insulation.

Or, cut 3-by-6-inch rectangular holes centered over the studs to gain access to two wall cavities through one hole. This method produces one-half the number of holes compared to drilling.

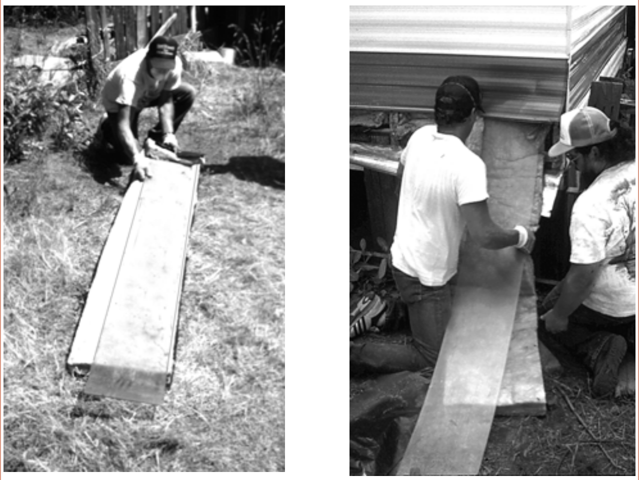
Depending on the method used, patch the holes with rectangular patches, round plastic or wooden plugs, or a continuous piece of wood trim. The wood trim should be beveled at the top to shed water and sealed carefully to the siding with caulking.

Stuffing Batts into Wall Cavities

Batt-stuffing is another technique used to reinsulate metal-sided mobile homes. Batt-stuffing would only work on wood-sided homes if the siding were cut off at the bottom for moisture-damage repair as described earlier. Fiberglass batts can be stuffed into empty or partially-insulated wall cavities with a strong but flexible plastic stuffer, made of clear polycarbonate plastic sheet 8 feet long and 13 inches wide and $^1/_4$-inch-thick. Polycarbonate sheet is available through glass dealers. Bending the last foot of the stuffer at about a 15° angle will make it more versatile for stuffing different types of wall cavities.

Batt-stuffing is much faster than blowing, but it won't work in all wall cavities—some will still have to be blown. Batt-stuffing does not work near corners or doors where the siding is difficult to loosen and pull back. Batt-stuffing also may not work well on some partially insulated walls that are particularly tight due to belt rails, wiring, or other obstructions.

Figure 8-9 Stuffing Batts



Fiberglass batts can be stuffed into partially insulated wall cavities, using a flexible metal or plastic batt stuffer.

Batt-stuffing can be very fast and easy when it works. The only way to discover whether it works on a particular home is to try it.

Here are 7 steps to follow for stuffing fiberglass batts into mobile home walls.

Step 1: Check the interior paneling and trim to make sure it is securely fastened to the wall. Prevent indoor air from entering the wall cavity by caulking cracks and repairing holes in interior paneling.

Step 2: While you are still inside, remove hanging pictures and the screws or nails that hang them. Check the wall's electrical boxes to see if they can be easily removed. If so, remove anchoring screws from the boxes and pull the boxes temporarily out of the wall to clear the cavity for batt stuffing. Don't remove the boxes from the wall unless you can easily refasten them—you can always blow insulation into those cavities instead.

Step 3: Remove the bottom two horizontal rows of screws from the exterior metal siding. If the joints in the siding interlock, fasten the bottom of the joints between pieces of siding together with $^1/_4$-or $^1/_2$-inch sheet metal screws to prevent the interlock from separating. For homes with horizontal siding, simply remove the bottom section of siding.

Step 4: Cut an un-faced fiberglass batt at least 8 inches longer than the height of the cavity. Cut a piece of flexible plastic sheeting (4-to-6 mils thick) the same size. Lay the plastic on the ground and place the batt on top of the plastic. Then put the batt stuffer on top of the batt. The top of the batt stuffer should be 4-to-8 inches down from the top of the batt. (Kraft-faced batts and new plastic-jacketed batts may also work well.)

Step 5: Fold the batt and film over the top of the batt stuffer. Pull back the siding. Put the side with the plastic sheeting against the interior paneling. Use the batt stuffer to push the batt and plastic film up into the wall cavity to its top. The plastic sheeting on one side and the stuffer on the other protect the batt act as lubricants to help it move up the wall without tearing. The existing insulation should be compressed against the exterior siding as you push in the new insulation. Shove the batt up into the wall cavity until the stuffer and batt hit the top plate of the wall.

Step 6: Let the excess batt insulation hang out to remind you which cavities have been stuffed. As mentioned earlier, some cavities will not accept stuffing and will require blown insulation. After you blow insulation into those cavities that require it, you can cut off the excess batt from cavities you stuffed. Or, fold it up into the wall.

Step 7: Carefully refasten the siding using sheet metal screws one size thicker and one size longer than the ones you removed.

Removing Exterior Siding to Insulate

Removing a mobile home's exterior siding is more time-consuming than blowing or stuffing insulation, but it requires less experience and no special equipment. Un-faced fiberglass insulation, sometimes known as friction-fit fiberglass is used.

Siding removal can produce superior results because you have complete access into the cavities to seal cracks and holes in the cavities, install insulation, and attach an air-infiltration barrier to the wall's exterior under the siding (to inhibit air leakage and convection in the wall cavities).

Siding removal is a practical alternative when you are:

1. Replacing siding (especially if existing siding is water-damaged);
2. Replacing or repairing doors and windows;
3. Repairing a wall's structural parts; or
4. Re-insulating a wall with missing or damaged insulation.

Doors and windows are usually installed over vertical metal siding, pinning it to the structural wood frames of the windows or doors. In most homes, the door and windows must be removed in order to pull the siding off.

To avoid leaving wall cavities exposed overnight, only remove as much of the siding and windows as you can reinstall in one workday. Using reversible drills to remove doors, windows, and siding, three good workers can re-insulate one-half of an averaged-sized single-wide home and reinstall that half's siding in an 8-to-10-hour day.

When insulating after siding removal, fill the whole wall cavity—from top to bottom, side to side, and interior to exterior wall surfaces. Although using insulation designed for deeper cavities may cause the insulation to bulge slightly before siding replacement, the wall will have a superior R-value, compared to a wall with less insulation and more air spaces. Use waste pieces of batt insulation to stuff around outlets and wires. Remember that even small voids will reduce the R-value.

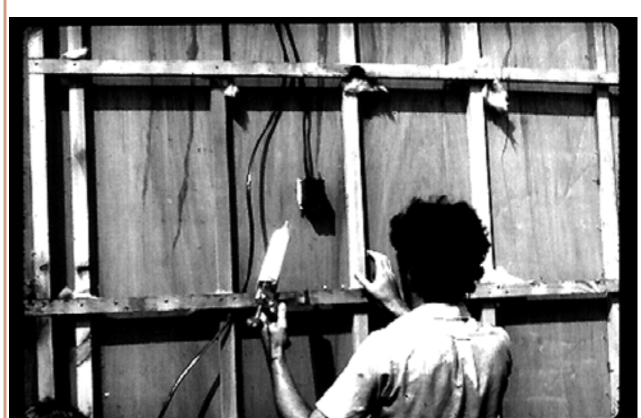
Manufacturers use different ways of attaching mobile home siding at its top and bottom. Carefully study your home's siding details to estimate how much work siding removal will entail. It may help to remove an easy panel—one without windows or doors—to judge removal difficulty and also to inspect the wall cavity.

If the siding is tied into the metal roofing at a joint at the roof's edge, you don't absolutely have to break that joint, which is often sealed with roof coating and putty tape. Sometimes you can prop the siding away from the framing to install insulation underneath it after loosening the siding's top and middle. Letting the siding hang, as described above, can be dangerous on a windy day and should only be done in calm wind conditions.

Figure 8-10 Installing Fiberglass Batts in an Open Wall Cavity

After siding is removed, batts designed for a $3^1/_2$-inch-cavity are compressed into a $1^3/_4$-inch cavity.

Figure 8-11 Sealing Walls



A technician caulks around electrical outlets and seams from the outside after siding panels have been removed tor re-insulation.

If you do have to disassemble the joint between roof and siding, seal the joint carefully with putty tape or exterior caulking under the roof edge and j-rail when you install old or new siding—the smallest leak at this joint can let a lot of water into the home.

Here are 8 steps to follow when insulating exterior walls by removing exterior siding.

Step 1: Use masking tape to mark each joint between siding panels. Also mark joints between siding and trim. Place tape across the joint, and write the same number on each side of the joint. Then, cut the tape. The tape and numbers will make reassembly much easier.

Step 2: Remove the windows and doors: They are usually fastened with hex-head screws and sealed with putty tape. Carefully pry the window or door away from the siding little by little moving around its frame with a flat pry bar. Label the windows and doors with masking tape noting their locations and the direction they face to ensure correct reinstallation.

Step 3: After the siding and trim have been marked, remove them. Most metal-sided mobile homes have starter strips at the top of the wall that are fastened to the metal roof. You don't have to remove this starter strip. The siding will slide out from underneath it, when you remove the screws going through both the starter strip and siding.

Step 4: If you find a vapor barrier fastened to the outside of wall studs, remove this vapor barrier. With the wall cavities now exposed, examine the studs, window sills, and plates. Repair any damage by fastening wood or metal patches to weak framing members and replacing rotten ones. Caulk and seal: cracks around outlets, holes in the interior paneling, and seams between studs and interior paneling (optional). At the same time, refasten any loose interior paneling from indoors.

Step 5: Insulate the cavity with un-faced fiberglass batts. Peel extra, partial sheets of batt to completely fill cavities around electrical boxes, wire, and other obstacles. Ideally, the insulation should touch the entire surface of interior paneling and touch the entire surface of the exterior air barrier, filling every cubic inch of every wall cavity.

Step 6: Wrap the newly insulated walls with an *vapor permeable air barrier.* This *house-wrap*, as it is sometimes called, stops air leakage but lets moisture out of the wall. This air barrier is stapled to the exterior side of the studs. Staple it in place, joining its edges at studs for support and sealing the edges with caulking or construction adhesive. The air barrier is tough material so tearing and puncture are not much of a problem. If you do punch a hole in the air barrier, repair it with rugged polyethylene tape or an air-barrier patch, glued on with construction adhesive.

Step 7: The old siding may not align perfectly with existing holes in the wood. This will not be a problem because the new screws will bore their own new, tight holes. Use larger screws, if the holes line up, so the screws aren't loose inside the old holes. After reinstallation, the siding should be flat and tight, looking as good as it did before.

Step 8: Reinstall windows and doors, using new putty tape. Then, caulk carefully around the exterior frames to prevent water leaks. Also, seal the screw heads with clear caulk.

Figure 8-12 Air Infiltration Barrier

After installing batts in an open wall cavity from outside and before the siding is re-installed, an air barrier is stapled and sealed tightly over the insulation.

Wall-Roof Retrofit

The following retrofit is designed for metal-sided or vinyl-sided homes with metal roofs located in hot and humid climates. It involves installing hardboard siding to strengthen the home and protect it from flying objects during a windstorm. The roof and walls are re-insulated before installing the new hardboard siding and polyurethane roofing.

Step 1: Remove the doors and windows.

Step 2: Remove the siding and trim.

Step 3: Follow steps 5 and 6 of the procedure in *"Removing Exterior Siding to Insulate" on page 99*, for retrofitting wall insulation and installing house wrap.

Step 4: Insulate the roof cavity with blown fiberglass as described in *"Roof-Cavity Insulation" on page 130*.

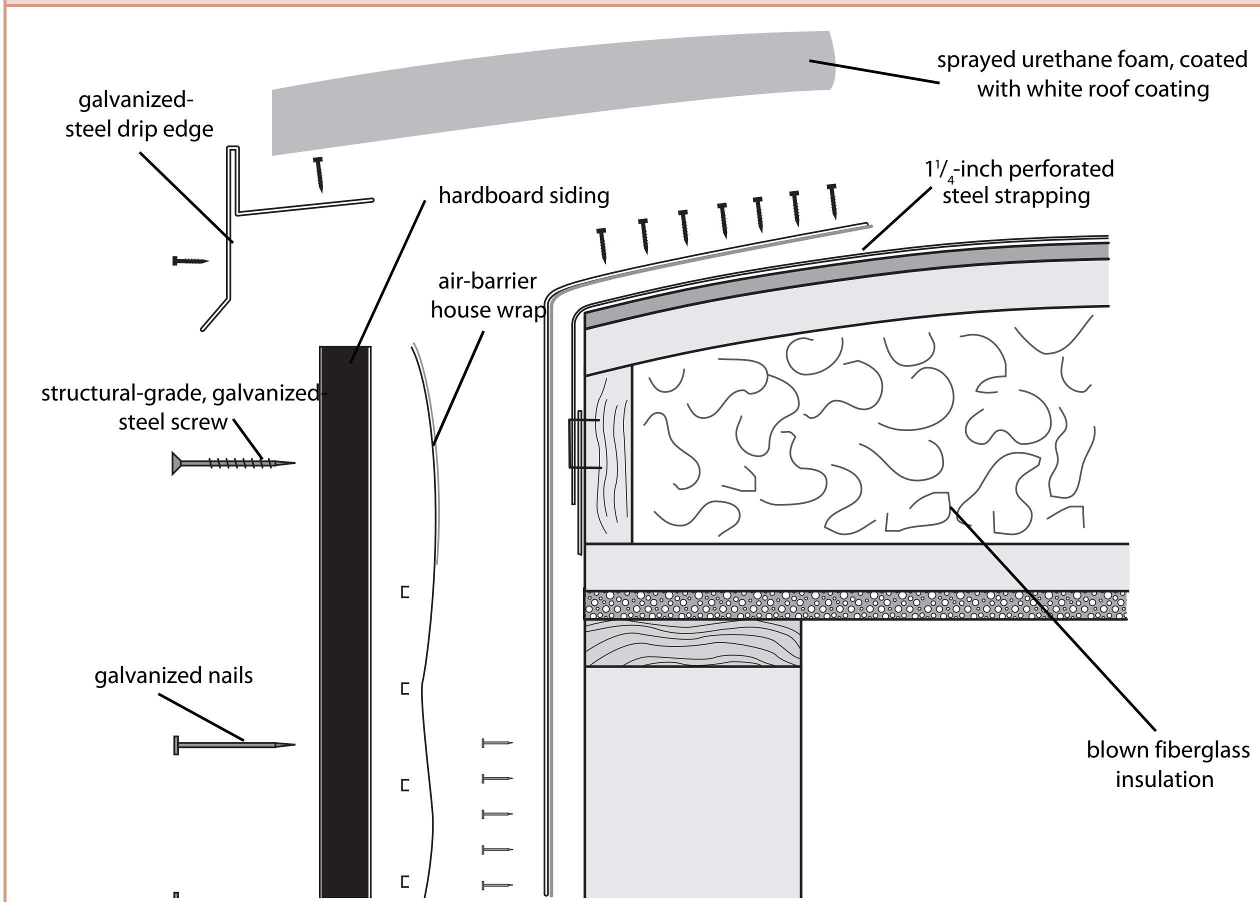
Step 5: Install perforated $1^1/_4$ galvanized-steel strapping every 4-to-8 feet where a stud lines up with a truss. Also use this strapping to bond the studs to the floor's rim joist and leave a few feet hanging out to attach to a double-headed anchor. Nail and glue the strapping to the studs and rim joist. Screw and glue the strapping to the truss through the metal roof. This bonds the roof to wall and wall to floor structurally. If studs don't line up with trusses, install blocking between the studs to fasten the strapping to.

Step 6: Spread a $^1/_4$-inch thick layer of construction adhesive at the roof-wall junction before nailing on the hardboard siding, which should be primed on both sides and all edges. Nail or screw the siding every 6 inches. Screw the siding to the roof edge, which is somewhat fragile.

Step 7: Install a galvanized-steel drip edge designed to accommodate 1.5 inches of sprayed urethane foam.

Step 8: Install urethane foam and roof coating as described in *"Rooftop Insulation" on page 134*.

Figure 8-13 Wall-Roof Retrofit for Southeast Hurricane Zones



Hardboard siding strengthens walls. Perforated steel strapping ties the walls to the roof and floor. Roof insulation can dramatically cut cooling costs and improve summer comfort.

Chapter 9 Doors and Windows

This chapter gives information on windows and doors in general and special features of windows and doors for mobile or manufactured homes. Also explained are ways to reduce heat flows through doors and windows by proper maintenance, repair, and weatherization of existing units and selection of new ones.

Doors

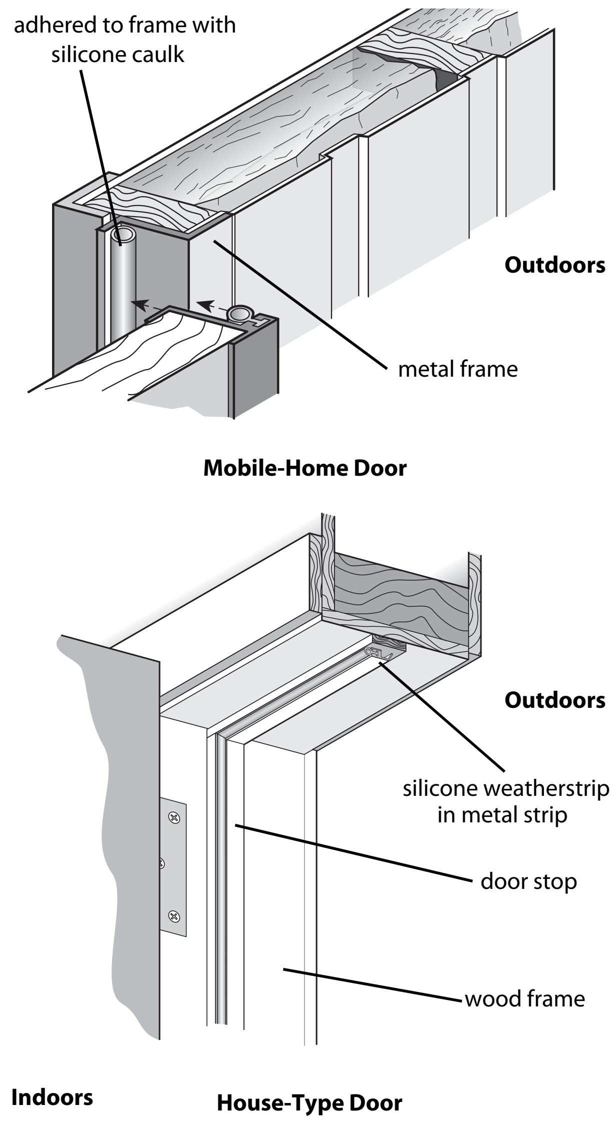
Most exterior doors in mobile homes are un-insulated. Heat loss or gain through the door is usually only a minor problem, however, due to the door's relatively small surface area. While repairing or replacing doors may be necessary for mobile home maintenance, this repair or replacement will probably not reduce household energy consumption significantly.

Exterior doors are often a maintenance problem because they get used so much and because they are exposed to weather.

Exterior doors can be repaired, weather-stripped, or replaced with insulated doors to improve comfort, operation, convenience, and appearance.

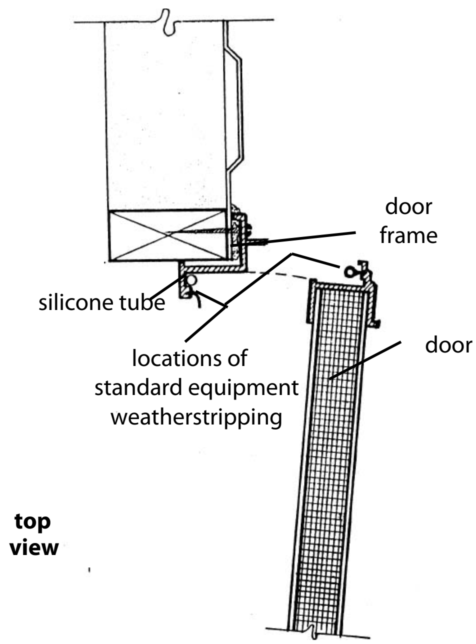
Interior doors are rarely a problem, except when they don't provide enough space at the floor for room air to return to the heating and cooling system. When an interior door allows less than an inch of clearance with the floor, it should be fitted with a louvered vent. Venting under or through the door is desirable, unless the room has a vent above the door or elsewhere in the room.

Figure 9-1 Mobile Home Doors and House Type Doors



Mobile-home doors swing outwardly in metal frames with weatherstrip attached to the door or frame or both. House-type doors swing inwardly in wood frames. Their weatherstrip is most often attached to the door stop.

Figure 9-2 Mobile Home Door



Drawing shows the two locations of weatherstripping that is standard equipment on this outwardly opening door. Also shown is the location for silicone tube weatherstrip used in retrofitting the door.

Door Design and Construction

Most exterior doors in pre-1980 mobile homes are hollow doors with wood or metal sheeting on a lightweight wood frame. They are generally filled with paper or cardboard honeycomb and give an approximate R-value of R-2.

New replacement doors are usually insulated to R-4 to R-7 with fiberglass or polystyrene foam, although R-13 urethane foam-filled steel doors are available.

There are two types of exterior doors common to mobile homes, inwardly opening doors and outwardly opening doors. Inwardly opening doors, called house-type doors, are mounted in a wood frame with standard butt hinges and usually have aluminum thresholds. The door bottom or threshold has a vinyl flap or bulb for sealing the door to its threshold. The assembled pre-hung door unit consists of a frame, threshold, door, hinges, and weatherstripping. House-type doors often have standard outwardly opening aluminum storm doors attached to their frame. The storm door is hinged in its own aluminum frame is fastened to the exterior trim of the door frame.

The outwardly opening door is mounted in a metal frame attached to the exterior of the home and is referred to here as a mobile-home door. These doors are shorter than standard doors and are usually located in hallways as a second door and fire exit. Mobile-home doors are weatherstripped with a vinyl flap or tube mounted in the door's aluminum frame and/or its aluminum mounting frame.

Inspecting Doors

The door should open and close smoothly without binding. It should fit closely against the doorstop with no significant gaps between the door and doorstop.

Push and pull on the door knob with the door closed. The door should not move back and forth. If it moves, you may be able to adjust the strike plate by bending a tab inside its opening. Or, you may be able to remove the door stops and move them closer to the door.

If the space between the door and frame appears uneven, check tightness of the hinges' screws. If they're tight, check the door opening for squareness. Place a framing square in the corners. Or, measure the opening diagonally from corner to corner, then diagonally from the opposite corners. If the opening is square, these measurements will be within $^{1}/_{4}$-inch.

A door opening significantly out-of-square indicates an un-level foundation and the need to relevel (See *Chapter 2* ***Foundations***). An extra footing and pier may be necessary underneath the door to prevent the home and door frame from moving again.

Seeing daylight through cracks when the door is closed or noticing uncomfortable drafts around the door indicate that the door needs adjustment or new weatherstripping.

Adjusting and Repairing Doors

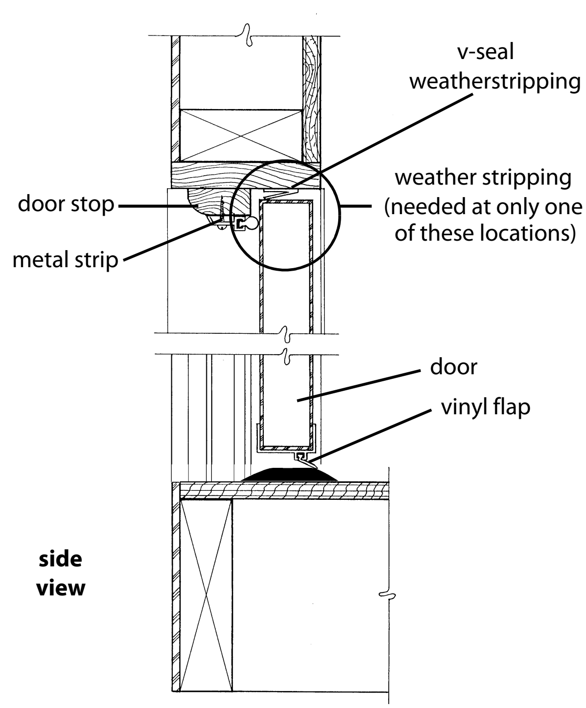
Repairs to the door, if necessary, should precede weatherstripping. Paneling on the faces of the door can be glued and screwed back to the frame. If patches are necessary select a paneling material that matches the door. Affix the patch with construction adhesive—and screws, if necessary.

Tighten the hinges, door knob, and strike plate if they're loose. Stuff glue and toothpicks into enlarged screw holes to help loose screws hold, or drill a larger hole and insert a piece of glue-coated wood dowel, if the hole is very sloppy.

If the door binds at the top, check the tightness of screws in the top hinge and tighten them if necessary. If the hinges are tight, check the space between the door and the frame's hinge-side. If there's a $^1/_4$-inch gap between door and frame on the hinge side, you can give $^1/_8$ inch of that gap to the latch side by deepening the mortise—the chiseled-out section of door frame directly under the hinge. If the door is too tight to the hinge side, install one or more pieces of cardboard underneath a hinge.

Doors can be adjusted by moving the hinges in or out. Moving the top hinge in moves the door upward and toward the hinge. Moving the top hinge out drops the door down and moves the door away from the hinge.

Figure 9-3 House-Type Door



Drawing shows three possible locations for weatherstrip on this inwardly opening door.Weatherstrip is needed at only one of the perimeter locations (door jamb or door stop).

Most doors have camber bolts that adjust the door's slightly bowed shape, to allow the top and bottom corners of the door to close tightly against its stops. Tightening the camber bolt increases the camber or bow of the door, pulling the corners in toward the stop. Loosening the bolt relaxes the camber.

If a door won't latch, inspect the door stops and weatherstripping to see if they are binding. If there is no obvious problem with the weatherstrip or stops, move the strike plate out slightly or use a file to remove a little metal from the strike plate. The strike plate is mortised into the door frame, that receives the latch. Use toothpicks or dowels to patch widened screw holes if you have to move the strike plate.

If a door swings open or closed by itself, you can bend one of the hinge pins slightly by tapping the center of the hinge pin with a hammer while it rests between two 2-by-4s. The slight bend will create friction and allow the door to remain in any position between open and closed.

Weatherstripping Doors

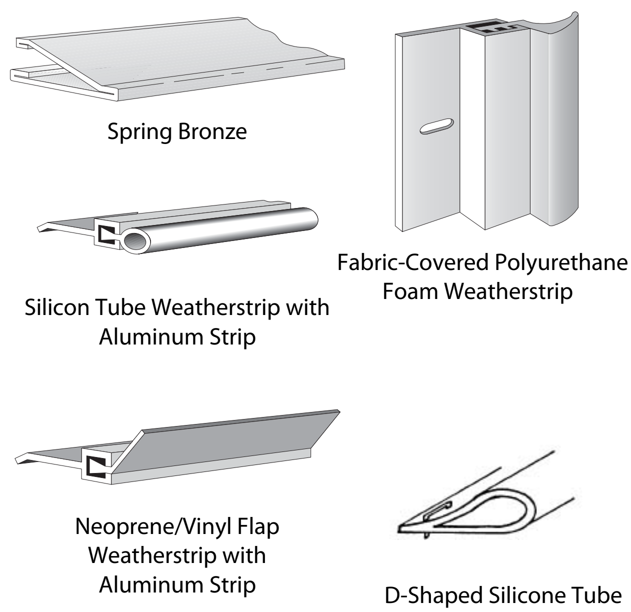
When the door opening is square, the door operates smoothly, and the hardware is tight, then weather-strip the door, if necessary.

Flexibility and longevity are important features for door weatherstripping. Flexibility is important, because doors move slightly with changes in temperature and humidity. New gasket materials like silicone rubber, neoprene rubber, and plastic jacketed foam rubber are very flexible. They allow door movement while still providing a good air seal. These weatherstripping products are available in rolls containing only the flexible material itself, or containing the flexible weather-strip attached to rigid aluminum strips. These strips are screwed or nailed to the door frame.

Many common types of weatherstripping, sold in lumber yards, discount stores, or hardware stores, are not very flexible or long-lasting. Vinyl tubing, roll-spring bronze, felt, and foam tapes are not recommended.

Silicone rubber tubing (without a aluminum strip), rigid plastic V-seal, or rigid bronze V-seal are very effective and are suitable for fastening with adhesives. Before using adhesive to fasten weatherstripping, clean the door frame's surface with alcohol or some other effective cleaner. Automotive weatherstripping adhesive, construction adhesive, and some caulks will stick permanently and tenaciously when fastening weatherstripping without nails, staples, or screws—to aluminum frames, for example. Weather-strips for wood frames need metal fasteners—screws, nails, or staples—even with adhesive.

Figure 9-4 Examples of Weatherstrip



The types of weatherstripping shown above offer enough flexibility to accommodate slight seasonal movement in a door and still maintain their seal.

Weatherstripping Mobile Home Doors — With outwardly opening mobile-home doors, the weatherstripping is embedded in a track within the door frame and often a similar track within the door itself. The vinyl flap is the most common type of weatherstripping for these doors. After removing the old weatherstripping from the track, you can install new vinyl by either prying it into the track or sliding it in from one end.

Silicone tube weatherstripping is particularly effective on mobile home doors. You can install the silicone tubing in any corner of the door or frame where it will be compressed sealing the door when it closes. It is available in several sizes, for closing a variety of gap sizes around doors. The silicone tubing sits in a corner out of the way, so it's unlikely to be damaged.

Silicone caulking adheres the silicone tubing to the aluminum door frame. Apply a bead of silicone caulking into the corner and press the silicone tubing into the corner with a small roller which is like a miniature pizza cutter. The roller works better than your finger because the finger drags and stretches the tubing.

Weatherstripping House-Type Doors — House-type doors are weather-stripped the same way as doors on site-built homes. Mount rigid plastic V-seal or bronze V-seal weatherstripping on the jamb where the edge of the door will compress the V. Flexible tubing or rubber flaps embedded in rigid aluminum strips are also effective for sealing house-type doors. Mount the aluminum strip on the door stop with the screws or nails provided. The more flexible aluminum-strip-mounted weather-strips seal tightly while accommodating the door's slight seasonal movements.

Replacing Doors

If the existing door is worn beyond repair and weatherstripping, consider replacing it. The decision to repair or replace depends on the condition of the door, the ease of repair, the home owner's budget, and concerns about energy efficiency or appearance. Replacement doors are most commonly available as pre-hung units, for both house-type doors and mobile-home doors. Pre-hung means that the door is already hung on hinges in the wood or aluminum door frame.

Replacing House-Type Combination Doors — The better pre-hung house-type doors are urethane-insulated steel doors with weatherstripping embedded in their wood frames. These doors have flexible jacketed-foam weatherstripping and are designed to seal the perimeter of the door very tightly.

If you have vertical metal siding, the new door will install over the siding. If you have horizontal lap siding, you may have to loosen or remove the siding around the door.

The combination pre-hung door unit includes the door, wooden frame, threshold, and storm door.

Step 1: Tear out the old door frame and inspect the rough opening. The rough opening is the opening created by framing lumber and flooring around the door opening. Scrape the sealant off the exterior of the door opening. Remove the threshold. If flooring under the door frame is damaged or rotten, replace it with 5/8-or-3/4-inch exterior plywood. Make sure the floor area under the new door is level.

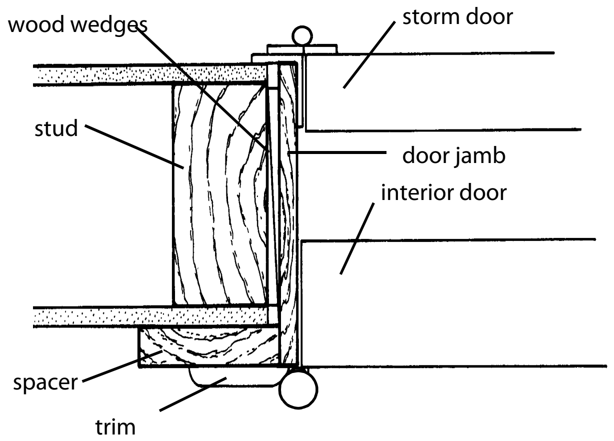
Step 2: Apply putty tape to the mounting flange. Make sure there is no dirt or debris on the floor or sticking to the bottom of the threshold. Move the door unit into the opening. Make sure that the threshold sits flat and level on the floor. Plumb the hinge side of the door. Then, drive three screws through both the left flange and the right flange.

Step 3: Remove the shipping screws and blocks. Make sure both doors—the primary door and storm door—open and close smoothly without binding.

Step 4: Drive the remaining screws through the mounting flange. Replace the drip cap or install a new one. Reinstall siding and trim, if you removed it to install the door.

Step 5: From indoors, fill the space between the door unit and the rough opening with fiberglass insulation or foam from a can. Install interior trim.

Figure 9-5 Door Installation



Pre-hung doors often have a frame that is thicker than the mobile home wall.The frame juts out past the inside wall paneling. A spacer is needed to bring the wall out for installing trim.

For a house-type door with wood moulding and no storm door, note the following differences from the above procedure.

Step 1: Place the door and frame in the opening from the outside. Push the frame's trim tightly against the exterior wall. Center the frame and door in the rough opening.

Step 2: Start a nail in the trim's upper hinge-side corner. Make sure the hinge side of the door frame is plumb. Drive four large finish nails into the tops and bottoms of the two side moulding pieces, but leave the heads of the finish nails protruding slightly in case you need to make an adjustment.

Step 3: From the inside, remove the shipping blocks and check the door for smooth operation, threshold seating, and proper door spacing from its jambs. Then, install three pairs of wedges between the jamb and rough framing on each side of the door. Nail through the door jamb, through the wedges, into the rough framing. Cut the wedges off, and attach the interior trim carefully to both the door jamb and interior wall with finish nails.

A standard pre-hung door frame may be deeper than an older mobile home's 2-by-3 wall. In this case, the door jamb will be flush with the exterior wall and will extend beyond the surface of the inside wall. Cut a wood spacer to match the protrusion of the interior jamb. Securely fasten the spacer to the wall around the frame—it should reinforce the opening in addition to being a spacer. Then, nail the door trim securely to the door frame and to the spacer. The trim and spacer strengthen the wall and help support the new door's weight—the new door may be heavier than the one it replaces.

If you are replacing just the house-type door without replacing the frame, brace the new door into its exact position within the frame with wedges. The distance between the door and frame should be approximately equal all the way around. Mark the hinge locations with great care because the door will be hard to hang if the hinges don't line up exactly. Finally, mortise the door and attach the hinges to the frame and door. Make sure that all the screws are driven straight and that they're tight. Lift the door into place, mate the hinges together, and insert the hinge pins. If the hinges won't mate, hit the frame's top hinge up or down with a hammer to move it as much as 1/16 inch.

Measuring for Replacement Doors —

Mobile home doors are ordered by their rough-opening sizes. The door unit is sized slightly smaller. Common mobile-home-door widths are 30, 32, and 34 inches. Common heights are 76, 78, and 80 inches.

Door manufacturers don't all measure doors the same way. However, if you tell the retailer who sells you the door the size of the rough opening, there should be no confusion. Replacement door rough-opening sizes begin at 28-by-72 inches and increase in 2-inch increments for both width and height to 36-by-80 inches although sizes vary slightly from one manufacturer to another.

A door is either left-hand or right-hand, according to which side the hinges are when you view them from inside the house. You have to specify this to your supplier. A left-hand door has its hinges on the left as seen from indoors. When ordering combination door units (house-type door with storm door), you must specify both the house-type door and storm door. A left-hand, left-hand combination has a left-hand house-type door and a left-hand storm door.

Replacing Mobile Home Doors — The better mobile-home door units are well-weather-stripped and well-insulated. They're somewhat easier to install than house-type pre-hung doors.

Step 1: Remove the existing door and its aluminum frame. Make sure that the siding is cut square at the corners of the opening. Remove the plywood jamb liner. Check to see that the belt rails don't protrude into the opening. Then, remove the caulk or putty tape from the home's siding to provide a clean, smooth mounting surface for the new door.

Step 2: Apply new putty tape on the backside of the new door flange and to the new door's threshold.

Step 3: Check the hinge side for plumb, and drive three screws through the flange into the stud. Then, drive three screws through the latch-side flange.

Step 4: Remove the shipping clips and drive the remaining screws through the flange. Then, reinstall the plywood jamb liners.

Note that combination doors are available in sizes small enough to replace mobile-home doors. The in-swinging interior door, however, must have enough room to swing open all the way to the wall, so there is no danger of it blocking the hall in a fire.

Windows

Windows are the home's thermal weak link. Their surface area is large compared to doors and their R-value is lower than any other building component. Windows cause energy and comfort problems in four ways:

1. Hot window surfaces heat the home in summer and cold window surfaces cool the home in winter.
2. Poorly-sealed windows allow air to leak through or around, especially during windy conditions.
3. Hot or cold window surfaces create convection currents, heating the home in summer and cooling it in winter.
4. Solar heat penetrates windows—a major source of unwanted heat during the cooling season.

However, replacing windows takes many years to return your investment in energy savings. This section discusses how to repair, maintain windows and how to improve their thermal performance. It also discusses how to choose new ones if your old ones are worn or damaged beyond maintenance and repair.

This book's *Chapter 12* ***Cooling Systems*** discusses window treatments to reduce solar heat's entry to the home.

Design and Construction Prime Windows

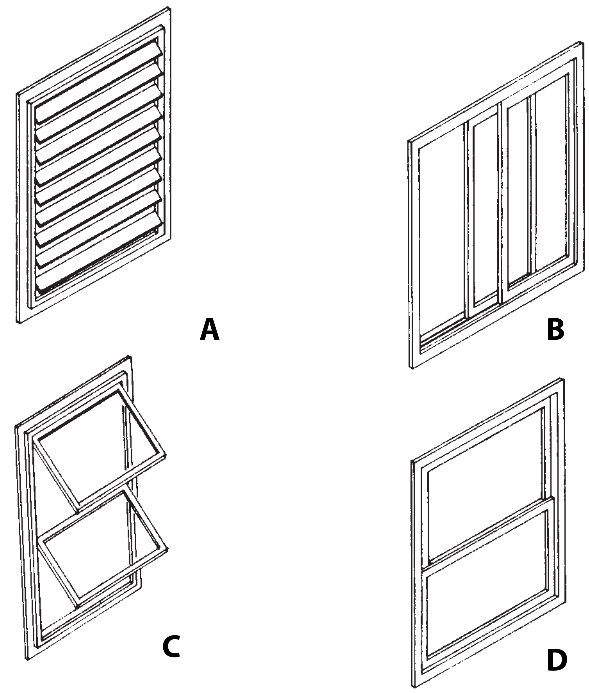
Windows on older mobile homes usually have aluminum frames and sashes. Windows in newer manufactured homes are either vinyl or aluminum. Prime windows are fastened to the outside wall of the home. Storm windows are fastened to the inside wall or window trim. Storm windows are either removable panels or vertical or horizontal sliding windows.

The aluminum or plastic frame of mobile home window has an external flange for mounting. The prime window frame is fastened over the exterior siding and into the framing beneath. There are four types of prime windows common to mobile homes: jalousie windows, awning windows, vertical sliders, and horizontal sliders.

Jalousie windows and awning windows are the most common type of window on homes built before 1976. Jalousies are the best ventilator for hot weather because their multiple panes open completely offering little resistance to ventilating air. However, they leak more air when closed than any other window type. Awning windows work like jalousie windows but have just two or three panes of glass rather than multiple panes.

Vertical or horizontal sliding windows are the most common on homes built in the 1980s and 1990s. Vertical or horizontal sliding windows are made of aluminum or vinyl. They open and close in similar double-track frames. Each window has a movable sash and a fixed sash. Vertical sliding windows have a spring counterbalance to keep the movable sash up when it is open. Both types have integral insect screens.

Figure 9-6 Types of Prime Windows



A. Jalousie; B. Horizontal Slider; C. Awning; and D. Vertical Slider.

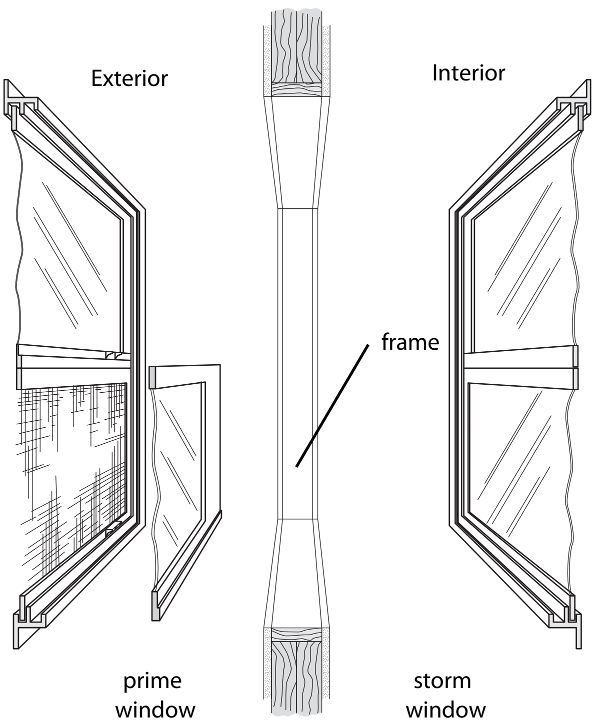
Design and Construction Storm Windows

Storm window frames and sashes are usually aluminum. Storm windows in manufactured homes are almost always mounted to the interior window frame.

Storm windows make a noticeable difference in comfort and will, in cold climates, repay an owner's investment in 5-to-15 years in saved energy. Storm windows are not as effective in warmer climates dominated by a need for cooling. Mobile home residents in warmer climates are better advised to pursue shading strategies such as those discussed in *Chapter 12* ***Cooling Systems***.

Fixed storm windows—seasonally mounted and removed—are common in older homes. Newer inexpensive vinyl, fixed storm windows offer low price as well as easy assembly and installation. Horizontal and vertical sliders are more popular and practical, however, because they remain in place year round and do not require removal and storage. Sliding storms are also more expensive than fixed ones.

Figure 9-7 Prime Window with Storm Window



Unlike site-built homes, mobile home storm windows are installed on the inside.

Some retrofit storm windows use plastic-sheet or plastic-film window panes. They are available in fixed panels, horizontal sliders, and vertical sliders. They have continuous seals around their perimeters to cut drafts and prevent the warm, moist, indoor air from circumventing them and depositing condensation on the primary window. These plastic-glazed storm windows may have aluminum or plastic frames.

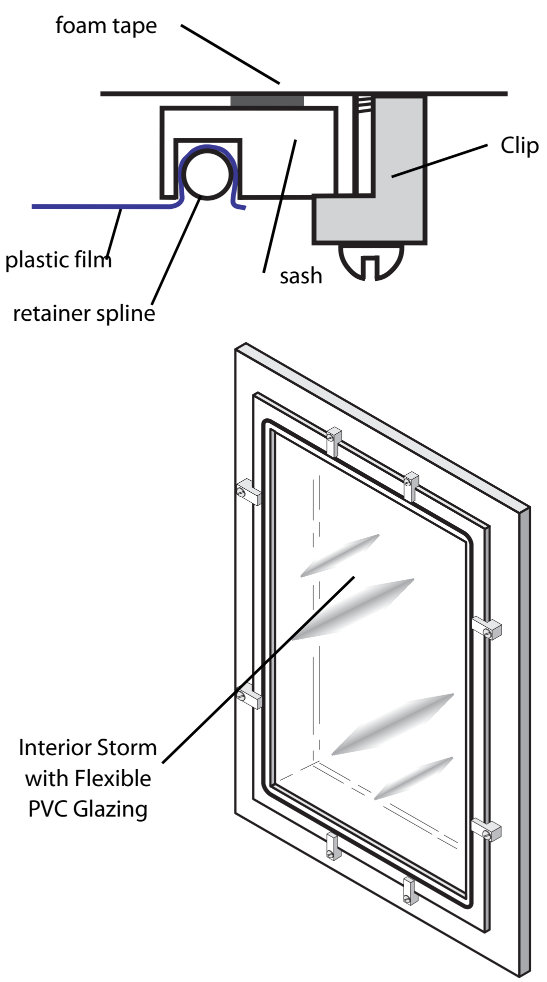
Fixed Storm Windows — Fixed-sash aluminum-and-glass storm windows clip to a wood, aluminum, or plastic frame with rotating clips. The frame remains in place year round and the sash is removed and reinstalled seasonally. Old jalousie and awning windows have special storm window frames with holes for their protruding cranks. Fixed storm windows, weather-stripped with $^{1}/_{8}$-to-$^{1}/_{4}$-inch closed-cell foam tape, seal very tightly against the wood or aluminum frame if the clips hold them tightly.

Fixed plastic storm windows are less expensive than sliding storms. However, the fixed storm window has to be removed seasonally for ventilation and, in the process, it is sometimes damaged or lost.

Flexible, clear vinyl and acrylic film is the least expensive of all glazing materials. It is fairly durable and very lightweight, too. It can be cut with scissors or a utility knife. The life span of storm windows made with flexible film will depend on the care used in mounting, removing, and storing these fixed storm windows. Although rigid acrylic plastic storm windows are lighter and stronger than glass storms, they are difficult to clean and the plastic scratches. Use water and a soft cloth to clean acrylic plastic or use a special acrylic cleaner and polisher.

Some fixed plastic storm windows have magnetic, Velcro™, or snap-together mechanical mounting and sealing systems. These mounts form an excellent seal, but they may not be strong enough to support the weight of the storm window throughout its life. The bottom of the storm window should rest on the sill, on a wood or aluminum strip, or on rotating sash clips. Beware of storm windows with self-adhesive frames because most thin adhesives eventually fail.

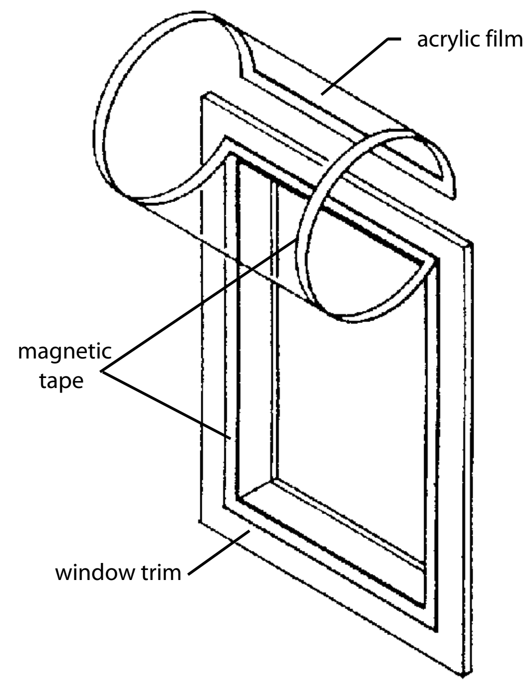
Figure 9-8 Fixed Storm Window with Flexible Film



This detail shows a low-cost interior storm window panel with an aluminum frame and flexible plastic film.This storm window is held in place by clips which rotate to install or remove the window.

***Sliding Storm Windows* —** Storm windows with movable sashes, either horizontal or vertical sliders, are lighter versions of prime windows. They resemble exterior aluminum storms used on site-built homes. The frames of these windows should be sealed to the interior wall with foam tape between the frame and wall. The movable sash of horizontal or vertical sliding storm windows usually has a spring-loaded sliding latch to lock it in place. Installation instructions are roughly the same as for exterior windows.

Figure 9-9 Lightweight Storm Window



A magnetically sealed storm window which uses an acrylic window film.

Inspecting Windows

Here are points to consider when you are inspecting mobile or manufactured home windows.

1. Single-pane glass is a serious energy problem in cold climates because they conduct heat 4 times faster than a totally un-insulated wall.

Sliding storm windows should be closed during the heating season and fixed units should be clipped in place.

1. The window's rough openings should be free from rot and other moisture damage.
2. The prime window should fastened firmly to the exterior wall with no significant gaps. All seams and gaps should be sealed with putty tape or caulking.

3. Interior storm window should be sealed tightly to its frame and the frame should be well-sealed to the wall.
4. The window's sashes should close completely without gaps more than $^1/_{16}$-inch wide. A little air leakage around the sash is tolerable.
5. Shading windows is a more important consideration in warmer climates than installing storm windows. If you live in the South, find a way to block 50% to 80% of the summer solar heat falling on the window. (*See "Shading and Reflecting" on page 166.*)

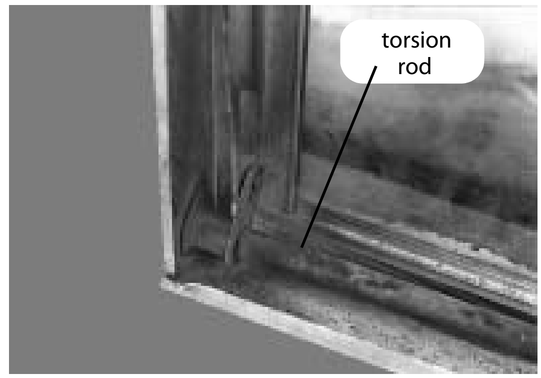
The decision to repair or replace a window depends on the above factors and also: the type and condition of the window; the labor time required to repair it; cost of materials; concern for appearance; and skills of the technician.

Windows and Condensation

Water condenses on the interior side of glass when humid indoor air touches the cold surface of the window glass. As the humid air cools, its capacity to hold water vapor is reduced. Water condenses, forming droplets, fog, or frost.

New windows alone may not cure window condensation problems. Even new energy-efficient windows may still be the coldest surface—the place condensation chooses to collect.

Figure 9-10 Torsion Rod



Note the torsion rod at the bottom of the photo and the torsion rod holder at the bottom left.The torsion rod holder can break causing the window to remain slightly open.

There are only three ways to stop condensation on home windows

1. Lower the humidity in the home. The three ways to lower humidity are: 1. Eliminating sources of water vapor; 2. Ventilating with dry outdoor air; and 3. Using an electric dehumidifier. (See *Chapter 4* ***Healthy Homes***.)
2. Raise the temperature of the home's inner panes of glass. Interior storms reduce condensation, because the inside surface of the glass in the storm window is warmer than the glass in the primary window.
3. Tighten existing or new storm window. If an interior storm window is not airtight, condensation may still occur on the primary window's interior glass surface as moist house air sneaks past the storm. The frame of the storm needs caulking between the frame and wall or foam tape underneath the frame to be reasonably airtight.

The condensation problem's severity depends on relative humidity inside the home, the outdoor temperature, the window's thermal resistance, and the tightness of an interior storm if one exists.

Egress (Fire Escape) Windows

Egress windows are required for bedrooms of manufactured homes. To facilitate escape by people of different sizes, the egress window must have the following characteristics.

1. A net clear opening of at least 20-by-24 inches.
2. Opening must be at least 5.7 square feet.
3. Sill height must be 36 inches or less
4. No locking device more than 54 inches from the floor.

Window repair or replacement must also conform to these standards.

Repairing Windows

Repairing the old window is a practical alternative to replacing it, especially since window replacement is not very cost-effective from an energy perspective.

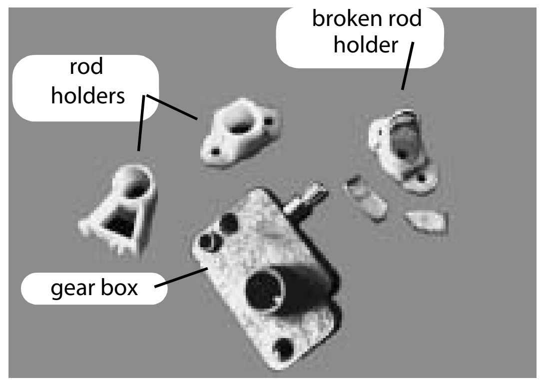
Window jambs and trim in many older homes often suffer serious moisture damage. Repair moisture damage to the framing by replacing all rotten wood. See *Chapter 8* ***Walls*** for instructions on replacing deteriorated wood. Inspect the condition of exterior caulking around the window frame and caulk if necessary.

Lubricate awning and jalousie gear boxes and all the moving joints in the opening mechanism.

Repairing Sliding Windows — If a sliding window doesn't slide easily, first brush and vacuum the channel, then spray the channel with silicone lubricant to make the sash slide easier. Often, the plastic piece that the window slides on called the glider has worn out or broken. Plastic latches often break too. These parts are often available at mobile home parts distributors or from mobile home parts catalogs. The parts aren't difficult to replace and involve just removing their screws and reinstalling them in the new part.

If a sliding window has worn-out pile weatherstripping, replace it. Take a sample of the weatherstripping to a local glass dealer or mobile home parts distributor to see if they can match it. The pile weatherstripping slides or folds into a slot in the aluminum sash during assembly. To replace the pile, either remove the sash from the glass and slide the pile in from one end, or place one side of the pile's plastic backer in the slot and fold the other side in with a screwdriver or knife.

Figure 9-11 Torsion Rod Holders and Crank Gear Box



Several types of torsion rod holders are shown, including a broken one. The gear box shown is available in replacement units if existing gear boxes are stripped out.

Replacing Broken Glass — To replace broken glass in horizontal or vertical sliding windows, remove the sash from the frame. Most prime sliding windows have to be completely removed to replace glass, but most sliding storm windows do not. If you have to remove the sash, the easiest way to replace the glass is to take the sash to a glass shop and let a glazier do it. The glass slides out of awning and jalousie windows for easy removal and replacement without removing the entire window.

If you replace this glass yourself, be careful to compensate for the correct inset of the glass into the sash rail when you measure. The inset is how deep the glass sits into its track. If you remove one piece of sash, you can see and measure how far the glass insets into the sash. If the rubber gasket that cradles the glass is missing or deteriorated, remove it and fill the gap and stabilize the glass with silicone caulk.

The prime window must be carefully sealed with new putty tape or caulking underneath the perimeter of its flange, when the window is reinstalled. Caulk between the edge of the flange and the siding with an exterior caulk after installation, too.

Repairing Awning or Jalousie Windows — Awning and jalousie windows are operated by a crank mechanism and a torsion rod. If an awning or jalousie window will not close tightly, check to see if the torsion rod bearing is broken. Often this plastic or metal bracket, which holds the torsion rod as it turns, breaks, preventing the window from closing tightly.

The torsion rod transfers the force of the closing mechanism to a push bar on the opposite side of the window from the crank. When the torsion rod bearing breaks and the window won't close tightly, people may turn the crank until the threads in the crank or the gears in the gear box strip out.

Replace stripped cranks, torsion rod bearings, and cranks with matching parts obtained through a mobile home parts supplier.

Hinges on many awning windows have several holes in the end of the hinge that pushes the window open and pulls it closed. Moving the small screw from one hole to another is a method of adjusting the window operator and allowing the window to close more tightly.

If you can't adjust or repair the window, install a clip on the exterior jalousie or awning window frame or siding to hold the window closed while heating or cooling the home. Most hardware stores carry rotating clips or spring-loaded clips that are used to retain storm windows and screens in older site-built homes. These clips work well to hold a jalousie or awning window closed until it can be repaired or replaced.

Replacing Windows

Some older windows, especially jalousie and awning windows, leak a lot of air and are worn beyond maintenance and repair. In this case, window replacement makes good sense. However, even replacing leaky jalousie windows may not have a noticeable effect on heating costs, unless the new window assembly has better thermal performance than the old one.

Energy-Efficient Windows — Energy-efficient windows use four strategies to improve the R-value of glass: multiple panes, gas fillings, metallized coatings, and less conductive frames, sashes, and glass spacers. The very best windows combine two or more of these strategies.

There are a wide variety of windows featuring two or three glass layers. The glass may have one of several types of heat reflective coating. Low-e coatings retard the radiant heat flow through the window. These new windows are called low-e windows. The low-e coatings are tailored to warm or cool climates—the cool climate variety reflects more solar heat.

Argon gas, which has a higher R-value than air, fills the space between panes in some high-performance windows. Recently double-pane glass manufacturers have been using improved edge spacers for assembling the double-pane glass. Standard spacers are made of aluminum which conducts heat rapidly. The newer spacers, made from dense foam plastic or plastic/metal composite materials, reduce heat loss through the edge of the glass.

Homes in very warm climates need reflective glass more than double glass because reflective glass is more effective at reducing air conditioning costs. (*See "Low-e Glass and Reflective Glass" on page 170.*)

Choosing New Windows — There are a variety of selection criteria for new windows:

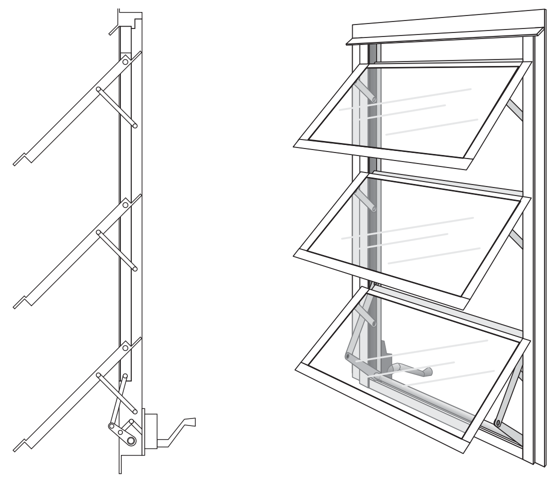
1. Compatibility with mobile or manufactured houses. Check the manufacturer's literature.

Ask the manufacturer's representative about compatibility and warranties.

2. The most important criteria for new windows for homes in northern climates are their U-values which are measurements of how fast a window conducts heat. Don't replace windows in northern climates without making a significant reduction in U-value. U-values for windows range from 1 to about 0.18. (A material's U-value is the number "1" divided by its R-value.)
3. The most important window selection criterion for southern climates is solar transmittance. Solar transmittance measures the percent of total solar energy admitted by the window glass. Energy-efficient windows have solar transmittances of 40% to 70%. Choose higher solar transmittances for cool, cloudy climates and lower ones for hot, sunny climates.
4. Frame and sash materials are important from the perspectives of thermal performance, maintenance, and life-span. Wood windows have good thermal performance and life-span, but maintenance is usually a problem. Wood windows aren't commonly used for manufactured homes. Aluminum windows have excellent life-span and freedom from maintenance, but poor thermal performance. Vinyl windows have excellent thermal performance and freedom from maintenance, but their life-span is still uncertain because of their relative newness to the market.
5. Visible transmittance measures how much visible light is admitted by the window glass. Visible transmittance is important because the window's main job is to provide a view and admit light. Very reflective coatings—which slash air conditioning costs, but also cut visible light up to 30%—may be unacceptable to some customers.

Air leakage is not a very important in selecting new windows because all but the very cheapest new windows are fairly airtight and they don't contribute much air leakage to a home.

Figure 9-12 Awning Windows



Millions of mobile homes built in the 1960s and 1970s have awning windows. They are repairable and can function adequately for decades, if properly operated and maintained.

Measuring for New Windows — Measuring for a replacement window is similar to measuring for a new door. You simply measure the opening that the window will fit into. The window should sit flat on the sill and have $^{1}/_{8}$-to-$^{1}/_{4}$ inch clearance from the top of the opening and approximately $^{1}/_{4}$ inch from each side.

Check the opening for squareness by measuring the diagonals or by placing a framing square in the corners. If the openings aren't square, leveling the home before replacing window is a good idea and will save time. For windows wider than 30 inches, check the height measurement in the center of the window opening.

Be sure to communicate to the supplier that you have measured the rough opening. Give the supplier the dimensions of the opening by stating the width first, then the height.

Know the thickness of both the existing window and replacement window and note how any difference may affect the installation. Also, measure the thickness of the wall to make sure it is thick enough to accommodate both the replacement window and the interior storm window if you intend to install a new one or keep your old one.

***Installing New Windows* —** Its easy to replace primary windows on homes with corrugated metal siding. The window installs over the siding. On metal or vinyl lap-sided homes, siding goes over windows, so the siding must be removed or at least loosened to replace windows. If you choose to merely loosen the siding, you'll need a zip tool to pry the joint apart between pieces of siding above and below the window. Loosening the siding rather than removing it can be tricky, so only attempt it if you're familiar with lap-siding installation and repair. After you deal with the siding, consider the following steps.

Step 1: Measure the window to ensure it is the size you ordered. Measure the window opening from inside the home to make sure the window will fit.

Step 2: Remove the old window and scrape all the old putty tape from the window opening. Check the opening again for square and correct dimensions.

Step 3: Apply putty tape or caulking to the flange. Place the window in the opening so it rests on the sill. Move the window left and right and note how far it moves. Move the window half this distance from one side so the window will be centered.

Step 4: While holding the window against the wall, drive a screw in the middle of one of the side flanges. Drive screws in the center of the 3 other flange pieces around the window.

Step 5: Check indoors to make sure the window is centered. Then drive the remaining screws. Caulk the seam between the window and opening to ensure against rain leakage.

Step 6: Remove the shipping clips and check the window's operation.

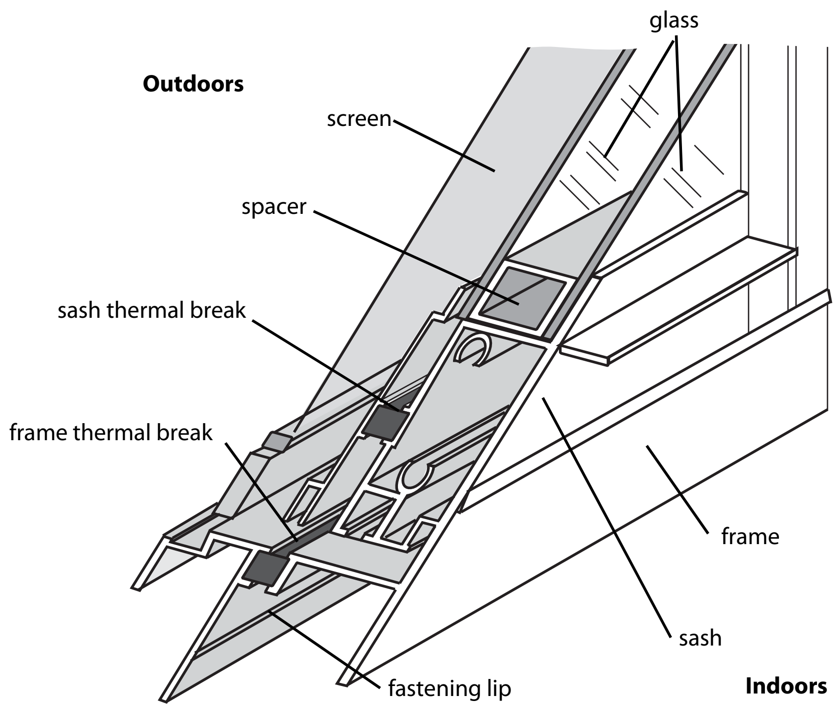
Follow all manufacturer's instructions when installing interior storm windows. Use adhesive foam tape to seal storm windows between their flanges and the interior wall. The steps for storm window installation are similar to the 6 steps listed above.

Window Insulation

Insulating shades and draperies are very effective at insulating windows and improving comfort indoors. They are expensive and require many years to return your investment, but they cost considerably less per square foot than a new window. Added insulation for the shell of the home and installation of storm windows should take priority over insulating window coverings, however.

If your home is well-insulated and the windows present a comfort problem in cold weather, window insulation will improve your comfort and save energy. The shades, draperies, or shutters are more effective if they are airtight, because they create a dead air space between themselves and the glass. This airtight seal also prevents warm, moist indoor air from depositing condensation on the glass.

Figure 9-13 Thermopane Window



Thermopane windows with thermal breaks are the replacement window of choice for cold climates. For hot climates, window shading is more important than installing multiple layers of glass.

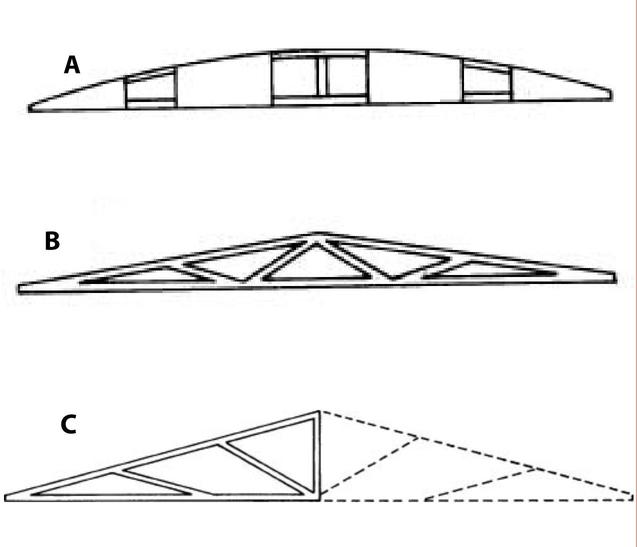
Chapter 10 Roofs and Ceilings

The roof of a mobile or manufactured home is often the most cost-effective place to reduce winter and summer heat flows. This chapter explains how to insulate and repair your home's ceiling and roof.

Roofs are the main source of heat loss in the winter and heat gain in the summer. As a result, roofs are the main contributor to high energy bills in manufactured homes.

A leaking roof is a serious and urgent problem that can also ruin the building quicker than almost anything else.

Figure 10-1 Three Common Types of Mobile Home Roofs

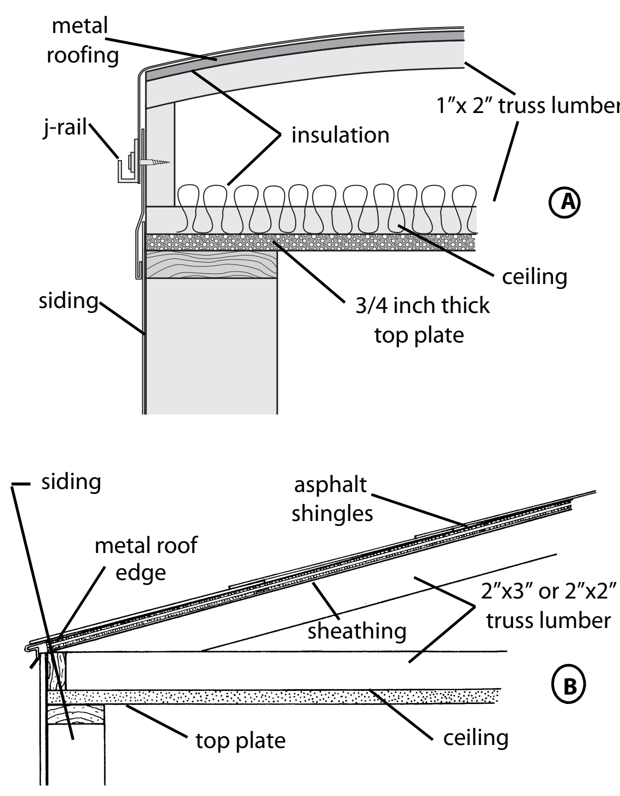


A. Bowstring trusses are common with metal roofs; B. Sloping standard trusses are common with shingle roofs; and C. On double-wides each unit has a half truss roof which combines with the other half to form a gable roof.

Roof Design

Most mobile home roofs are built with either bowstring trusses, standard sloped trusses, or half trusses. The centers of trusses are generally spaced 16 inches apart. Occasionally, you may find trusses spaced 24 inches apart.

Figure 10-2 Corner Details of Mobile Home Roofs



A. Construction detail of a metal roof; and B. Construction detail of a standard sloped roof with asphalt shingles.

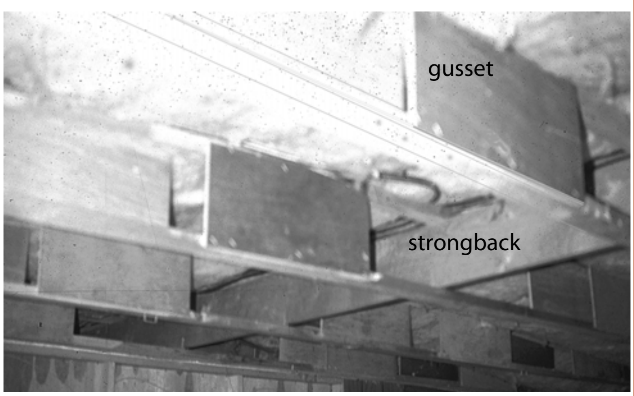
Bowstring trusses have the shallowest cavities. These cavities are usually not vented. Standard-sloped roofs on single-wide homes usually have a little more room. Half trusses on double-wide homes have as much as two feet of space between the ceiling and roof. Cavities under shingled roofs are usually vented, and HUD now requires homes with non-metal roofs to be vented. (*See "Ventilating Attics and Crawl Spaces" on page 66.*)

Roofing Materials

Manufactured homes have either metal roofing or asphalt or fiberglass shingles. Metal roofs are 30-gauge galvanized steel, rolled and crimped together in pieces 3.5-to-4.5 feet wide. The seams run crosswise across the roof. Metal roofing isn't attached to the trusses, but instead is attached to the top edge of the wall.

Shingles usually accompany sloped roofs on newer single- and double-wide homes. Shingles are nailed to plywood or some type of wood composite sheathing attached to these trusses.

Figure 10-3 Bowstring Trusses



Trusses are held together by gussets and reinforced by a strongback.

Existing Roof Insulation

Older single-wide mobile-home roofs are constructed with shallow roof cavities that have 1-to-4 inches of insulation installed on top of the ceiling between the trusses. Metal roofs often have some insulation underneath the metal roofing to reduce condensation. Some homes have insulation both on top of the ceiling and underneath the roofing—fiberglass, 1-or-2 inches thick in each place.

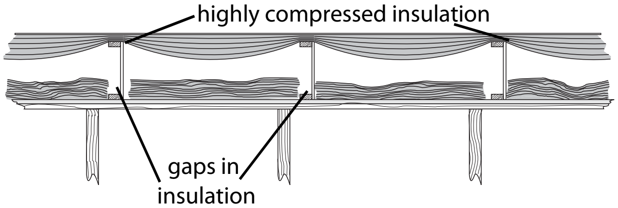
Many mobile and manufactured homes have inadequate roof insulation. Gaps in the insulation between trusses, insulation voids created by careless installation, and shifted insulation caused by the home's transportation all reduce roof cavities' R-values. Fortunately, mobile home roof cavities can be re-insulated.

Trusses and other objects in the roof cavity are obstacles to installing more insulation. The arrangement of roof framework will dictate what methods are used to add insulation to the roof cavity, or how insulation will be fastened to the roof surface. Roof-cavity installation methods must install insulation completely around any obstacles for the insulation to be effective. Obstacles on the roof like chimneys, vents and strongbacks require care and planning when installing rooftop insulation.

On metal roofs, you can determine the location of trusses and other structural framing by walking on the roof and feeling where the roof is most solid. To inspect the roof cavity from inside the home, look for some convenient access where you can see the construction details and thickness of insulation. The furnace closet or water-heater closet may have a hole or gap around the chimney that allows for inspection.

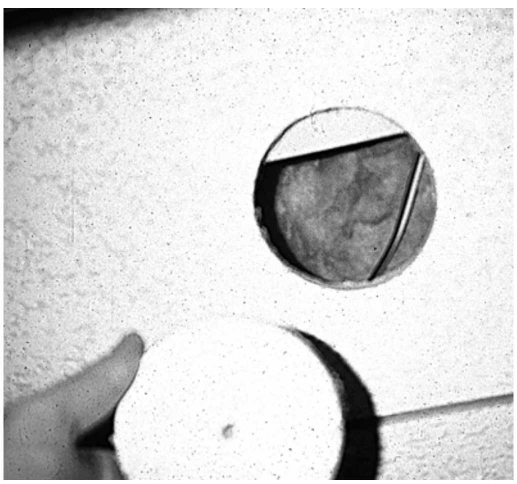
Or, drill a 4-inch hole with a hole saw in the ceiling of a closet near the center of the home's width anywhere along its length. A 4-inch hole allows room to reach up into the cavity, measure the thickness of existing insulation at the ceiling or roof, and note construction details that affect insulation installation. (Patch the hole with a 4-inch plastic plug or the original round piece of ceiling tile sealed with caulking or construction adhesive).

Figure 10-4 Insulation Installation



Gaps in insulation and highly compressed insulation are two reasons why roof R-values are often low in manufactured homes.

Figure 10-5 Ceiling Inspection Hole



A 3- or 4-inch inspection hole allows the inspector to look and actually reach up into the narrow cavity to measure the depth of the insulation.

Removing the siding at the gable end gives an excellent view of the roof's construction and its insulation level. Corrugated-metal gable siding and even lap siding are fairly easy to remove. Installing insulation through the gable can be an effective way of filling part of the roof after the inspection.

Use great care when inspecting roof cavities from up on the roof, because of the potential for causing a leak. On shingle roofs, remove a gable vent (gables are the triangular wall sections at the roof's ends) and inspect the cavity with a flashlight. Or, remove vents or patches on the roof to inspect the roof cavity. The vents or patches should be carefully resealed when inspection and insulation are complete.

Roof Moisture Problems

Condensation and roof leaks cause moisture problems in roof cavities. Repair leaks and solve condensation problems before insulating. Otherwise, moisture problems could damage the insulation and reduce its effectiveness.

Vapor barriers are used to prevent attic condensation problems. The 1976 HUD Code required a vapor barrier in mobile home attic. The HUD Code's 1994 revisions required attic ventilation. Carefully air sealing the ceiling is even more important than the vapor barrier because air leaks can transport moisture faster than vapor diffusion.

How do you discriminate between a roof leak and a condensation problem in the roof cavity? Roof leaks will show themselves after rain or during snow melt. Roof leaks are usually marked by stains having concentric rings—darker at the center and lighter toward the edges.

Roof-cavity condensation usually occurs during cold weather, especially during a sudden thaw or on a sunny day when the sun melts ice frozen in the roof cavity. Condensation stains tend to be found in clusters near the home's edge. Condensation stains might look like roof leaks if they're near a large air leak between the home and roof cavity.

Figure 10-6 Incomplete Roof Insulation

In winter, the uninsulated metal roof at the edge of this mobile home sweats, staining the ceiling. Installing blown ceiling insulation solves this problem.

Roof Condensation

Condensation in roof cavities is often mistaken for roof leakage. Condensation occurs when warm moist air touches a cold surface or mixes with cool air. If warm, humid, house air escapes into the roof cavity during winter months, water condenses when this air touches the roof's cold underside. Water droplets form on the roof's underside soaking wood sheathing, rusting metal roofing, and/or dripping down and staining the ceiling below.

Condensation can saturate wood roof sheathing, softening the sheeting by dissolving its glue. Localized areas of softening are usually caused by large air leaks or roof leaks. Wider areas of softening may be caused by high indoor relative humidity coupled with no vapor barrier. Or, the attic may be cooler than humid outdoor ventilating air, leading to condensation on the sheathing. If the plywood or particle board under the shingles feels soft throughout the roof, the problem is probably caused by widespread condensation, wetting the sheathing from underneath.

In summer months, cool, dry, air-conditioned air from the home and hot, humid air from the roof cavity meet at ceiling penetrations (such as holes around pipes and wires) or at seams (such as the marriage wall of a double-wide home). This summertime condensation is often marked by dark-colored mold colonies in the ceiling panels and surrounding lumber.

Homes with ducts in the ceiling may see condensation during summer air-conditioning, when water condenses on the cool ducts or at leaks in the ducts, and then drips onto the ceiling.

To reduce roof-cavity moisture, provide better site drainage. Install a ground-moisture barrier. Reduce indoor humidity. Seal air leaks in the ceiling and walls. Check existing vents—they may not be circulating air or the roof may be un-ventilated.

Roof Leakage

Roof penetrations and seams are the most likely places for metal-roof leaks. Water puddles are also a common problem on the metal roofs of single-wide homes because these roofs don't have much of a slope, and water can collect in small indentations. Rumble washers, used to reduce roof rumble, are also a common roof-leak area. The edges of shingle roofs sometimes deteriorate from ice-damming in cold climates. Shingles often blow off in windy areas, causing leaks.

Inspect the following areas carefully for leaks.

- Flashing around vents, pipes, and chimneys,
- Seams in metal roofs,
- Joint between roof and wall on metal roofs,
- Rumble washers on metal roofs,
- Damaged shingles, especially at the roof edge, and
- Flashing around evaporative coolers.

Localized areas of soft sheathing around penetrations or at the roof edge are probably due to roof leaks or to large air leaks in the ceiling that deposit condensation in the roof cavity.

If you encounter a wet roof cavity, seal roof leaks and all areas that might leak.

Roof-Cavity Ventilation

Stopping the moisture's entry is essential to preventing attic moisture problems. Attic ventilation is a last resort for removing condensed moisture or leaked rain water. Relatively dry outdoor air can be used to ventilate and remove accumulated moisture from attics. Attic ventilation usually has a drying effect on attics but sometimes has a wetting effect.

Ventilating with outdoor air can remove moisture from the attic, but only if air circulates through the wet parts of the attic and only if the air is relatively dry—two requirements not always fulfilled. Even with this ventilation, moisture still invades the attic.

If the cavity is still wet after sealing roof leaks and reducing moisture sources, consider power-ventilating the roof cavity. Buy a fan-powered vent and install it on the rooftop or in the gable. Run the power-ventilator when the weather is the warmest and driest for your region. Humidistatic controllers can automatically ventilate the roof cavity when the humidity is favorable. Power ventilators should pressurize the roof cavity in cold climates and depressurize the cavity in warm climates. Pressurizing the cavity in cold weather keeps moist indoor air out. Depressurizing the roof cavity in hot weather prevents hot humid attic air from being forced into the air-conditioned home.

The 1994 revisions to the HUD Code require attic ventilation with at least 50% of the vent area located high on the roof of new manufactured homes. At least 40% must be low on the roof—soffit vents, eave vents, or low gable vents. Metal-roofed mobile homes having no roof sheathing are an exception to the new rule and need not be ventilated. (*See "Ventilating Attics and Crawl Spaces" on page 66.*)

Roof Maintenance and Repair

Roof maintenance and repair are the most important tasks to insure the longevity and structural integrity of the home. Whether or not you plan to add insulation to the roof cavity, roof maintenance and repair work should be your first priority.

Sealing Cracks and Holes Ceilings

The roof cavity's underside inside the home is commonly called the ceiling.

To patch a large hole in the ceiling, cut out a rectangular piece including the damaged section between two truss centers. Use the trusses as fastening backers for the patch. To reinforce the patch's other two joints, use two 1-by-4 or 2-by-4 wood pieces installed at right angles to the trusses. Attach these cross pieces with screws and construction adhesive. Predrill holes for the screws. Make the patch from matching material such as white fiberboard or sheetrock.

Figure 10-7 White Latex Roof Coating

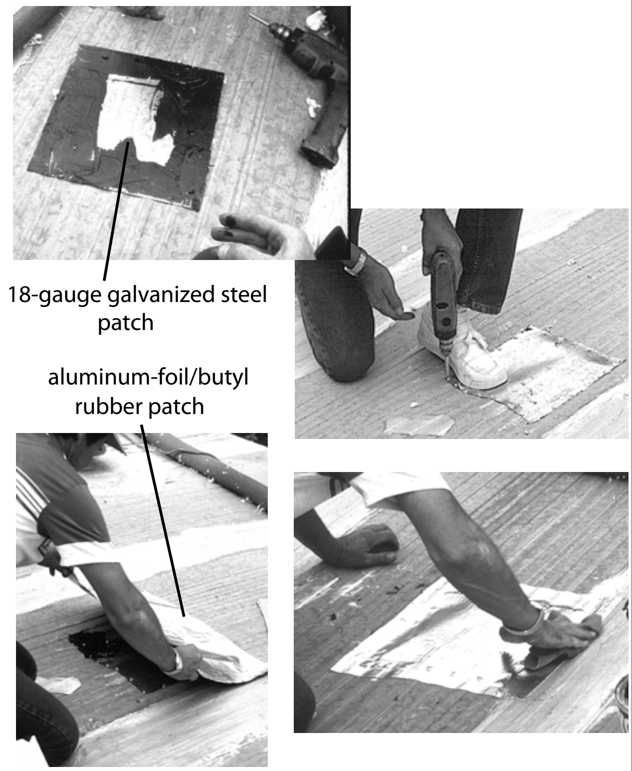
Technician applies a patch, using two layers of the coating with reinforcing fabric in between.

Smaller holes can be patched without cutting all the way back to the trusses. Use short pieces of 1-by-4 for backers on two sides of the patch. First screw through the ceiling into the 1-by-4 pieces while holding these pieces firmly against the attic side of the ceiling. Next screw the patch to these same 1-by-4s. Then seal the seams with caulking or sheetrock joint compound and fabric tape.

Medium-sized gaps around penetrations can be stuffed and then caulked. For stuffing, use foam rubber or fiberglass (be sure to use fiberglass around chimneys, since it is fire-resistant). Use pure silicone caulk near chimneys that may get hot. Manufactured homes usually have double- or triple-wall chimneys, so special caulking around them isn't usually necessary, because they don't get much warmer than 140°F. Even triple-wall chimneys need to be 2 inches away from combustible materials. Double-wall chimneys often have additional protective metal collars around them at the ceiling. If your chimney collar is missing you can make a new one out of a doughnut-shaped piece of lightweight aluminum sheeting with a slit to allow its installation around the chimney.

Seal smaller cracks and gaps (around flues and plumbing vents that penetrate the ceiling) with acrylic latex caulk.

Figure 10-8 Patching a Large Hole



A technician screws a metal patch to the metal roofing after applying mastic to the patch's underside. A second patch of foil-faced sticky butyl rubber is applied over the first. This second patch is rubbed (in cold weather, it's heated too) to help it adhere.

Repairing Roof Leaks

Roof leaks are among the most destructive of building problems. Roofs should be inspected and maintained regularly.

Metal-Roof Repair — The most important consideration for patching a metal roof is to try to build up the area to be patched so that it doesn't lie in a depression. You may need to make the hole bigger in order to insert plywood or insulation to push the flexible roof up slightly at the patch. A patch located at a low point in the roof will likely fail.

The most common and inexpensive all-purpose patching system for metal is asphalt-based black mastic, reinforced with fabric webbing. Apply this patch by spreading the mastic in a thin even base coat with a trowel. Then, lay fabric webbing into the base coat, and cover the webbing with a top coat. After drying, brush the patches with an asphalt-aluminum coating. This bright-silver coating, which contains reflective aluminum particles, will help protect the patch from damaging sunlight and heat.

Sheets or strips of butyl rubber with aluminum-foil skin make quick patches on metal roofs. These instant patches stick tenaciously to warm roofs. If installed during cooler weather, they may need to be heated to make them stick adequately. This butyl-aluminum sheeting, packaged in rolls 4-to-36 inches wide, is clean and convenient to install.

White latex rubber roof coating is a long-lasting and highly reflective roofing material. Latex rubber is spread from 5-gallon buckets with a brush, roller, or spraying machine. The most durable applications are reinforced with fabric webbing with coating applied in several coats. Surface preparation is crucial to adhesion of latex roof coating, which is very sensitive to both water and oily residues. Follow the manufacturer's instructions precisely to ensure success. Some latex coating systems employ a primer coat with one or more top coats. Latex roof coatings can be used on both metal and asphalt roofs.

Covering the entire metal roof with white latex rubber coating or with asphalt-aluminum coating prolongs roof life, saves money on air conditioning costs, and improves summertime comfort. The bright-white latex coatings are preferable in hot climates because they are such good solar-heat reflectors.

Shingle-Roof Repair — Leaks in shingle roofs are difficult to find. These roofs have many seams that could be leaking, but how do you know which ones are? The sun, rain, hail, wind, and the thawing and refreezing of snow eventually wear shingles out. This wearing process takes 15-to-30 years, depending on climate.

When a shingle roof leaks, it's usually time to replace it. You'll have to tear the existing shingles off before installing new ones because a manufactured home's roof is not designed to support the weight of multiple layers of shingles. Carefully renail the roof sheathing before installing new shingles.

It's possible to replace a shingle or a section of shingles, damaged by wind or ice-damming. Pry the damaged shingles' nails out and then loosen the nails in the shingles above the damaged ones. Remove the damaged shingles and nail in their replacements, reinforcing the bonds between them with roof cement if you live in a windy area.

Sheets of aluminum or galvanized steel are also used to patch shingles. These 5-inch-wide patches are shoved under shingles, to protect worn surfaces under the tabs. Use roof cement to glue them in.

If appearance isn't important, worn shingle roofs can be renewed by applying a generous coat of asphalt-aluminum roof coating every 5-to-10 years.

Roof Structural Repair

If you live in a windy region, consider installing straps or metal plates to fasten the trusses more tightly to the wall. Strapping that bonds the truss to a wall stud every 2-to-4 trusses is particularly effective. During repairs, inspect the perimeter of the roof carefully to make sure that the edge of shingles or metal roofing lay flat, especially if you live in a windy region. There should be no roofing, trim, or fasteners protruding, open, or loose. The wind can pry under protruding areas and eventually tear them off.

If water stands in puddles on a metal roof, eventually the roof will leak there. Large indentations or creases in metal roofing may indicate a leveling problem. If this is the case, the sagging should also be noticeable at the floor level—refer to information about leveling mobile homes presented in *Chapter 2* ***Foundations***. If your foundation is level, the indentations are likely due to a sagging roof structure.

Truss repair can be done from the rooftop or from underneath; the rooftop option is generally easier. But, if the roof has leaked and you have to replace the ceiling, you can repair the trusses and sagging roof at the same time you replace the ceiling. If you replace the ceiling tile, note that it extends over top of the interior wall. Therefore, you'll have to cut the ceiling at the wall's edge to remove a piece of ceiling tile damaged near its edge. Be sure to reinstall the vapor barrier if you replace sections of ceiling unless you live in a warm climate.

To fix indented sections of metal roof caused by sagging metal or damaged trusses, cut out three sides of a rectangle, leaving the fourth as a hinge in the area of the metal roof where the water puddles. Fold back this flap of roofing and repair damaged trusses. The metal roofing isn't usually attached to the trusses.

Usually a truss can be repaired in place, without removing it. Since the lumber is of smaller dimensions—typically 1-by-2s, 2-by-2s, or 2-by-3s—than lumber used on site-built houses, repairing the truss is more like furniture-making than ordinary house carpentry. Use construction adhesive and screws driven into pre-drilled holes to fasten repair lumber and plywood. Gussets (sheeting fastened to the sides of trusses to strengthen them and help them hold their shape) can be made from scrap wood paneling or $^1/_4$-inch plywood.

It's not usually necessary to remove broken truss lumber. Unless splinters are obstructing the repair, just bridge the break by a couple feet on each side with similar-dimension lumber as the broken piece. If the lumber is badly splintered or rotten, cut the damaged lumber out. Avoid attaching patches to the truss's flat side—this will allow you room to reinforce the truss's weak area with a plywood gusset glued and screwed to that flat side. Fasten the lumber patches and gussets with both screws and glue for maximum strength.

Reinforcing a sagging metal roof involves slipping plywood or $^3/_4$-inch-thick lumber underneath the metal roofing and over top of the trusses. The plywood or lumber will raise the low area, establishing better water drainage. But, be careful that during the repair you don't create another low spot by building the sagging area up too high. After fastening the plywood to the trusses with glue and screws, fold the roofing flap back to its closed position and fasten it to the new plywood with short sheet-metal screws. Cover the whole cutout area with a metal patch overlapping 4 inches in all directions. Screw the metal patch to the existing metal roof and to the plywood reinforcing panel with sheet-metal screws. The edge of the patch should be bedded in roof cement and the seam sealed with one of the coating methods described in *"Repairing Roof Leaks" on page 126.*

Eliminating Roof Rumble

Roof rumble is a common complaint from occupants of manufactured homes with metal roofs. Since metal roofs are typically attached only at the perimeter of the roof (along the top of the wall), the metal roof skin lays loosely on top of the trusses. As a result, some metal roofs move and rumble in the wind or with changing temperatures.

On a windy day, you can look up to the roof and see what areas are making noise. Then, after the wind quits blowing, get up on the roof and secure the roof's rumbling areas to its trusses. A rumble washer is large washer with a rubber gasket and a small hole for a sheet metal screw in the center. Install screws and rumble washers one or two at a time. Don't use any more than necessary, because they are can cause leaks. Use roofing sealant over the rumble washers to prevent them from leaking. Remove the rumble washers before moving the home to prevent them from wearing holes in the roof, which moves during transport.

Roof-Overs

A roof-over or Ramada Roof is a new site-built roof, installed atop a mobile-home roof. Roof-overs should be self-supporting like pole barns. In fact, many roof-overs are just small pole barns. Insulating the roof cavity with fiberglass and installing an insulated rubber or urethane roof is less expensive and usually a better way of obtaining a new insulated roof.

Roof-overs weigh thousands of pounds that the home was never designed to support. If you have an existing roof-over that is not self-supporting, you should install perimeter footings and piers every 8 feet underneath the home's edge to prevent the home's rim joist from sagging. If you plan to build a roof-over, consult a book on pole buildings.

Figure 10-9 Protecting the Chimney

This technician is stuffing unfaced fiberglass batts around the chimney, forming a dam to prevent blown-in polystyrene beads from touching the double-wall chimney.

Roof Insulation

Adding insulation to a mobile and manufactured home roof cavity presents special challenges, because it is usually not possible to physically venture into the roof cavity, as usually can be done with a site-built home.

Before following the procedures below, review *Chapter 6* ***Insulation*** for a thorough discussion of general materials and techniques.

Moisture and Roof-Cavity Insulation

Filling a mobile home's metal roof cavity with insulation is controversial. Eliminating the cavity's 2-to-6-inch air space will inhibit drying should the insulation get wet. Therefore it's very important to ensure that the insulation doesn't get wet by patching and coating all potential leak sites and by thoroughly air-sealing the ceiling from the interior.

Filling the roof cavity can actually prevent condensation by eliminating the air spaces where the warm, moist air and the cool, dry air mingle. Insulation also can restrict the flow of moist air from home or outdoors. The insulation closer to the ceiling is likely to remain drier than before, because it is kept warm by new insulation above it.

Moisture problems are caused by filling metal roof cavities with blown fiberglass. Most metal roof cavities are not vented. The new insulation doesn't restrict outdoor ventilation air in these cases, because there wasn't any to begin with.

However, vented roof cavities—primarily shingle roofs with sheathing—should not be completely filled. Doing so would reduce outdoor air circulation that can carry moisture away through vents. A space at the top of the cavity—including areas underneath roof vents—should remain open.

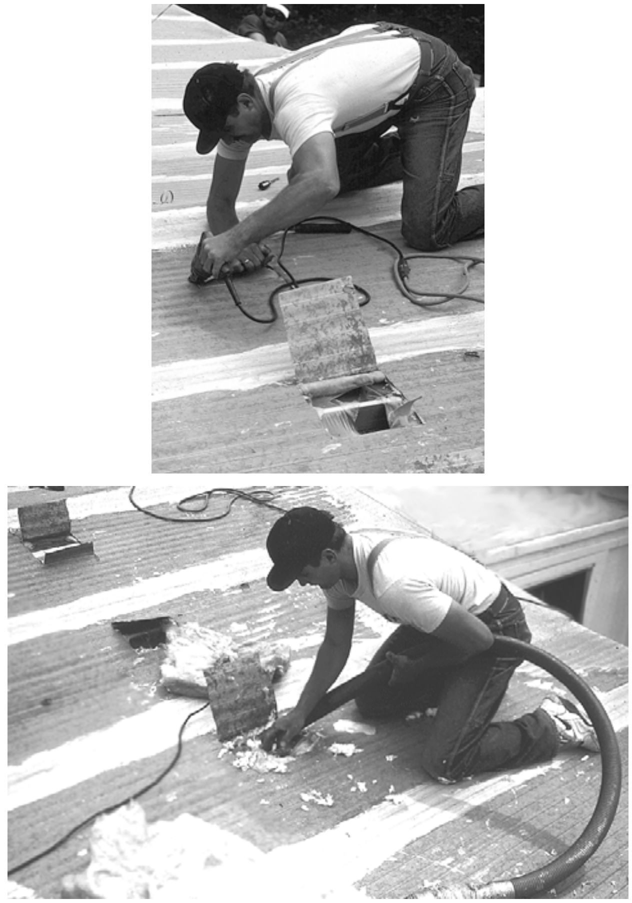
In case condensation or roof leakage do occur in the future, select lighter and less absorbent insulation materials for insulating roof cavities. Cellulose is too absorbent to be used in un-vented metal roof cavities. Fiberglass absorbs far less water than cellulose. Polystyrene beads absorb even less than fiberglass.

Roof-Cavity Insulation

Blowing insulation into the roof cavity is the most effective and economical method for adding insulation to the manufactured home's roof assembly.

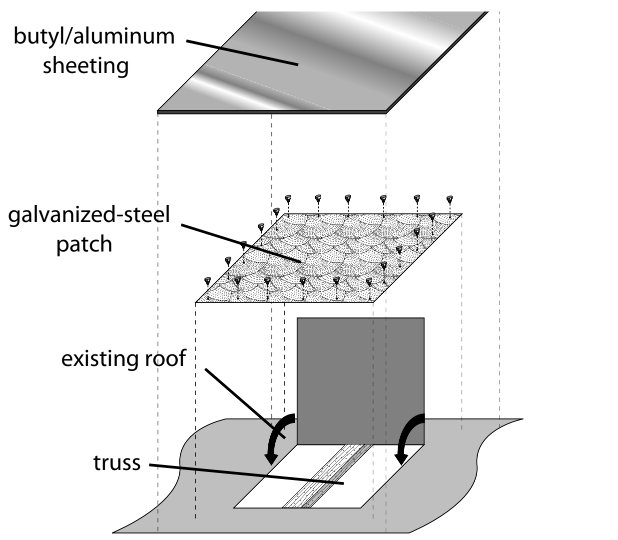
Blown insulation is cheaper than the foam insulation installed on rooftops. And, it's more effective than merely installing rooftop insulation, because blown insulation provides a continuous, seamless blanket where it does the most good—directly above the ceiling. Leaving an air space between indoors and the new insulation—as happens with most applications of rooftop insulation—doesn't work as well as a thick insulation blanket right above the ceiling.

Figure 10-10 Blowing a Metal Roof Cavity



A technician cuts 10" by 10" holes, inserts a flexible fill-tube all the way to the edge of the home, then blows insulation, pulling the tube out as the cavity fills.

Figure 10-11 Square Holes for Insulating



Square holes can be easily patched with galvanized steel glued with roof cement and screwed with self drilling screws. The second patch is stick butyl rubber with an aluminum-foil skin.

Preparing for Roof-Cavity Insulation —

Remember, insulation will lose its thermal resistance if it gets wet. Look for signs of past water damage inside and outside. Find out why the damage occurred.

Before proceeding with roof-cavity insulation on metal roofs or on shingle roofs, carefully follow these preparatory steps:

Step 1: Inspect the ceiling, including closets and cabinets. Completely seal all penetrations and seams in the ceiling.

Step 2: Inspect all seams on the roof, especially those around roof penetrations. Seal open seams and repair damaged areas before or during insulation.

Step 3: Take steps to maintain safe clearances between insulation and hot objects like flues and recessed light fixtures—especially when using polystyrene-bead insulation.

Roof-Cavity Insulation – Metal Roofs —

After you have adequately prepared, you are ready to gain access to roof cavities under metal roofs. Be sure to have your patching materials selected and on-site. Read the relevant parts of *"Repairing Roof Leaks" on page 126* before cutting holes and installing patches. Listed below are five options for getting access and blowing insulation:

Option 1: Cut 10-inch-square holes in the center of the metal roof on top of every other truss. This will allow access to roof cavities on both sides of the trusses. Centering the 10-inch-square hole on top of the truss produces two 4-by-10-inch rectangular holes that provide access into two adjacent truss spaces. These holes provide enough room for roof-cavity inspection and for moving the insulation fill-tube around, providing good coverage. Blow fiberglass insulation through a 2-or-$2^1/_2$ inch diameter flexible fill-tube into the cavity all the way out to the edges. To patch the holes use 14-by-14-inch square piece of 18-gauge galvanized steel, screwed to the galvanized roof and glued with roof cement. Cover that patch with an 18-by-18-inch square of foil-faced butyl rubber.

Figure 10-12 Blowing Insulation through the Roof's Edge

Technicians stand on scaffold to blow fiberglass insulation through the edge of the roof and into a metal roof's cavity.

Option 2: Remove the screws from the metal j-rail along the length of the roof edge on the leeward side of the home, if possible. Then remove the staples or nails that hold down the roof edge. Pull up the metal roof far enough to insert a 10-to-14-foot rigid fill-tube. Blow fiberglass insulation through the fill-tube into each truss space. Reseal the edge thoroughly using putty tape or exterior-grade caulking under the roof edge and j-rail. This method won't work if the roof has a strongback that prevents the tube from going all the way across the home. (*See page 122* for a photo.)

Option 3: Remove the siding on each end of the roof cavity. Insert a long, rigid fill tube into the cavity as close to one edge as possible. Fill the cavity from the edges toward the center. The longer the fill tube the more difficult to ensure an adequate fill. This method is best combined with one of the other options, especially Option 1. Filling from each end with a 16-foot fill tube would save cutting and patching about a dozen 10-by-10-inch holes.

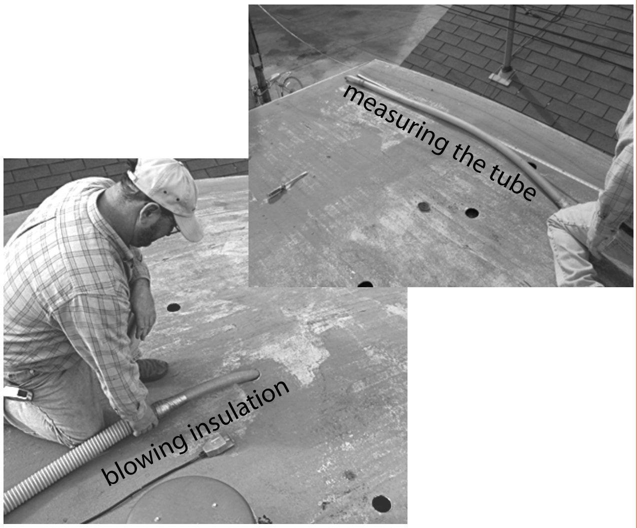
Option 4: Drill one or more rows of $2^1/_2$-inch holes in the metal roof. Use these holes to blow insulation into the roof cavity through a $1^1/_2$-inch flexible fill tube. After insulating, patch the holes with $2^1/_2$-inch plastic plugs, cemented in place with pure silicon caulk. Then, cover plugs with a 6-inch square butyl-aluminum-foil patches.

Figure 10-13 Blowing through the Ceiling Indoors

The technician is careful not to damage the ceiling board when inserting the tube and pulling it out.

Option 5: Drill one or more rows of $2^1/_2$-inch holes in the interior ceiling along the length of the home. Use a line or spacer block to drill the holes in straight rows. Next, blow in fiberglass or polystyrene beads through a flexible fill tube. Then, cement $2^1/_2$-inch white plastic plugs into the holes with construction adhesive or adhesive waterproof caulk. The plugs appears fairly natural against a white ceiling.

Figure 10-14 Blowing the Roof Cavity through Holes in the Metal Roof



Before blowing insulation, the technician first measures and marks the tube so he'll know when the tube is inserted all the way to the edge.

Figure 10-15 Insulating a Single-Wide from the End Wall

It's fairly easy to insulate the first 15-to-25 feet of roof cavity from the ends. Starting from the edges and working toward the center usually works well.

Roof-Cavity Insulation Shingle Roofs —

Shingle roofs usually have a steeper slope and more space inside the roof cavity than metal roofs. Shingle roofs are usually vented—these vents should not be obstructed. Leave at least 12-to-18 inches of vent space above the insulation at the peak of the roof. New roof vents may even be added to improve ventilation and provide better access for blowing insulation.

Figure 10-16 Insulating Shingled Double-wide Roof Cavities

Technicians can look into a double-wide home's roof cavity to monitor their progress. With a deeper cavity, it's easier to move the hose around and to insulate a large area from one hole exposed by removing a vent.

Use the two options below—separately or together—to insulate shingle roofs:

Option 1: On double- and single-wide homes, you can insulate large areas of the roof by blowing insulation through existing roof vents. The roof-vent holes are usually about 10-inch square and provide enough room to move the hose around, blowing in all directions through each hole. Areas of the cavity that may be unreachable from existing vents can be insulated through newly-installed vents.

Option 2: Remove vents in the gable end—the roof's triangular end wall; or, cut new vents in the gable end; or remove the siding from the gable end. Removing the siding from the entire gable end gives superior access to the roof cavity for insulation installation and inspection. Insert a long rigid fill-tube. Blow insulation very carefully, starting from the middle of the roof cavity and filling toward the gable ends. Stop frequently to inspect the cavity using a flashlight. Notice where insulation has covered and where it hasn't.

Rooftop Insulation

Adding insulation to the top of a metal roof is a more common practice than blowing the cavity under the metal roof. However, rooftop insulation is more expensive than cavity insulation, and it isn't as effective as cavity-filling for homes in cold climates. Rooftop insulation is most economical for homes with high air conditioning costs and high heating costs that also need major roof repairs. Before adding rooftop insulation, fill the roof cavity with blown fiberglass to maximize energy savings. Rooftop insulation over a poorly insulated roof cavity will provide considerably less energy savings than roof-cavity insulation.

There are three common ways to add insulation to the top of a roof:

1. Installing 2 inches or more of rigid insulation, followed by a synthetic rubber cap over the insulation.
2. Installing 2 inches or more of rigid insulation, followed by a metal roof over the insulation.
3. Spraying 2 inches or more of polyurethane over the existing metal roof and coating it with a waterproof coating.

Figure 10-17 Rooftop Insulation

A crew installs beadboard insulation over a metal roof, fastening the insulation down with screws and large washers.

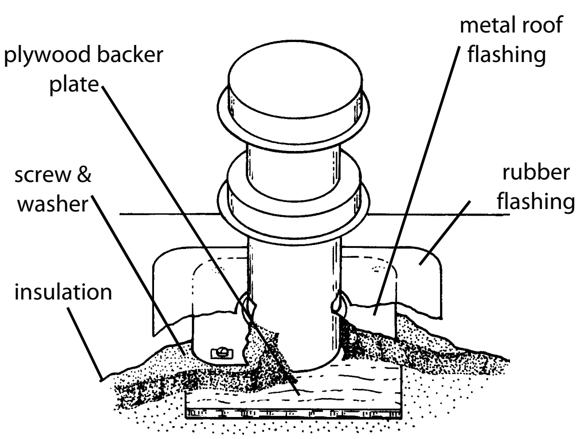
Insulated Rubber Roof Cap — An insulated synthetic rubber roof cap significantly reduces winter heat loss and summer heat gain through a roof. This roof cap covers the home with a membrane that will last at least 30 years, if installed correctly.

Follow the manufacturer's instructions carefully. If installed with excellent workmanship, the membrane could last 50 years. With poor workmanship, the membrane could leak in 10 years or less.

Figure 10-18 Covering the Insulation with Rubber Roofing

A technician drags the continuous sheet of rubber roofing across the roof.

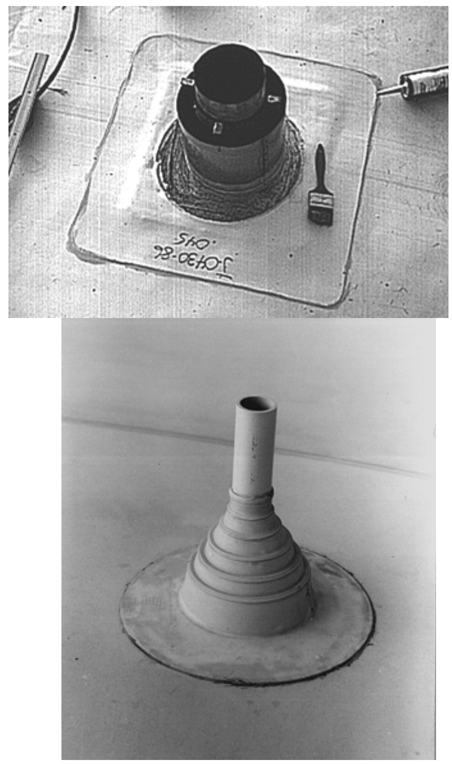
Figure 10-19 Flashing Detail for an Insulated Rubber Roof



The plywood plate, fastened to the old roof under the insulation and new roofing, gives solid backing for the screws that hold the metal flashing down.

Although black is the most common and least expensive type of rubber roofing, a bright white rubber is preferred. Black roofs get hot and the heat could shrink the insulation. Especially in warm climates, white rubber roofing is worth the extra cost.

Figure 10-20 Flashing Around Chimneys and Plumbing Vents



The lifespan of the roof depends on the careful installation of flashing around chimneys, pipes, and vents. The flashing on the top is manufactured; the one on the bottom is site-fabricated.

With insulated rubber roofing systems, insulation board—polyurethane foam or polystyrene foam—is installed directly over the existing roof and then covered by rubber roofing material. These are general instructions to let you know what's involved. Follow the specifications and instructions of the roofing manufacturer carefully when you actually install the roof. Following are general installation instructions.

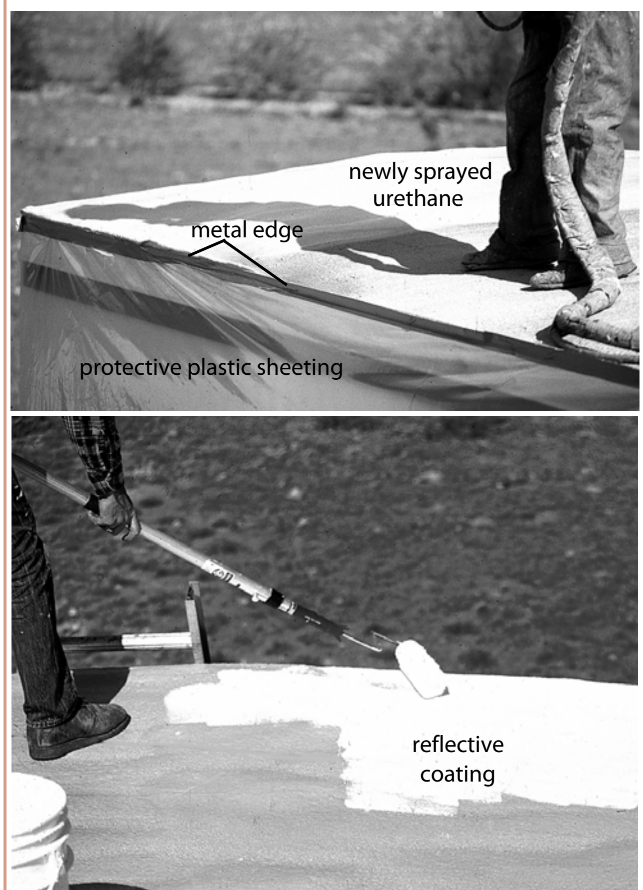
Step 1: Remove existing plumbing and heating vents protruding from the roof; also remove the vent flashings around these protrusions. Remove roof-mounted evaporative coolers and raise their mounting blocks above the level of the new roof. The new roof level equals the old roof level plus the thickness of the insulation and the rubber roofing. If there isn't any solid surface around the chimney underneath the existing metal roofing, fasten plywood squares to the existing roof surface around the chimney to provide a wood backer for fastening the chimney flashing through the new roofing and insulation.

Step 2: Fasten the insulation board to the roof trusses using screws long enough to penetrate into the truss $^1/_2$-to-1 inch. Use large washers, called fender washers or roof deck plates, to prevent the screws from pulling through the insulation. Cut the insulation to fit around all the vent holes. Leave at least 3 inches clearance around hot vents like wood stove flues. Stuff fiberglass around pipes and vents to insulate spaces left by mis-cuts or spaces intentionally left for fire safety clearance (heat shouldn't be a problem here—fiberglass is noncombustible and all legal chimneys are double- or triple-wall).

Step 3: Lift the leading edge of the membrane over the edge of the roof and drag it up onto the roof. This is a job for two-to-four people. Spread the membrane out so that at least 6-inch overhangs on all sides. Then locate all the vent holes and cut openings in the membrane for each vent.

Step 4: Extend plumbing, heating and exhaust vents at least 10 inches above the new roof level. Fabricate or buy new rubber flashing for around the vent pipes. New flashings can be purchased from a roofing-materials dealer or fabricated from rubber membrane on-site. Apply the membrane's special contact adhesive to the back of the flashing. It is important to apply this adhesive evenly and continuously. It is also important to keep the rubber membrane around penetrations clean during the flashing installation. After the contact-type adhesive dries, adhere the flashing, seal all seams and edges of the membrane and flashing on the roof with a special seam sealant. Remember that most roof leaks occur at seams and flashings: Careful adhesive application and seam sealing will determine how long the roof will keep water out.

Figure 10-21 Polyurethane Roof Cap



Sprayed polyurethane roofing needs a metal edge to maintain a constant thickness to the roof's edge. Plastic sheeting protects the home from overspray.

Step 5: Install the new termination bar just above or below the existing j-rail at the junction between the roof and wall. Begin at the center on both long sides of the roof and work towards the ends of the roof, driving sheet metal screws into the termination bar's pre-drilled holes. Straighten the membrane and work out any wrinkles as you proceed. Do not fasten the termination rail the last 1-to-2 feet at the corners until you have folded the corners of the rubber roofing (see Step 6). Follow the same procedure for the ends of the roof. Begin in the center and work towards the corners. Again, do not fasten the termination rail the last 1-to-2 feet at the corners until you have folded the corners (see Step 6).

Step 6: Fold the membrane at each corner so that the crease faces downward. Fasten the last 1-to-2 feet of the termination rail. Then, trim off the excess membrane hanging below the new termination rail.

Sprayed Polyurethane Roof Cap — A polyurethane foam roof cap can be installed for about the same cost as an insulated rubber roof, or maybe a little less. The polyurethane foam roof cap is not quite as durable as a well-installed rubber roof cap but could last 40 or 50 years if recoated every 4-to-10 years.

As with insulated rubber roof cap, chimneys and vents should be extended. The polyurethane must be protected from contact with chimneys. You can wrap the chimney with fiberglass during spraying so the urethane doesn't spray and adhere to the chimney.

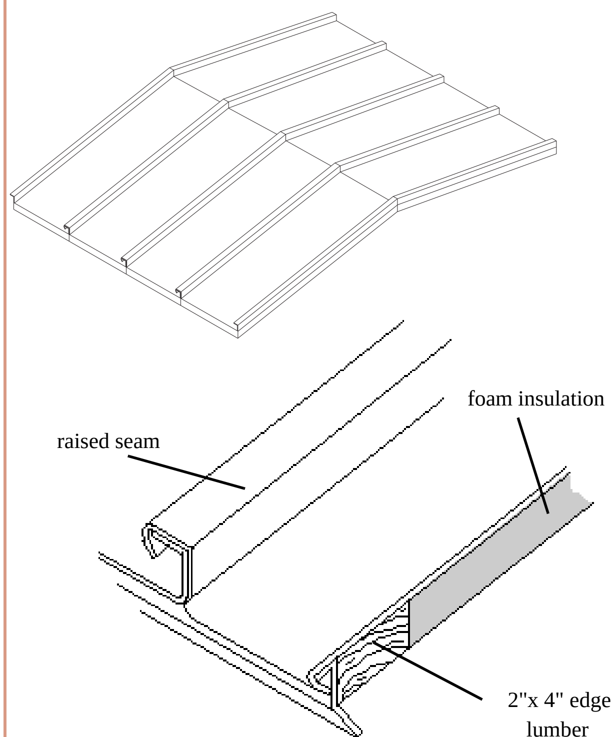
The contractor should install a metal edge around the perimeter of the roof to maintain the thickness of the insulation—usually 2-to-3 inches—all the way out to the edge of the roof.

Polyurethane insulation should not be installed on windy days or when the temperature is below 50°F. The contractor should use plastic or paper masking to prevent over-spray that could damage walls and other objects around the home.

The newly sprayed polyurethane insulation should have a smooth grainy surface like an orange peel and not look like the rougher surface of a popcorn ball.

The polyurethane should be coated with a reflective coating specially designed to protect polyurethane from sunlight and water. The coatings used with polyurethane are similar to latex roof coatings described in *"Repairing Roof Leaks" on page 126*.

Figure 10-22 Insulated Metal Roofs



Insulated metal replacement roofs are durable and offer the option of a small overhang, but they are expensive.

Metal Roof Caps — Combining rigid foam board insulation with a metal roofing system is attractive and very durable. These insulated metal roofs for mobile homes are generally the most expensive type of rooftop insulation.

Metal roof caps are available from roofing contractors and mobile home contractors. Installation requires specialized metalworking equipment.

One advantage to some metal roof systems is that the technicians can allow the new roof to overhang the exterior walls an inch or two on roofs currently lacking overhangs. Supported by metal roofing's strength, the foam insulation extends out and is boxed in by metal. The overhang provides a little shading and drops rain water away from the wall.

Roof Insulation Safety

There are important safety considerations when insulating and repairing mobile home roofs.

For occupants, roof insulation and repair can be accompanied by two major fire dangers: 1. Recessed light fixtures; and 2. Flue pipes from furnaces, water heaters, and wood stoves. And, workers must be particularly aware of two major safety considerations: 1. Walk-boards and scaffolding; and 2. Respirators.

Fire Prevention

Mobile home flue pipes are usually double- or triple-wall pipe assemblies. The surface of the outer pipe is not likely to ever exceed 140°F—within the safe range for most building materials, fasteners, and sealants. However, to be completely safe, don't install combustible material within 2 inches of these flues. Use noncombustible materials, like fiberglass insulation, an additional metal pipe sleeve, and a metal collar at the ceiling to protect combustible materials from flue's warm surfaces.

You should never see a single-wall flue pipe going through the ceiling of a manufactured home. If someone has mistakenly installed one, corrective action should be taken immediately.

Keep all insulation at least 3 inches away for recessed light fixtures except for those fixtures specifically rated for contact with insulation (IC-rated). Since crawling around in the roof cavity is usually impossible, the best way to protect a recessed light fixtures and bathroom fans is to blow insulation around them from the roof, and then remove the fixture from inside and push the insulation back 3 inches.

Installing fiberglass insulation in a roof cavity rather than rooftop insulation generally makes the roof cavity safer from a fire safety perspective, because the noncombustible insulation surrounds combustibles like wood and inhibits a fire from spreading.

Working Safely on Roofs

Metal roofs may feel a little flimsy, but they're usually safe to walk on. If you doubt the structural soundness of a roof:

1. Walk near the edge where the roof is strongest; and
2. Use plywood or wooden planks near the center.

Extend ladders at least 3 feet above the roof for ease and safety getting on and off them. Or, secure them with rope so they don't slip when you're climbing.

Use scaffolding when insulating the roof cavity from the edge or end. The long fill-tube used for this operation is too clumsy to use safely from a ladder.

Remember: Blowing any type of insulation creates dust that irritates the lungs. Always wear a respirator when you are blowing insulation.

CHAPTER 11 HEATING

This chapter discusses the operation, maintenance, safety, and efficiency of mobile- or manufactured-home heating systems.

Neglect of necessary maintenance and repair breeds high energy costs and safety hazards. Although most heating-system repair is performed by qualified technicians, home owners can be alert for malfunctions, safety hazards, and inefficiency and can perform some maintenance tasks.

Most heating technicians can repair no-heat problems with furnaces. However few know how to improve furnace or heat-pump efficiency. Improving efficiency involves measuring combustion efficiency and furnace temperature for combustion furnaces and refrigerant charge and airflow for heat pumps.

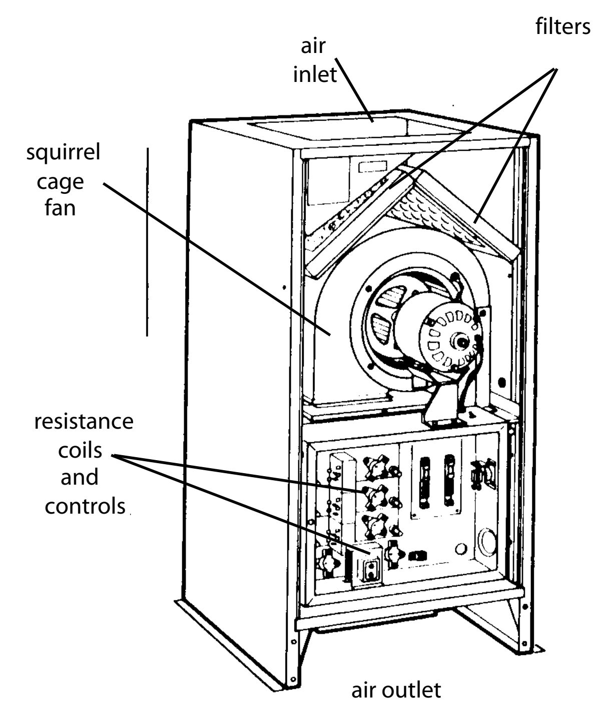
This introduction to mobile home heating equipment is not intended to be a complete repair and energy conservation reference. Manufacturers of heating devices (*See "Businesses and Organizations" on page 226.*) have owner's manuals, installation manuals, and service manuals for their equipment. These manuals have operating instructions, parts lists, troubleshooting procedures, detailed drawings, and wiring diagrams. Having a parts-and-service manual for your heating system is an excellent idea.

Furnaces

Combustion furnaces, combustion space heaters, and electric furnaces must be specifically designed and rated for use in manufactured homes. The HUD Code lists specific requirements to insure the safety of heating systems.

This section provides particulars about different types of combustion furnaces, electric furnaces, heat pumps, and space heaters.

Figure 11-1 Electric Furnace



A squirrel-cage fan blows air over 3 to 6 electric resistance coils and down into the main duct below the furnace.

Sealed-Combustion Furnaces

Heating systems in manufactured homes are different from those of site-built homes. Older furnaces in site-built homes, for example, are ***open-combustion furnaces***. Open combustion means that indoor air is pulled into an open firebox and flue.

Since manufactured homes tend to be smaller and tighter than site-built homes, open-combustion furnaces are a potentially dangerous design because they depend on outdoor air leakage to replace combustion air. Since the furnace blower inlet, near the flue, is open to the home, the ***blower*** could suck flue gases into the home if the flue or firebox were open, like they are in most site-built homes.

For occupant safety, ***sealed-combustion furnaces*** have been standard equipment since the early 1970s. Sealed combustion means that all the combustion air comes from outdoors. The firebox and flue have no openings to the interior of the home.

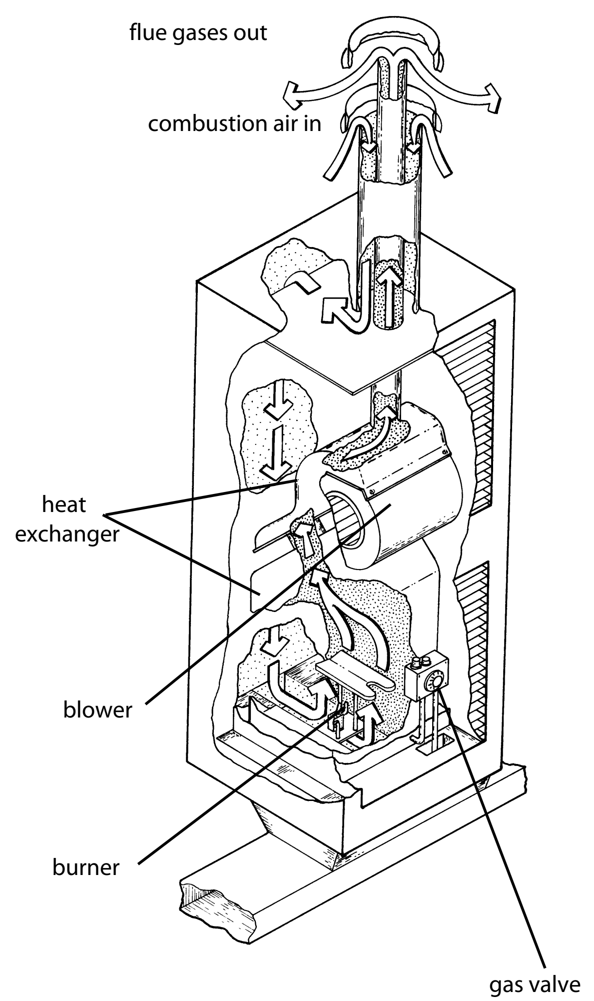
Almost all mobile home furnaces are ***down-flow furnaces***. Down-flow furnaces take in return air at the top of the furnace, heat the air, and force it into ducts beneath the furnace in the floor. Return air from the rooms is pulled back to the furnace through the hallway by the blower, which creates a large suction at its inlet.

Natural Gas and Propane Furnaces

Natural gas and propane furnaces are actually the same except for burner orifices, the pilot orifice, and the pressure setting on the automatic gas valve. An orifice is a small hole for regulating the flow of gas. A conversion kit comes with most furnaces containing the necessary parts for fuel switching. A tag, attached to the furnace, indicates the type of fuel for which it is equipped.

Gas and propane furnaces are rated by their Annual Fuel Utilization Efficiency or AFUE. Atmospheric furnaces have an AFUE of about 78%, which is the minimum allowed by modern energy standards. Modern fan-assisted gas and propane furnaces have AFUEs of over 80%.

Figure 11-2 Atmospheric, Sealed-Combustion, Downflow Furnace



Combustion air from the roof comes down the outside of the flue pipe, around the furnace cabinet, and into the heat exchanger where it mixes with gas during combustion.

Natural gas and propane burn very cleanly. A properly installed furnace should operate for decades without adjustments to its gas burners. However, some furnaces have installation or adjustment problems, indicated by the presence of soot and carbon monoxide.

Natural gas and propane can ignite outside the furnace, causing fire or explosion. If you smell gas, don't try to light any appliance and don't touch any electrical switches. Call your gas supplier, service technician, or the fire department.

Gas furnaces are classified as either ***atmospheric or forced-draft***, both described below. Both utilize what is called a ***heat exchanger***, a metal shell that transfers the flame's heat to the air circulating through the furnace. The heat exchanger also separates the home's air from the combustion gases so they won't pollute the home.

Burners and Heat Exchangers — The burner assembly on atmospheric gas furnaces should not need to be cleaned. The presence of even a small amount of black soot near the burner is a cause for immediate action. Soot indicates incomplete combustion and the formation of carbon monoxide, a poisonous gas. Soot can ruin a heat exchanger. It's almost impossible to clean soot out of the upper reaches of the heat exchanger because the interior spaces are too small to clean. Contact a service technician if you see any sign of soot. Inadequate draft and inadequate combustion air are common causes of soot and carbon monoxide.

Forced-draft gas furnaces use a little fan called a ***draft booster*** to pull combustion air into the firebox and push exhaust gases out. Gas furnaces with draft boosters are adjustable, but only by factory-trained technicians.

A draft booster is set at the factory to provide adequate draft for combustion, but only combustion-testing a burner can determine whether the draft is correct. Too much draft will waste energy by moving too much heat-absorbing air through the firebox. Not enough draft can starve the flame for air, producing soot and carbon monoxide.

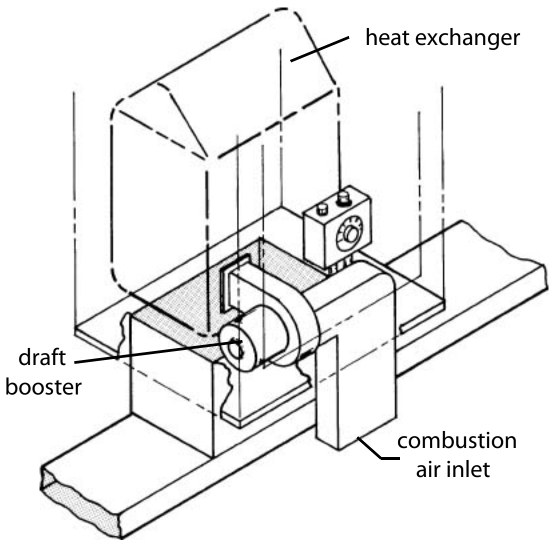
Gas forced-draft burners bring outdoor combustion air from: the crawl space; from the chimney assembly through the roof; or from a separate metal pipe through the roof. These combustion-air inlets connect the draft booster's outdoor air with the firebox. It's important to check the flue pipe and combustion-air inlet on the roof during very cold or snowy weather because one or both can be plugged with ice and snow.

The interior of combustion air passageways should not be visible from inside the home: If you can see the passageway, it isn't sealed. Don't confuse combustion air ducts with other open metal ducts in the floor or ceiling near the furnace. These open ducts bring fresh ventilation air into the furnace blower to relieve moisture and indoor air quality problems.

Atmospheric Gas Furnaces — Atmospheric, sealed-combustion gas furnaces use the weight differences between cool outdoor air and the hot flue gases to move combustion air into the firebox and to exhaust combustion by-products up the flue. Most atmospheric gas burners on mobile home furnaces are adjustable. The adjustments are made originally or checked by a factory-trained technician.

The flow of air and gases in an atmospheric furnace start at the combustion air inlet and end at the flue's outlet, both outdoors. The chimney cap of this type of atmospheric furnace contains both the combustion air inlet and the flue gas outlet. Combustion air travels down through a doughnut-shaped cavity created by a double-pipe assembly as shown. Combustion air flows from the double-pipe assembly into a narrow duct space around the furnace and into the bottom or backside of the heat exchanger. The air mixes with the gas at the flame. Flue gases travel up and out through the inner pipe. On leaving the firebox, the gases create a vacuum pulling more combustion air down through the inlet and into the firebox.

Figure 11-3 Forced-Draft Mobile Home Furnace

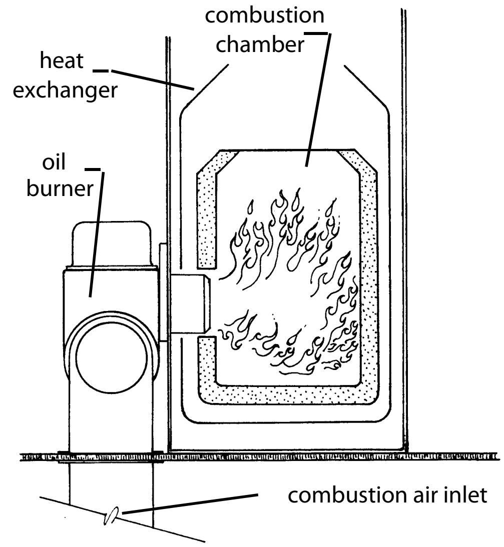


A small fan called a draft booster pulls combustion air through a metal duct from the crawl space and then forces this air into the heat exchanger.

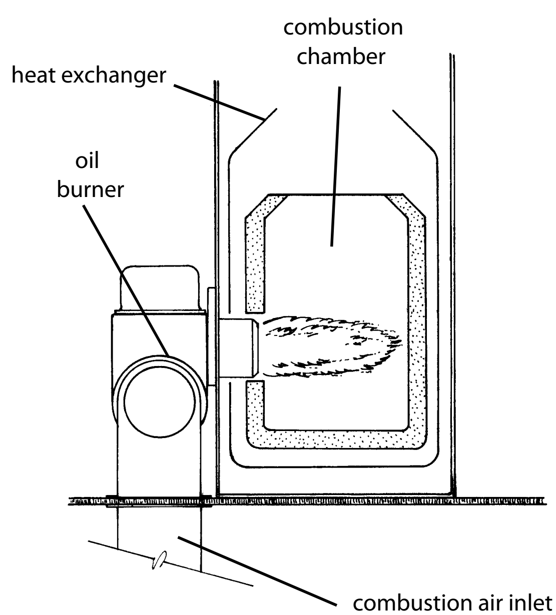
Gas-burner service checklist — Maximizing gas-furnace efficiency requires measurements of furnace temperature, carbon monoxide, and efficiency to thoroughly understand and react to existing problems.

1. Look for soot and adjust burner if necessary.
2. Test flame safeguard control.
3. Test high limit. Furnace should shut off before reaching 250°F.
4. Clean burner and combustion-air fan.
5. Check furnace operating temperatures as described in *"Furnace Operating Temperatures" on page 149.*

Figure 11-4 Oil Burners



Typical Oil Burner - Oil sprays from a nozzle and mixes with combustion air that is pulled from the crawl space by a fan in the gun-type oil burner. The combustion chamber radiates heat back to the flame keeping it hot enough to burn all the oil.



Flame-Retention Burner - Oil and combustion air swirl and mix in a tight flame pattern which leads to more complete combustion and a better combustion efficiency.

Oil Burning Furnaces

Oil burning furnaces require more maintenance than gas furnaces. The burner is more complicated, and oil doesn't burn as cleanly as natural gas or propane.

The pump in a ***gun-type oil burner*** pumps the oil through a nozzle at about 100 pounds per square inch (psi). The nozzle, which should be replaced annually, has a particular spray angle (usually 90°) and spray pattern (hollow or solid). The manufacturer's specification for nozzles should be the technician's guide to replacement.

Sparking electrodes light the oil spray, and a fan in the burner housing pulls combustion air from the roof or crawl space, and mixes it with the oil to support combustion.

Oil burners spray oil into a ceramic ***combustion chamber***, which sits inside the steel heat exchanger. The ceramic chamber protects the metal heat exchanger from the intense heat of the oil flame, and it also radiates heat back towards the flame to aid in vaporizing and burning the oil. The combustion chamber's shape matches the flame angle and pattern produced by the nozzle.

Unlike propane and gas combustion efficiency, which remain stable over periods of years, oil combustion efficiency deteriorates as soot and sludge are deposited around the nozzle, in combustion chamber, and on the heat exchanger. It is important, therefore, to have an oil furnace serviced regularly by a qualified technician.

The difference in fuel usage between an efficient oil burner and a very inefficient one can be 30%—an important reason why oil burners should be tested, and then cleaned and adjusted if necessary.

Combustion Testing — Technicians working on oil-burning furnaces should know how to use combustion testing equipment. Two combustion test measurements are particularly important:

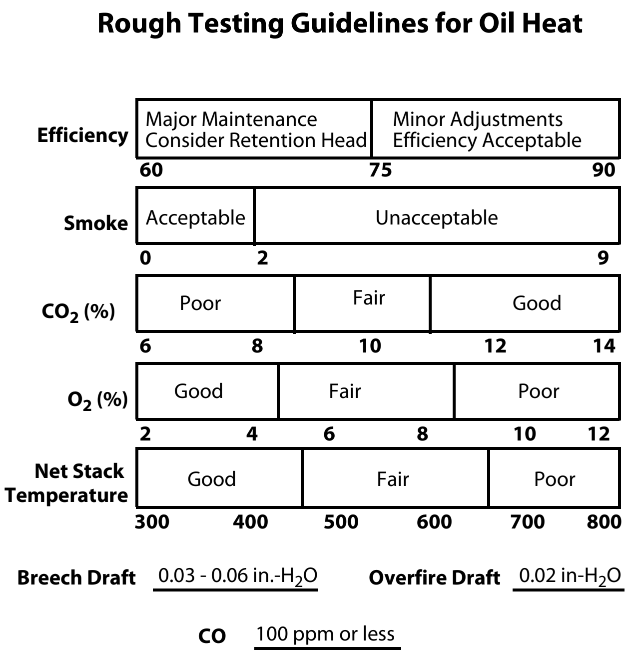
1. A measurement of both carbon monoxide and smoke will give the technician information on whether the combustion process is burning all the fuel. If there are excessive amounts of unburned or partially-burned oil in the flue gases, steps should be taken to clean up the combustion process.
2. A measurement of carbon dioxide or oxygen taken with a flue-gas temperature will tell the technician how much heat is escaping up the flue. Burning efficiency can then be improved by adjusting the fuel/air mixture.

Oil Furnace Service Checklist — As mentioned, oil-burning furnaces may require professional service every one-to-two years depending on their hours of use. If however, an oil furnace is clean and operating efficiently, it may not be necessary to perform maintenance. Below is a checklist for scheduled service:

1. Replace nozzle;
2. Replace fuel filter or install filter if none is present;
3. Adjust electrodes;
4. Clean blast tube, electrode, and burner fan;
5. Check for soot accumulation in combustion chamber and heat exchanger;
6. If necessary, clean combustion chamber and heat exchanger;
7. Test flame sensor; and
8. Perform combustion tests and make necessary adjustments.

Flame-Retention Burners — A ***flame-retention burner*** is a newer type of oil burner that gives a higher combustion efficiency by swirling the mist of oil and air to produce better mixing. Flame-retention burners waste less heat and have combustion efficiencies of 80% or slightly more.

Figure 11-5 Oil-Heat Specifications



The operating conditions listed above are rough guidelines used by oil heating technicians to measure and adjust oil furnaces.

Replacing an existing burner with a flame-retention model is usually cost-effective if the existing combustion efficiency is less than 75%, or if the burner needs major repairs. The combustion chamber may have to be replaced at the same time to match the flame angle and pattern of the new burner as well as its higher temperature.

***Oil Storage and Delivery* —** Oil is stored in a tank outside the home. An approved and readily accessible shut-off valve should be installed at the outlet of the tank.

The tank should be kept at least half full, especially in summer months. A nearly empty tank has too much cold interior surface area that will condense water out of the air inside the tank. Water can interfere with oil burner operation. Moisture and sediment at the bottom of the tank may mix with the new oil and clog the system. When the tank is almost empty, drain it to remove the dirt and moisture before filling it again. Dispose of this sediment properly.

One-pipe fuel systems have to be bled of air before they will start after service or after running out of fuel. The bleed valve is located on the side of the fuel pump. Open the bleed valve and direct its hose into a container close it after oil flows into the container.

***Starting an Oil Burner* —** When you are attempting to start an oil burner, do not push the reset button repeatedly. Pushing the reset repeatedly may deposit a pool of oil in the bottom of the combustion chamber. This pool is difficult to remove and can be dangerous when the furnace finally starts. If the furnace does not start properly after the second try, call a qualified service person to diagnose the problem.

***Solving Cold-Oil Problems* —** Oil must vaporize to burn cleanly and efficiently. Standard #2 fuel oil starts to gel at 30°F. Colder, thicker oil retards vaporization and increases oil flow rate, making the oil burn dirtier and less efficiently. Very cold oil may make the burner fail to start.

The most common cure for cold-oil problems is switching to a lighter oil during cold weather. Switching from the standard #2 fuel oil to #1 fuel oil or a winter blend of #2 and #1 solves most cold-oil problems.

Boosting oil pressure from the standard 100 pounds per square inch (psi) to between 120-to-125 psi often solves cold-oil problems, too. Boosting pressure this way increases flow around 10%, so reducing the nozzle by one size is recommended.

Oil pre-heaters aid vaporization and produce a cleaner flame during cold weather. Insulated and heated oil tanks are also used to improve oil-burner performance and efficiency.

Electric Furnaces

An electric furnace heats air by blowing it over a series of electric resistance heating elements that work like the elements in a toaster. Electric furnaces have three to six of these 5-kW elements.

A 24-volt thermostat circuit energizes devices called ***sequencers*** that bring the 240-volt heating elements on in stages when the thermostat calls for heat.

Staging the elements avoids home electrical problems that might occur if they were all connected at once. Many electric furnace blowers have two or more speeds to maintain a stable air temperature as the number of live heating elements changes. A variable speed blower switches to a faster speed as more elements engage. When the thermostat setting is obtained, these elements disconnect in stages—the blower slows then stops.

Virtually all electricity that enters the heating elements is turned into useful heat, so we say that electric furnaces are 100% efficient. However, electric furnaces often have large energy losses from duct leakage which can waste up to 30% of the home's total heating bill.

Replacing air filters regularly is crucial to operating electric furnaces efficiently. The filters are normally located at the top of the furnace. Cleaning electric heating elements isn't necessary when filters are changed regularly. When filters are neglected, electric heating elements should be dusted and vacuumed when they appear dirty.

Caution must be exercised beyond the above maintenance of electric furnaces. The 240 volts used by the furnaces can kill or injure a person who comes in contact with them. Only qualified technicians should repair electric furnaces.

Electric Heat Pumps

Electric heat pumps are the most efficient type of electric heating system for much of the southern and south-central United States. Heat pumps are reversible air conditioners that move heat into the home during the heating season and out of the home during the cooling season.

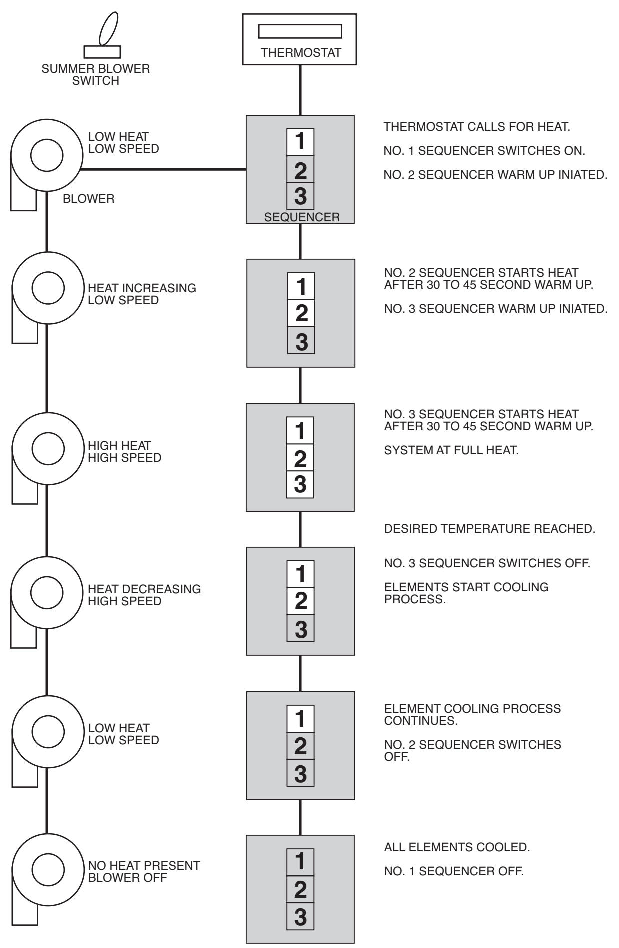
Electric heat pumps work like mechanical air-conditioning systems. A heat pump has valves that allow the refrigerant to follow two different paths, one for heating and one for cooling.

Heat pumps are actually two furnaces packaged in the same unit. The first furnace is a the reversible air conditioner and the second is a set of electric resistance heating coils.

Heat pumps are available as ***packaged units*** or as ***split systems***. They are also available in a smaller unit which closely resembles a room air conditioner.

Follow the same maintenance procedures for heat pumps as you would for air conditioners (*See "Air-Conditioner Maintenance" on page 172.*)

Figure 11-6 Operation of an Electric Furnace



Electric elements are engaged in a sequence and the furnace blower changes speed as elements go on and off.

***Two-Stage Thermostats* —** Heat pumps are controlled by two-stage thermostats. The thermostat's first stage is the heat pump. If it's too cold for the compressor to keep up with the heat loss, electric resistance coils, the thermostat's second stage of heat, come on. Heat pumps may have an additional thermostat outdoors to prevent the less efficient electric resistance heat from coming on until the outdoor temperature is below 40°F. Automatic thermostats for heat pumps should be equipped with a function to limit resistance heating also. If this function is absent, you may forfeit the automatic thermostat's savings to high-cost resistance heating when the temperature is returning to normal after setback.

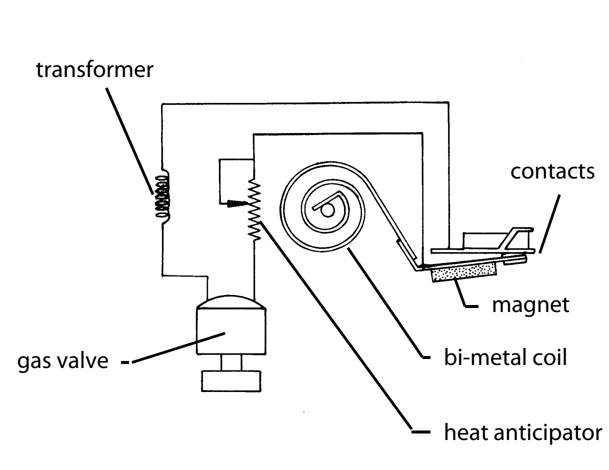
***Heat Pump Efficiencies* —** Because the heat pump is primarily a heat-mover and not just a heat-producer, it can actually deliver more kilowatt-hours of heat to your home than the number of kilowatt-hours of electricity it uses. Therefore, the heat pump can be more than 100% efficient in delivering heat energy. In fact, the heat pump will give you 1.6-to-2.5 kilowatt-hours of heat for every kilowatt-hour of electricity it uses.

The Heating Seasonal Performance Factor (HSPF) is an official heating efficiency for central heat pumps. It tells how many Btus of heat are moved for each kilowatt-hour of electricity used. The HSPF is listed on the energy guide label of each heat pump sold. HSPF includes both the very efficient heating done by the compressor and the less efficient heating done by the electric resistance elements. The most efficient heat pumps have a HSPF of around 10.

Heat pump cooling efficiency is expressed as Seasonal Energy Efficiency Ratio (SEER). The SEER is the ratio of the Btus of heat a heat pump removes for each kilowatt-hour of electricity it uses. An SEER of 12 is considered efficient.

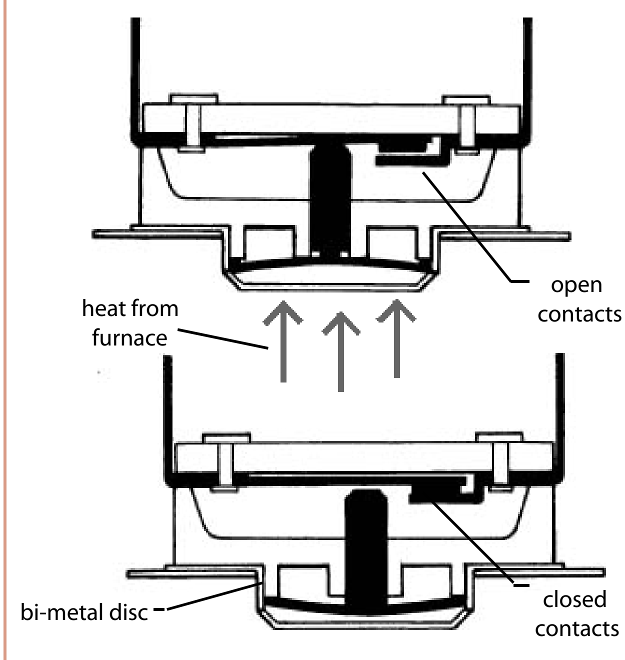
Heat pump efficiency is very dependent on correct installation and proper maintenance. Many heat pumps never achieve their rated efficiencies because of poor installation, or they lose their efficiency because of neglected maintenance or incorrect service procedures.

Figure 11-7 Thermostat Circuit



The bimetal coil moves as the temperature changes. With the aid of a magnet, the coil opens and closes contacts. This turns the heating equipment on and off.

Figure 11-8 Snap Disc Thermostat



A bimetal disc connected to a switch snaps in and out with changes in temperature. A rod attached to the disc opens or closes electrical contacts. Snap-disc thermostats are used as a high limits protection, fan controls, or sequencers in heating equipment.

Heating Controls

Almost all mobile home heating systems use 24-volt control systems and ***bimetal thermostatic controls***. Commonly used voltage in most homes is 120 volts. This house power is reduced to 24 volts by a ***transformer*** to provide a safer and more convenient power source for heating control.

The transformer is the source of power for the 24-volt control system. The other parts of the control circuit are the ***thermostat***, safety switches (called *limits*), and a ***final operator*** that actually engages the heating. The final operator for gas and propane furnaces is an automatic gas valve. For oil furnaces, the final operator is a relay, which is a magnetically-operated switch for activating the oil burner. For electric furnaces, the thermostat engages small heating elements that in turn activate a series of bimetal switches called *sequencers* which turn on the electric heating elements.

Bimetallic thermostatic controls—thermostats, limits, fan controls and sequencers—function as automatic switches to turn heating components on and off. Bimetal controls work by employing a disc, strip, or coil, made of two different metals bonded together. The bimetal disc, strip, or coil moves as the temperature changes. The movement of the bimetal element opens and closes switches controlling heating devices and fans.

Bimetal controls also control the sequenced operation of heating elements and fan speeds in electric furnaces. They provide high-limit protection for all types of furnaces, turning the furnaces off if they become too hot.

Bimetal controls react to the temperature around them and they sometimes have small heating coils near them. These little heating coils make the bimetal control a time-delay switch in staging the operation of fans and electric heating elements in electric furnaces.

To determine whether controls are functioning properly, the technician measures temperature and observes the controls' operation.

Thermostats

Magnetic thermostats use the opposed forces of a bimetal and a magnet to switch heating systems on and off. One of the thermostat's contact is attached to a bimetal strip or coil. The bimetal's movement brings the contact together with a stationary contact with the aid of a magnet.

Mercury-bulb thermostats have a bimetal coil attached to a vial where contacts are connected and disconnected by a moving ball of liquid mercury. Mercury-switch thermostats need to be level to control the temperature accurately. If the thermostat setting and thermometer reading don't match, the mercury-switch thermostat may be un-level.

A miniature heating element inside most thermostats causes the bimetal element in the thermostat to turn the furnace off early, in anticipation of the heated air left in the heat exchange and ducts after the heating element goes off. This small adjustable heater, called the ***heat anticipator***, is designed to prevent the temperature from exceeding the thermostat setpoint. Adjustments to the heat anticipator can often solve comfort problems related to the burner cycles being too long or short.

Thermostat Location — Thermostat location is very important to the functioning of a heating system. Localized sources of heat or cold can trick the thermostat. Troublesome locations for thermostats include outside walls and areas near windows, doors, light bulbs, registers, or anything that can heat or cool the thermostat. Even interior walls may have cold drafts inside them that can lead to erratic furnace functioning. In cases where there are problems—furnace cycles to long or too short, for instance—the thermostat may need to be relocated to an inside wall away from drafts and heat sources.

Burner Controls

Burners in oil and gas furnaces are the final operator of the 24-volt control circuit. This circuit opens and closes the automatic gas valve or turns the oil burner on and off.

The burner turns on when the contacts in the thermostat and the ***high-limit control*** are closed (touching one another). Both sets of contacts must be closed at the same time. The contacts in high-limit controls are always closed unless the furnace reaches a dangerously high temperature.

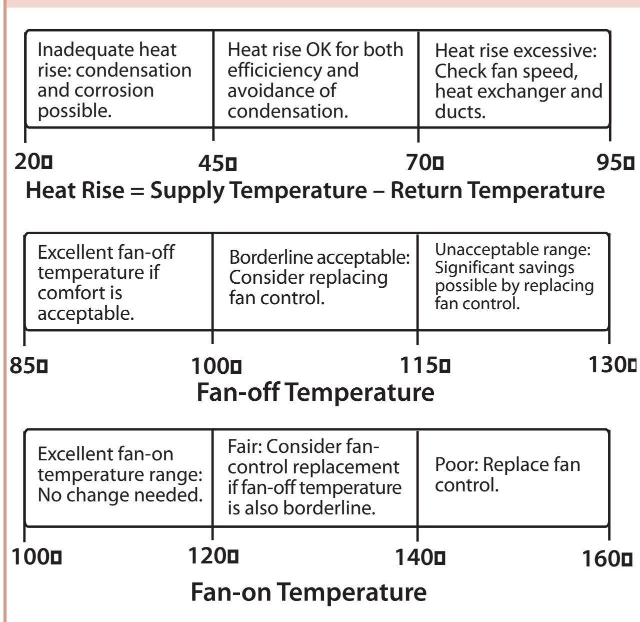
The contacts in the thermostat close when the temperature in the room drops below the thermostat's set point. If the contacts in the thermostat or the contacts in the high-limit controls are open, electricity can't flow through the circuit and turn on the burner. Some gas and propane furnaces with draft boosters also have centrifugal safety switches (with another set of contacts that must be closed for electricity to flow) that won't allow burner ignition unless the booster fan is operating.

The pilot safety ***thermocouple*** is a separate circuit. The pilot light heats the thermocouple, a rod that generates a small electric current. The current energizes a magnetic valve stem called a ***solenoid*** in the automatic gas valve. The solenoid keeps the passageway open for the flow of gas to the pilot light and the burners, in case the thermostat calls for heat. If the pilot light goes out or if the thermocouple fails, the current stops flowing. A spring then returns the valve stem to the valve seat, like a cork in the neck of a bottle, insuring that gas can't flow to the pilot light or gas burner.

Newer furnaces have ***hot-surface ignition***. A fork-shaped igniter (a heating element) ignites the burner flame that burns in contact with that igniter. The igniter is also the flame-safety device and the flame conducts electricity as part of the flame-safety circuit. If the flame is extinguished, the circuit opens and the automatic gas valve shuts the gas off.

Gun type oil burners have flame sensors that won't allow the fan and oil pump to run for longer than 45 seconds, unless they sense a flame.

Figure 11-9 Furnace Operating Temperature



The operating conditions listed above are rough guidelines used by technicians to measure and adjust fan control and fan speed on furnaces. Oil furnaces may have slightly higher temperatures.

Furnace Operating Temperatures

Well-trained heating technicians measure three different furnace operating temperatures that affect seasonal heating efficiency. These temperatures are:

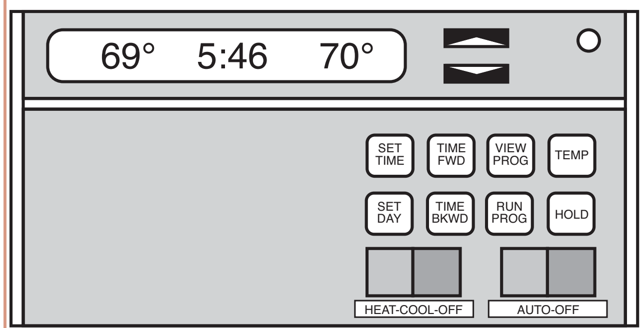
1. The heat rise across the heat exchanger;

2. The ***fan-off temperature***; and

3. The ***fan-on temperature***.

The heat rise across the heat exchanger is the number of degrees air is heated as it flows around the heat exchanger. If the return-air temperature is 65°F and the supply-air temperature is 125°F, the heat rise is 60°F.

Figure 11-10 Programmable Thermostats



Savings from programmable thermostats range from 5% to 20% of heating and cooling costs for occupants who leave the settings constant.

Testing the fan control is important since fan controls frequently malfunction and reduce the furnace's efficiency. The fan-off temperature is the most important measurement relating to seasonal efficiency. The fan-off temperature is the air temperature—measured in the closest register—when the fan turns off at the end of a cycle. The fan-on temperature is the temperature in the furnace (measured near the blower) when the blower comes on after the burner cycle has started.

Part of the heat from each burner cycle is wasted unless the blower operates long enough to deliver most of the heat to the home before it escapes up the chimney. Each time the burner cycles on and off, the fan should also cycle on and off. Fan controls usually turn blowers on at air temperatures of 110°F to 150°F at the beginning of cycles. These fan controls turn blowers off at furnace air temperatures of between 100°F and 140°F at the end of cycles.

Fan Controls and Fan Speeds

The fan control is usually an inexpensive ***snap-disc thermostatic control***. In many furnaces, these snap-disc fan controls do not hold the furnace blower on for long enough to get all the available heat out of each burner cycle. Unfortunately, the original controls are seldom adjustable. However, snap-disc controls are inexpensive and easy to replace with new adjustable controls.

The fan control is located in the furnace's electrical service box near a very similar looking control—a high-limit control. Some of the replacement snap-disc fan controls are adjustable; these are better than nonadjustable types. The fan control is usually held in place by two sheet metal screws and has two wires connected to it. These wires attach interchangeably to the terminals of the new control.

Many furnace blowers have several speeds. Increasing the speed can improve heating efficiency in cases where the heat rise is excessive. The larger volume of air, circulated by the higher fan speed, extracts more heat from the heat exchanger and allows less heat to escape up the chimney. However, if fan speed is too high, occupants might complain of drafts or the heat exchanger might cool too much, causing condensation and corrosion.

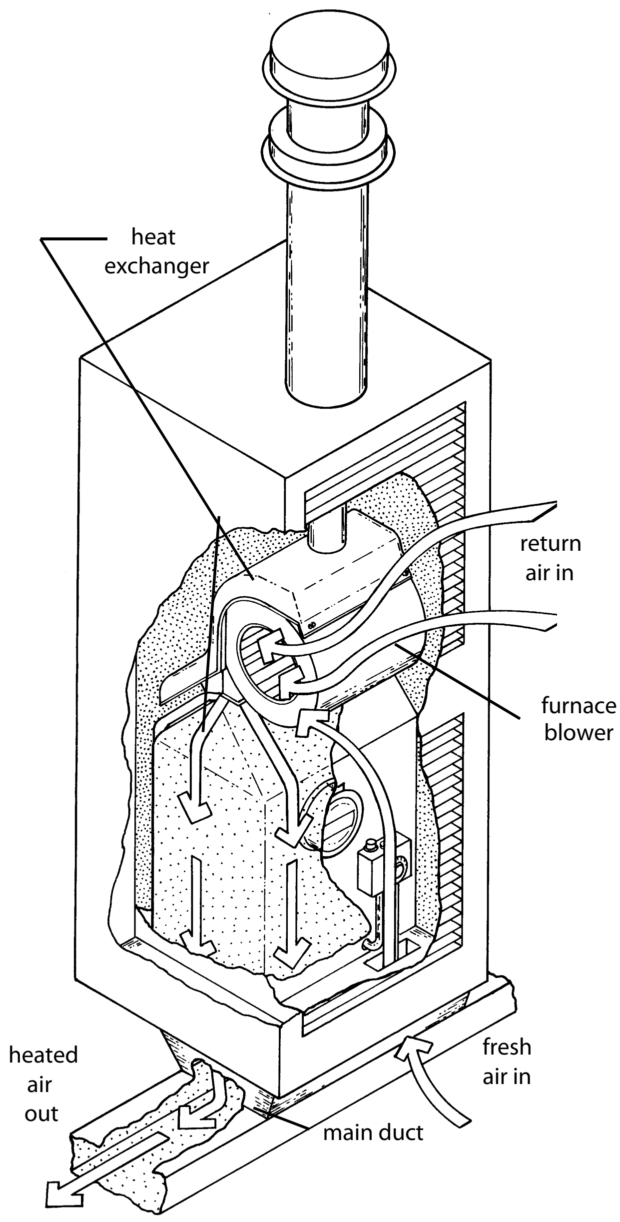
Different speeds are usually represented by different-colored wires coming out of the fan motor. Increasing the fan speed usually involves removing a wire representing a lower speed from a terminal and replacing it with a wire representing a higher speed. This color coding is likely noted in the wiring diagram attached to the furnace. Some furnaces provide a fan speed switch to more easily change speeds.

Programmable Thermostats

Programmable thermostats are a convenient and effective way to save heating and cooling energy, especially for families who leave home during the day. They combine a clock and a thermostat in order to control home temperatures automatically.

Programmable thermostats are ideal for people with regular schedules of occupancy or vacancy, and activity or sleep. You can save 5% to 20% of heating and cooling costs depending on the duration of setback periods and the number of degrees of temperature setback.

Figure 11-11 Downflow Furnace Air Circulation



The furnace blower pulls air in from the hallway and blows the air down over the hot heat exchanger into the main duct.

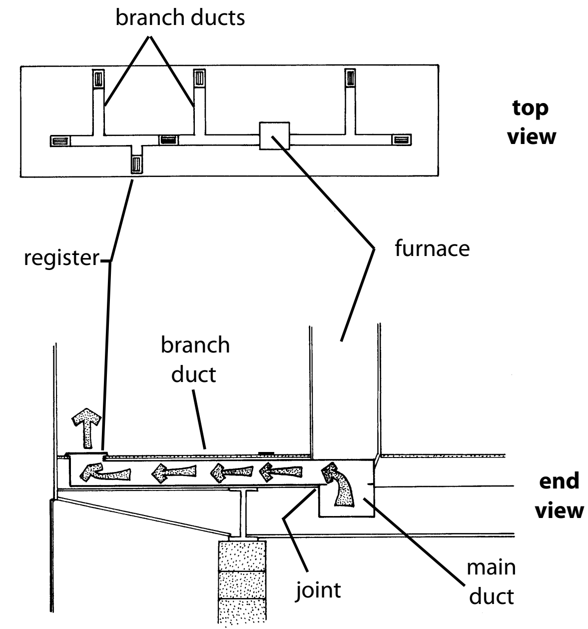
Automatic thermostats will save the largest percentage in milder climates with both heating and cooling, but are effective energy savers in all climates. Be sure to install a heating and cooling automatic thermostat if you have both heating and central air conditioning.

There are two types of automatic thermostats:

1. The ***electromechanical thermostat*** employs an electric clock with a switching mechanism that is part of the clock movement. This type actually contains two thermostats with two different settings. The movement of the clock and the position of movable pins on a dial determines which thermostat is controlling heating or cooling at any time.

2. The *electronic thermostat* is a digital clock with an electronic brain that switches between high and low settings. Most electronic thermostats provide two or more setback periods per day and also allow different weekend settings. They usually give a wider range of temperature settings than electromechanical models. Electronic thermostats have more convenient features, but are usually a little more expensive.

Figure 11-12 Branch Ducts



Some homes have branch ducts. Joints between these branch ducts and the main duct should be inspected for air leaks.

Air Supply Ducts

Forced-air heating systems take air from the home, called ***return air,*** and heat that air by forcing it past a hot metal heat exchanger. After it passes the heat exchanger, this heated air flows through ***supply ducts*** out ***registers*** into rooms.

Supply ducts are usually installed in the floor, but many homes in southern climates have ceiling supply ducts because ceiling registers work better for air conditioning.

Leaky Supply Ducts

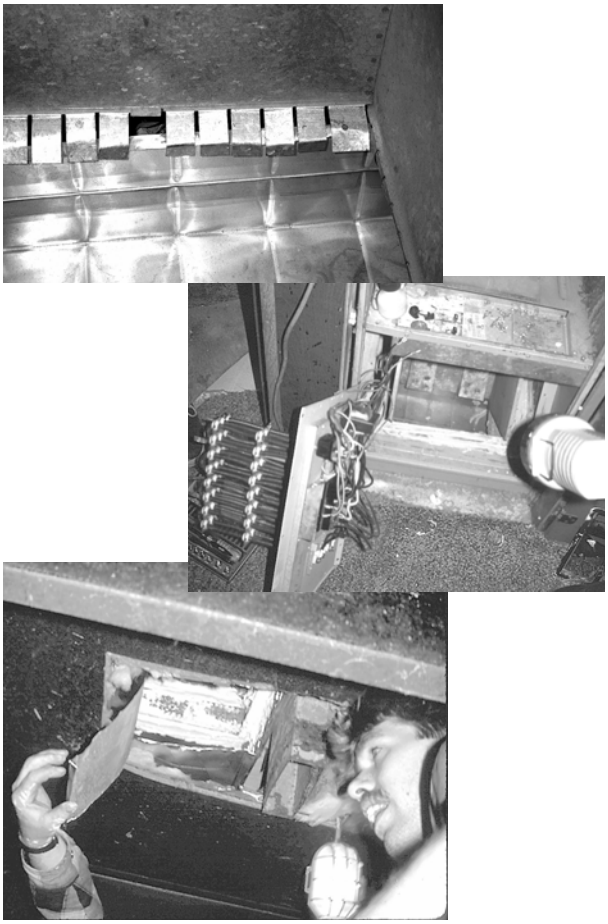
Supply ducts often have significant leaks at the seams between the main duct and its connections. Boots are connections between the main duct and registers. The furnace also has a large boot or sleeve connecting it to the main duct. Branch ducts are ducts branching off the main. Crossover ducts connect the main ducts of halves of double-wide homes. Termination caps plug the ends of the main and branch ducts. Leaks in these jointed connections allow warm air (or cool air—if ducts are also used for air conditioning) to escape, wasting significant energy and money.

Duct Inspection — Inspect ducts with small mirrors, flashlights, and trouble lights from inside the home. For air leaks away from indoor registers, inspect the duct from the crawl space underneath the home.

Laying a mirror on the bottom of the duct at the registers and moving the mirror around will show you the corners of the joint where that boot meets the main duct. There may be large leaks there.

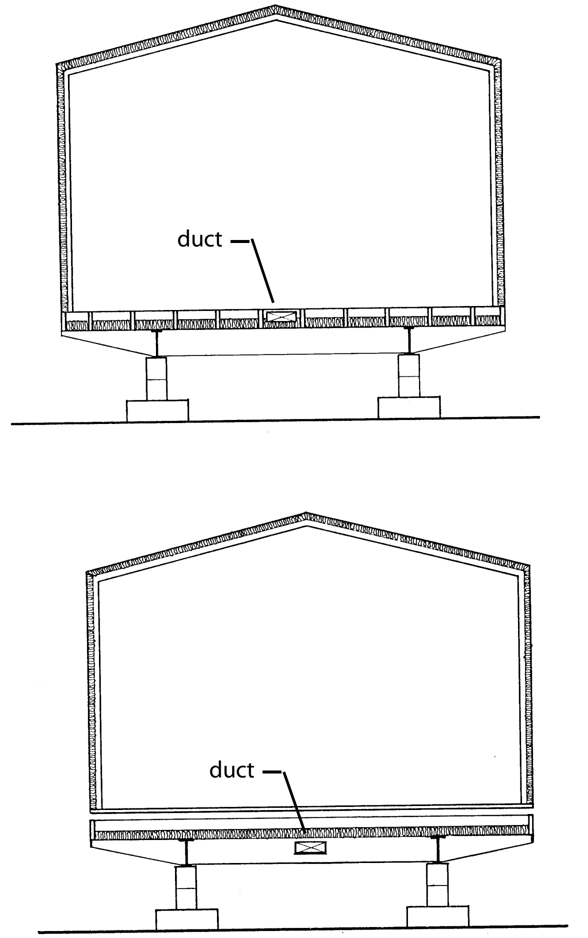
Putting a trouble light in one register and looking toward it at the next register using a mirror will enable you to see major leaks and obstructions.

Figure 11-13 Leaks in the Furnace Plenum



The furnace plenum is often poorly sealed at the factory or comes loose from the main duct during transit as shown in the top photo. If possible, inspect through an access door at the bottom of the furnace or by taking electric elements out temporarily, as shown at center. Cutting the duct underneath is often necessary to seal leaks, found by the blower door, in the plenum as shown at bottom.

Figure 11-14 Duct Location



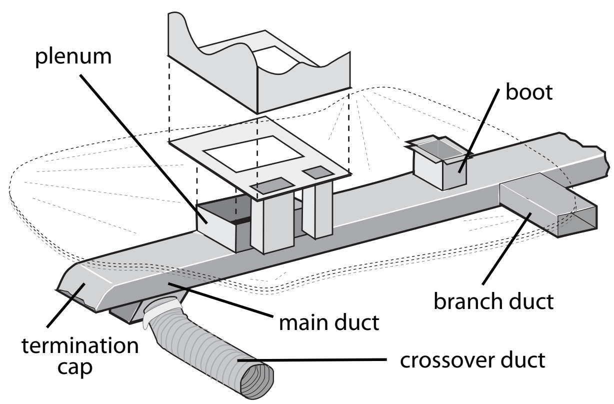
In homes with lengthwise joists, the main duct is installed between the floor joists, touching the flooring material. In homes with crosswise joists, the main duct is installed below the floor joists

The light illuminates the duct and the mirror allows you to view the duct's inside between the two registers.

If you see a large leak between the registers, pinpoint the leak's location with a tape measure so you can find the leak underneath the floor from the crawl space. When you're looking for duct leaks underneath the home, it may help to run the furnace blower so you can feel the air blowing out the leaks. Two locations to always inspect from the crawl space are ***crossover ducts*** and ***branch ducts***.

Using a blower door will locate air leaks in difficult hidden locations inside ducts that can't be seen by looking into the ducts. If you feel air entering through the ducts while the blower door is depressurizing the house, then the ducts have leaks. Pillows made of insulation inside plastic bags, used to systematically plug sections of the duct, can help to locate the air leaks during blower door testing.

Figure 11-15 Duct Leaks



Joints in the mobile home duct system are a major source of air leakage.

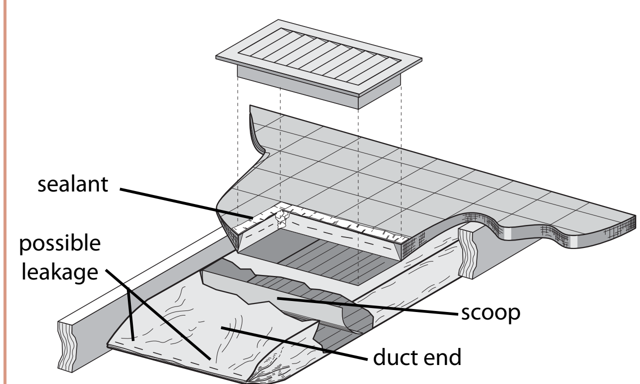
Duct-Sealing Materials — Standard duct tape works poorly for sealing ducts, because the adhesive doesn't stick permanently.

There are, however, several effective materials for sealing leaky metal ducts. Silicone caulking works well for narrow cracks and small holes. Aluminum-foil tape or aluminum-foil-faced butyl tape work well for larger holes and cracks, especially in corners. These tapes usually fails if installed on dirty surfaces or on the ducts' outside where air pressure is pushing on it. Latex duct mastic (a thin putty) is the most effective and permanent material for patching holes and cracks in ducts. For larger holes and cracks, use duct mastic with fiberglass reinforcing tape—the same tape used for patching sheetrock and plaster—so the cracks do not reappear with duct movement caused by temperature changes. Easy to install with a brush or rubber glove, duct mastic is available from heating wholesalers.

Regardless of the sealant you're using, be sure to clean duct surfaces around seams and holes with solvent or steel wool before patching.

Sealing Ducts — Many supply duct leaks can be patched from inside the home near registers and near the furnace where leaking seams are located. In homes with lengthwise floor joists, the main duct should be sealed to the floor at every register. Fill the space between the flooring and the duct at the register with foam rubber and caulk the crack. Or, attach a lightweight metal channel to bind the duct to the flooring. Then seal the seams with duct mastic.

Figure 11-16 Duct Sealing at Register



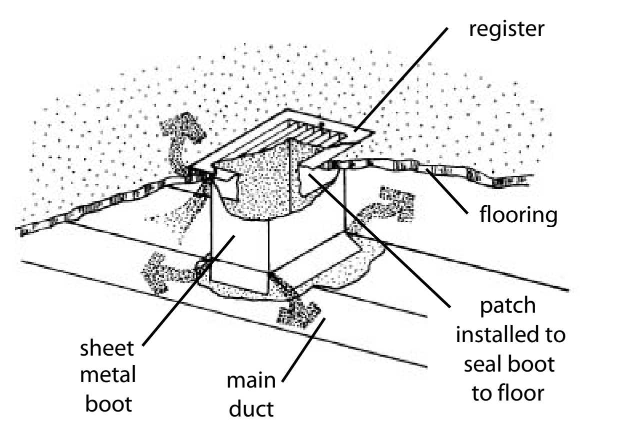
In mobile homes with lengthwise floor joists, the main duct should be sealed to the floor at the register. A scoop, fit inside the duct, blocks off the duct's possibly leaky end.

In homes with crosswise floor joists, seal seams around boots joining the main duct to the floor. The boots connect the main duct—located below the floor's 2-by-6 joists—to the flooring.

At connections where crossover ducts, branch ducts, and the furnace meet the main duct, leaks must be patched from underneath the home. The connection between branch ducts or crossover ducts with the main duct may be leaking at loose or unsealed connections.

You may have to cut into the underbelly to access the duct joints for repairs. To locate a joint, look inside for a register that branches from the main duct and measure indoors using exterior walls

Figure 11-17 Register Boot



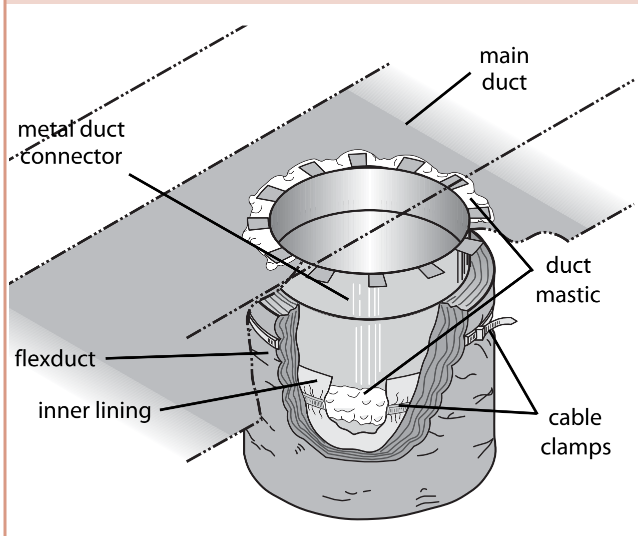
Mobile homes with crosswise joists have sheet metal boots that connect the main duct to the floor register. This illustration shows the common air leakage in connections between the boot and duct, and between the boot and floor.

and windows as landmarks. Then, transfer these measurements outside and into the crawl space so you know where to cut.

The furnace's connection with the main duct is a serious problem in many homes. Sometimes the furnace was poorly installed. Sometimes the furnace was jostled during transit, loosening it from the main duct. Either way, the result is major air leakage directly under the furnace where the duct air pressure is greatest. Materials for this fix are inexpensive, but repairs can take an hour or two.

The most common way to seal the furnace-main-duct connection is to cut the underbelly beneath the furnace. Then, cut a temporary hole in the duct's bottom directly under the furnace—a three-sided rectangular hole, 8-to-10 inches square. This is usually easier than removing the furnace. With a temporary hole, you can clearly see and seal the furnace-duct connection and its leaks. Use duct mastic and fiberglass tape to seal the leaks and afterwards to seal your hole in the duct. Duct tape works well for holding the flap in the duct's bottom together until you seal it with duct mastic. The mastic with its fiberglass tape encases the temporary duct tape seal in a permanent patch.

Figure 11-18 Metal Connector



A short piece of 10-or-12-inch metal pipe is often used to connect the flexible crossover duct with the main duct. Two cable clamps fasten the flexduct to the metal pipe. Duct mastic seals the inner liner to the metal pipe.

The furnace may have a cooling coil compartment at the bottom with a removable panel. If by chance the furnace has a compartment but no cooling coil, this compartment provides easier access to the main duct underneath the furnace. The coils of an electric furnace can be removed for access, instead of the whole furnace. If neither of the previous methods is appropriate, the furnace can be removed temporarily to seal the leaks.

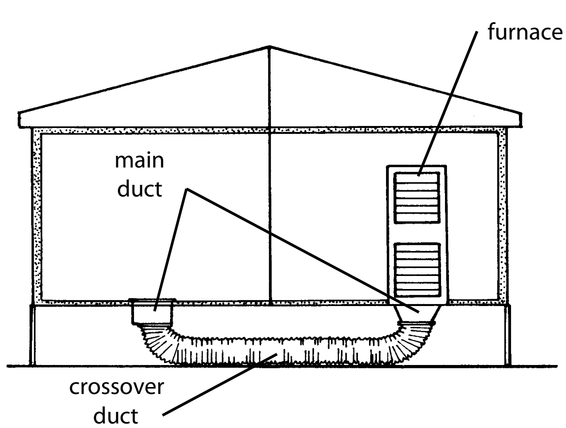
However you get access, use a mirror to thoroughly inspect the furnace sleeve's connection to the main duct. Be meticulous—there are several seams.

Sealing Flexduct — Insulated flexduct is a flexible wire-reinforced polyethylene tube, insulated outside with a fiberglass insulation and surrounded by an outer polyethylene tube. For crossover ducts using insulated flexduct, there are two different seams to seal: 1. The seam between the metal connector and the main duct; and 2. The seam between the flexduct and the connector.

Before reattaching the flexduct, seal the metal connector to the main duct with duct mastic or foil tape. Then, apply a band duct mastic or putty tape to the circumference of the connector, and clamp the inner lining of the flexduct against this sealant with a long plastic *cable tie*. A cable tie is a plastic belt with notches that tightens permanently when you pull its end through a loop. Another way to secure the inner liner is with 3 self-drilling screws with their heads clamping the wire reinforcing to the metal connector. After sealing inner liner with aluminum tape or duct sealant, clamp the outer flexduct layer with another cable tie.

Older crossover ducts or ducts from air conditioners may be torn or deteriorated from age. Replace these ducts with new flexduct. There are two common types of flexduct, insulated to R-4 or R-8; the R-8 flexduct is recommended.

Figure 11-19 Crossover Duct



Double-wide homes have crossover ducts to take heated air from the side with the furnace to the side without the furnace. Crossover ducts can be a major source of air leakage.

Cold Air Return

Most site-built homes have ***return ducts***—metal ducts for bringing the home's air back to the furnace to be heated. Most manufactured homes don't have return ducts, however. In most manufactured homes, air is pulled from the rooms, down the hallway, and into the furnace by the furnace blower. However, some older homes use the ceiling or floor cavity as one huge return duct. These large cavities—used as ducts—are seldom very airtight.

The return air side of the furnace contains the blower and sometimes one or two furnace filters. Dirt on the blower and filters can reduce furnace efficiency by slowing airflow through the furnace.

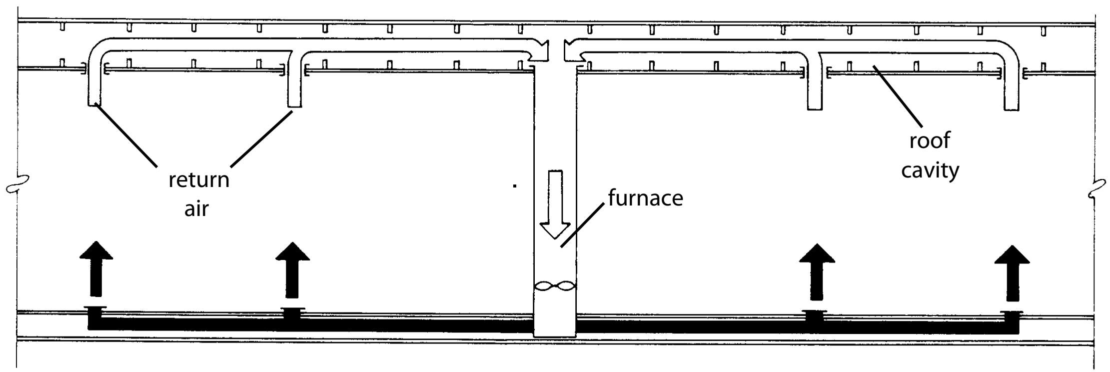
Furnace Filters

Furnace filters are designed to keep the blower and heat exchanger clean. It's easier to change or clean filters than to clean blowers and heat exchangers. Dirt on air filters also blocks airflow, reducing efficiency.

Filters are usually located near the blower, so the return air enters through them leaving its dirt behind. Filters are composed of fiberglass wool framed in cardboard, air-permeable foam rubber, or fibrous plastic. A metal bracket supports the cardboard-framed fiberglass filter. A wire retainer clamps the foam, or fibrous plastic filter to the furnace's removable louvered front panel.

Electric furnaces and heat pumps always have provisions for filters. Many gas and oil furnaces have no filter, or else the filter is an option. Furnace manufacturers fear that the occupants may neglect cleaning filters, leading to the furnace cycling on the high limit due to overheating. The blowers and heat exchangers in mobile home combustion furnaces are fairly easy to clean as described in the next section. If your furnace lacks a filter, you can order and install one. How-

Figure 11-20 Roof-Cavity Return Air



Air from the home enters the roof cavity through grilles and returns to the furnace through the roof cavity. If the roof is ventilated or if there are air leaks in the roof, excessive air leakage can result between the home and outdoors.

ever, be vigilant about cleaning the filter. Or, live without the filter and clean the blower and heat exchanger every 2-to-4 years.

Cleaning Blowers and Heat Exchangers

Cleaning the blower's fan blades and cleaning or replacing the air filter (if present) are two of the most effective energy conservation measures for any home.

Dirt on the fan blades of a furnace blower greatly reduces the blower's ability to move air over the heat exchanger. Low airflow, from dirty blowers reduces heating and cooling efficiency.

Before cleaning the blower, shut off the power to the furnace at the breaker box or main switch. With some blower motors, the wires from the motor are connected to wires in the main control box by a foolproof plug that pulls off easily. Other blowers have wires that are individually connected to terminals in the main control box. Before disconnecting these wires and terminals, label them so there is no possibility of reconnecting them improperly.Most of the time, it isn't necessary to remove the blower wheel from the motor and housing. But, you may need to remove a plate in the blower housing to get more space to work on the blades. The blower's blades can be cleaned with a brush and vacuum cleaner. Tooth brushes and hairstyling brushes work well for cleaning blowers. Cleaning blowers with compressed air or pressurized water is faster than brushing and vacuuming, if you have those options.

While the blower is removed, a large portion of the heat exchanger is exposed. This is a good time to inspect the heat exchanger for cracks and dirt. Clean the heat exchanger with a brush or rag, using soap and water if necessary. Use a long handled brush or rag tied to a stick to reach further down into the heat exchanger if necessary. Also, be sure to clean the blower motor thoroughly and add a few drops of 20-weight oil to lubrication ports.

Ceiling and Floor Return-Air Systems

In the 1970s and 1980s, some manufacturers thought that using the ceiling cavity or floor cavity for a large return-air duct was a good idea. They have since learned that these cavities, with their large surface areas, are difficult to build and maintain airtight.

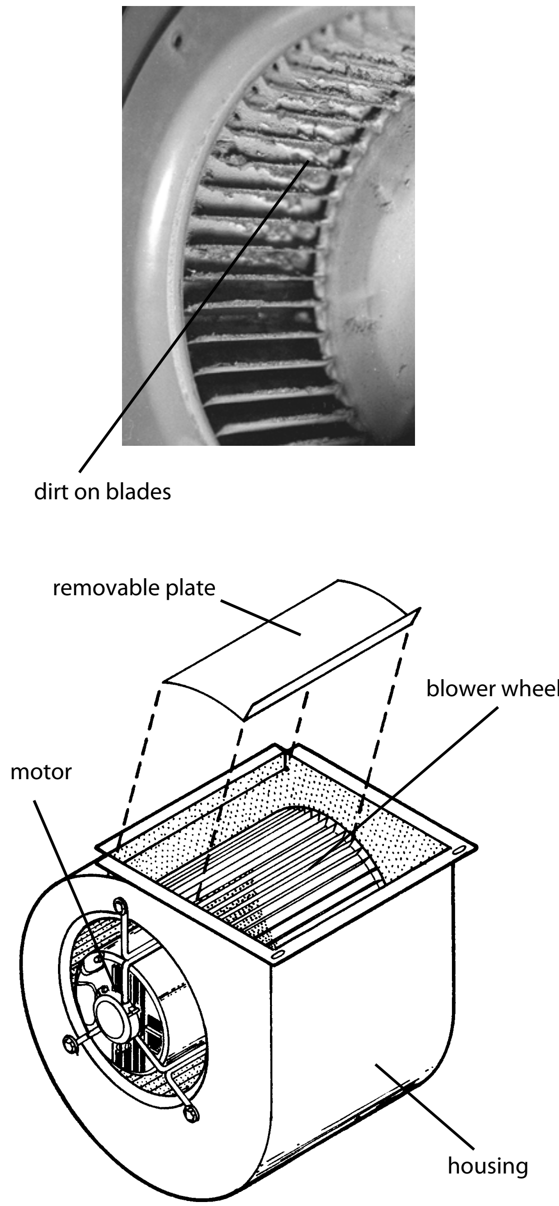
Ceiling and floor return-air systems usually aren't airtight at all. Returning air through ceiling and floor cavities let lots of outdoor air into the home, through both the furnace and return registers, which are merely holes in the ceiling or floor covered by grilles.

It's best to seal off return-air registers in the floor or ceiling with wood or metal patches to prevent airflow between these cavities and the living space. Also seal the main return-air opening in the floor or ceiling of the furnace closet. This makes the furnace blower pull its return air from the rooms through the hall.

When eliminating floor or ceiling return air systems, provide as large an opening from the home into the furnace cabinet as possible. This may involve installing one or two large grilles in the wood door to the furnace closet or even taking that door off permanently. The rooms most distant form the furnace may require a return air duct with registers near the room and at the furnace connected by insulated flexduct.

Remember, the amount of airflow through the furnace affects the efficiency of the heating system. The HUD Code specifies at least two square inches of return air area (through the furnace closet door) for each 1000 Btuh of furnace capacity.

Figure 11-21 Squirrel Cage Blower



These fans are used in almost all furnaces, air conditioners, and evaporative coolers. Dirt on the blower's blades reduces the efficiency of the entire heating or cooling system.

Improving Air Distribution

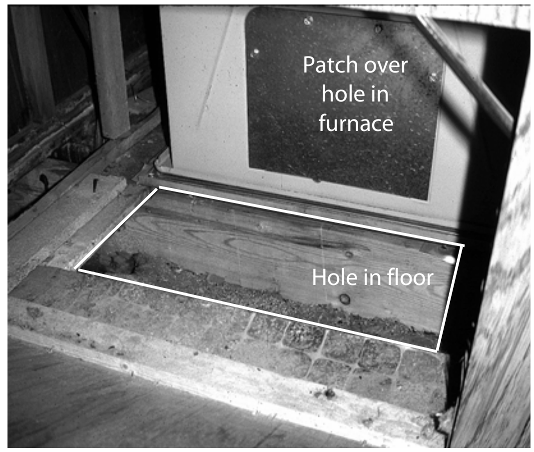
Anything that prevents the free flow of air to and from the furnace reduces furnace efficiency and increases the home's air leakage by pressurizing the home. Blockages reduce furnace efficiency because without good airflow, the furnace's heat exchanger gets too hot and the heat escapes up the chimney. As mentioned earlier, a high temperature rise of air going through the furnace may indicate low airflow.

Blockages increase air leakage by creating pressures in some rooms and a powerful suction near the furnace's blower. Blockages can occur on the supply side or the return side of the furnace. Supply-side blockages include dented ducts, obstructed registers, and objects placed inside ducts. Return-side blockages include dirty filters and interior doors without vents or clearance under them.

Supply ducts may have been dented during the home's moving and setup. When registers are not screwed to the floor, children will often lift the registers and put toys and other objects into the ducts, partially blocking airflow. Supply registers can be mostly blocked if their fins are flattened by foot traffic or coated with dust and dirt. A dirty air-conditioning coil can severely block the furnace's supply airflow.

Some metal doors in furnace cabinets may not have adequate area for return air passage. Installing grilles in solid sections of these doors may improve air circulation.

Figure 11-22 Main Return Duct for Floor-Cavity Return



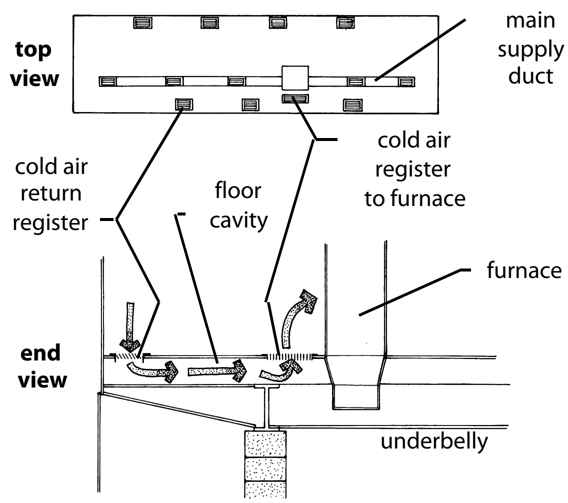
A hole in the floor and a hole in the rear of the furnace connect the furnace to the floor cavity where it gets its return air. This obsolete system should be retrofitted as described in the text.

Filters, if present must be kept clean because the heating efficiency steadily deteriorates as the filter collects dirt. Most filters are made of washable fiber or foam although many filters for electric furnaces are replaceable fiberglass in a cardboard frame.

Duct blockages should be identified and removed. All registers should be screwed to the floor. Flattened fins should be straightened or registers replaced to allow maximum airflow. Dirty registers should be cleaned by brushing them with a stiff brush from both sides. (Dirty air-conditioner coils should be cleaned as described in *"Split-System Air Conditioners" on page 176*.)

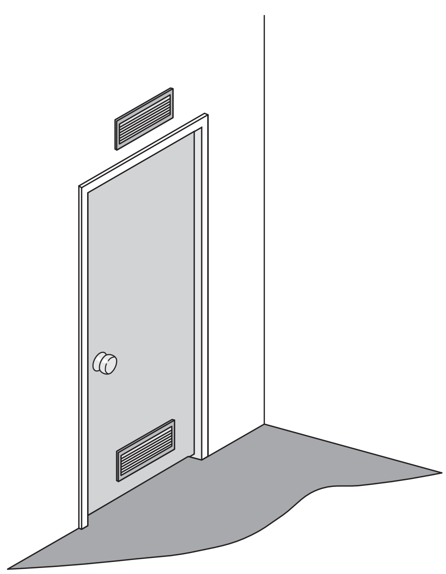
Supply registers often deliver more heat to rooms near the furnace than to rooms farther away. End rooms may not receive enough air to keep them comfortable, due to lower airflow and because these rooms lose more heat from their greater area of outside walls and windows.

Figure 11-23 Floor-Cavity Return Air



Registers near the wall let return air from the home into the floor cavity, where it travels back to the furnace. Floor return-air systems are often a source of excessive air leakage.

Figure 11-24 Return Air Through Interior Doors



A register in or above the interior door lets return air back to the furnace. Cutting the door off 2 inches from the floor is also effective.

You can improve airflow in distant rooms by opening adjustable vanes in the distant registers and by closing vanes or partly sealing the room registers closer to the furnace. Blocking off sections of registers can increase duct leakage and reduce airflow slightly, so don't block parts of registers unless it solves a comfort problem in a distant room. Don't block off any registers completely, because this builds pressure and reduces airflow too much.

Before you block off part of a supply register, be sure that return air has an unobstructed path back to the furnace by cutting off interior doors or installing grilles in interior doors, if necessary. Interior doors should have an inch or more gap underneath or a grille through them for return air. Some newer homes have grilles above the door.

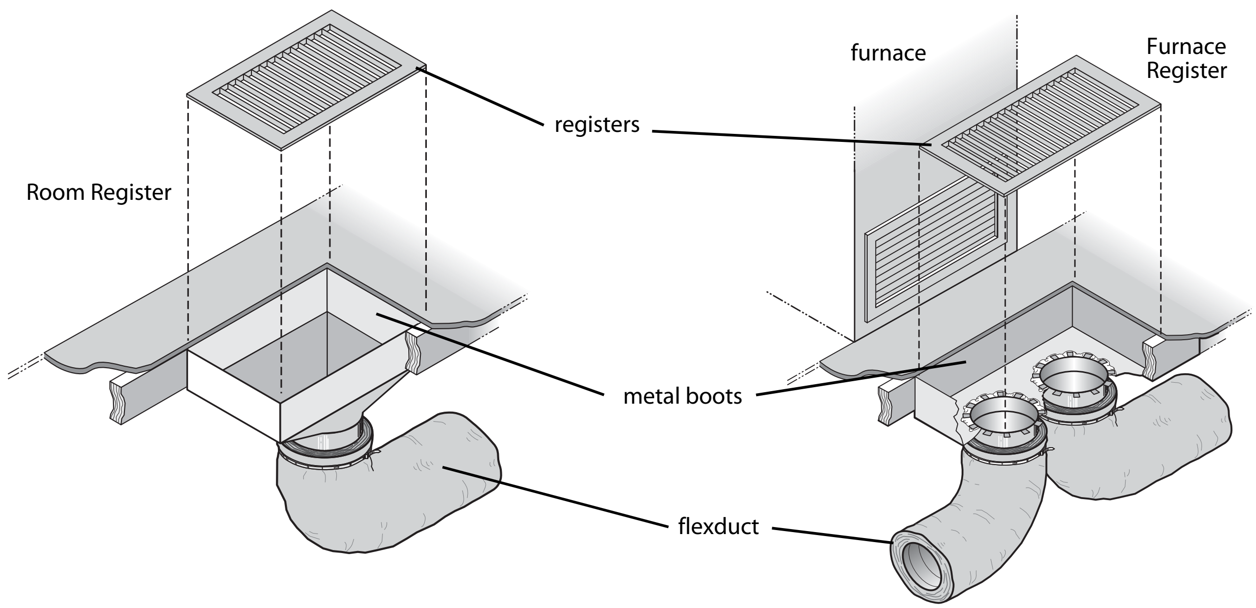
Interior doors are usually hollow core doors with a framing member at the bottom. If you have to cut the door off for return air, it is best not to cut through this framing piece. Instead, remove the bottom framing piece, cut the door, and then glue the piece back in place.

Rooms distant from the furnace which are hard to heat may require a new return duct, running through the crawl space, connecting the room to the furnace with metal fittings and flexduct (R-4 flexduct—10-to-14 inches in diameter—is sufficient for return duct).

Zone Heating

Zone heating is heating the home's occupied section to a comfortable temperature while unoccupied sections remain cooler. Zone heaters can save energy by keeping people warm in a localized area of the home. Unoccupied parts of the home remain cooler due to a low thermostat setting on the central heating system. Zone heating can produce energy savings of up to 20%.

Figure 11-25 Return Air Ducts



Air distribution from the furnace to hard-to-heat areas, like additions and back bedrooms, can be improved by retrofitting return air ducts with registers in the rooms and at the furnace. This method can help bring return air from the far corners of homes that formerly had return air in the floor.

Zone heating is a practical and effective way to reduce heating costs in homes. Zone heaters are more efficient than central heating systems because zone heaters do not have ducts which lose a portion of the heat that the furnace produces.

Zone heaters can supplement the central heating system by providing heat to specific areas where occupants spend most of their time. Savings from zone heating how residents combine the use of space heaters and centralized heat.

One zone heating strategy involves controlling the central heat with an ***programmable thermostat*** that provides a comfortable temperature throughout the house during main activity periods. For the remainder of the day, the automatic thermostat sets the temperature back to between 50°F and 60°F. Zone heaters provide heat where the home's occupants spend their time. To provide extra comfort in bathrooms, a 250-watt heat lamp radiates heat from an approved ceiling-mounted fixture. Residents use electric blankets at night.

If you use zone heat, check that your water supply is heavily insulated. Self-regulating heat tape is also a good idea to keep pipes from freezing during very cold weather.

Electric Zone Heaters

Some homes are equipped with built-in electric resistance heaters. These zone heaters—electric baseboard heaters and wall heaters—should have their heating elements gently dusted periodically to remove dust. You should leave adequate clearance around these heaters to allow air to circulate.

Electric space heaters can pose a safety hazard unless they are designed and used properly. Many cheaper and older portable electric space heaters are not safe. Their red-hot elements and lack of safety features can lead to fires.

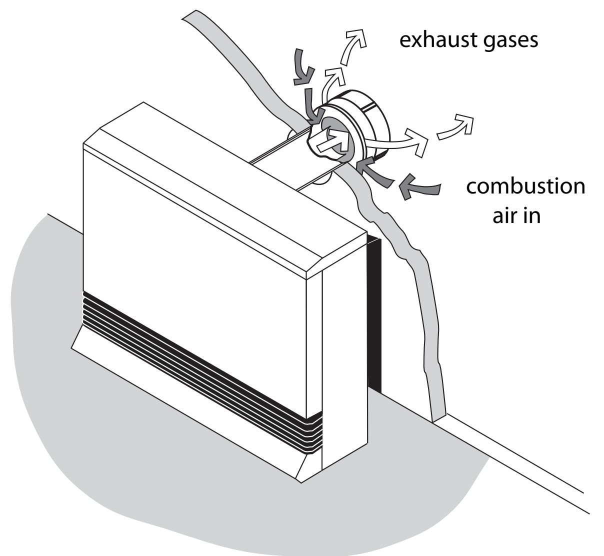
Use portable electric space heaters safely by following the guidelines listed below:

1. Use safe space heaters. Note the characteristics of a safe space heater described below.
2. Do not overload circuits. Avoid using other heat-producing appliances like irons and toasters on the same circuit as the electric heater.
3. Avoid using extension cords with space heaters. If you absolutely must use extension cords, use only short heavy-duty extension cords.
4. Make sure that you have a properly functioning smoke detector.

If you decide to use a portable electric space heater, select one with the safety features described below:

1. Tip-over switch. Tip-over switches automatically shut the portable electric heater off if the heater falls over.
2. Protective grille. All electric elements that glow must be protected by a sturdy guard. A wire grille or other protection is essential to keep fingers and fabrics from touching hot elements.
3. Sealed heating elements. The heating elements should be sealed—encased in metal or ceramic. Young children might push objects through the protective grill. Sealed heating elements reduce the risk of fire and electric shock.

Figure 11-26 Gas/Propane Space Heater



Combustion space heaters must be rated for use in mobile homes. Like furnaces, they must take combustion air from outdoors and their burners must be sealed from indoors.

Gas, Propane, and Kerosene Space Heaters

Combustion space heaters for manufactured homes must be sealed-combustion and specially designed for use in manufactured homes. Heating capacity for combustion space heaters ranges from 11,000 Btus per hour to 40,000 Btus per hour. Space heaters are available in two different designs—an approximately 82% AFUE model and an approximate 92% AFUE model. AFUE means Annual Fuel Utilization Efficiency, a rating intended for comparison shopping. The more efficient model costs significantly but they are much more efficient at heating the central area of the home.

Never use unvented gas, propane, or kerosene space heaters. These unvented space heaters can deplete oxygen and produce carbon monoxide—a poisonous gas. If you use combustion space heaters, they must be sealed-combustion units specifically rated for use in mobile homes.

Wood Stoves

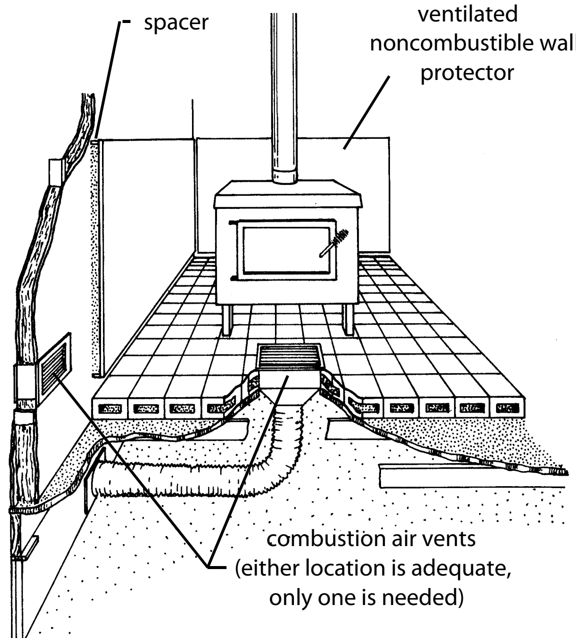
In some areas of the country, people use wood stoves as zone heaters in manufactured homes. Safety is the main consideration when using wood heat. For safety, HUD requires that all heat producing appliances installed as original equipment—including wood stoves—be approved for use in mobile homes. Wood stove installations into existing homes should carefully follow the guidelines summarized below and in the accompanying illustration.

***Safety* —** Wood stoves approved for mobile homes have a double metal shell. Approved wood stoves bring combustion air into their firebox from outdoors. Un-insulated double-wall pipe is used between the stove and about 4 inches from the ceiling. Class A chimney—insulated double-wall or triple-wall pipe—takes the chimney through the ceiling and roof. This triple-wall pipe, extending 36 inches or more above the roof, is supported by a bracket that sits on top of the roof.

Wood stove installers must comply with any local building codes or with fire codes applicable to wood stoves. Be sure you understand these requirements. Contact a knowledgeable official or wood stove expert before buying or installing a wood stove. Have your new wood stove installation inspected by a local building or fire official, to ensure it meets fire codes and safety conventions.

Many home insurance companies now inspect wood stove installations for compliance with safety regulations. Their caution is well-advised. If your wood stove installation does not meet the minimum requirements described here, you should not light another fire in the stove until you have made the necessary improvements. Fires started due to faulty installation may not be compensated by insurance.

Figure 11-27 Wood Heating Safety



Wood stoves installed before current regulations should have outside combustion air delivered to the area of the wood stove. New wood stoves should have combustion air delivered directly to the firebox. Walls and floors should be adequately protected from the high temperatures of the wood stove.

Most house fires caused by wood stoves result from sparks thrown out of the firebox or from inadequate clearances between the wood stove and surrounding combustible materials.

Sheetrock or wood paneling near the stove should never be uncomfortably warm to the touch. It is best to cover floors and walls adjacent to wood stoves with a noncombustible material. However, if adequate clearances are not met, these noncombustible materials won't protect your home. Without adequate clearances, heat can conduct to nearby wood or other combustible materials. This heat could dry the wood, reduce its ignition temperature, char it, or even ignite it.

Install a smoke detector in the same room as the wood stove. Put the detector at the opposite end of the room from the wood stove, so the alarm won't be needlessly triggered.

Minimum Clearances — The National Fire Protection Association (NFPA) and other experts have created guidelines for protective materials and clearances between wood stoves and their surroundings. Stove manufacturers are required to attach a metal tag to the stove listing its clearances. The following are general guidelines to be used only if the guidelines from the stove's manufacturer are not available:

1. The wood stove should be at least 36 inches away from wood or other unprotected combustible materials. Wood stove wall clearances can be reduced if the wall is protected by an approved, ventilated, noncombustible wall protector. You can use galvanized sheet metal or an approved manufactured wall protector. The wall protector must be spaced out from the wall at least one inch with screws and spacers (made of porcelain or other noncombustible insulators). Air must be able to flow into through the space between the protector and the wall—in the bottom and out the top. The spacers should be kept as far as possible from the hottest parts of the stove, so they don't overheat the wood stud to which they are fastened.
2. Single-wall steel stovepipe should be at least 18 inches from a combustible wall. The stovepipe can be 9 inches away from a ventilated protector or from a combustible wall, if it is shielded by another piece of stovepipe 2 inches larger in diameter than the single-wall chimney pipe.
3. The floor protector should extend 18 inches beyond the stove's front and 12 inches beyond its sides.
4. The double-wall flue pipe from the stove should terminate 4 inches or more from the ceiling. Class A pipe should begin at that point and should maintain at least 2 inches clearance from combustibles in the roof cavity.

The recommendations above are minimum safety guidelines only. Don't hesitate to exceed these recommendations by providing additional clearance and shielding for the wood stove, chimney, and the surrounding wall, floor, and ceiling surfaces.

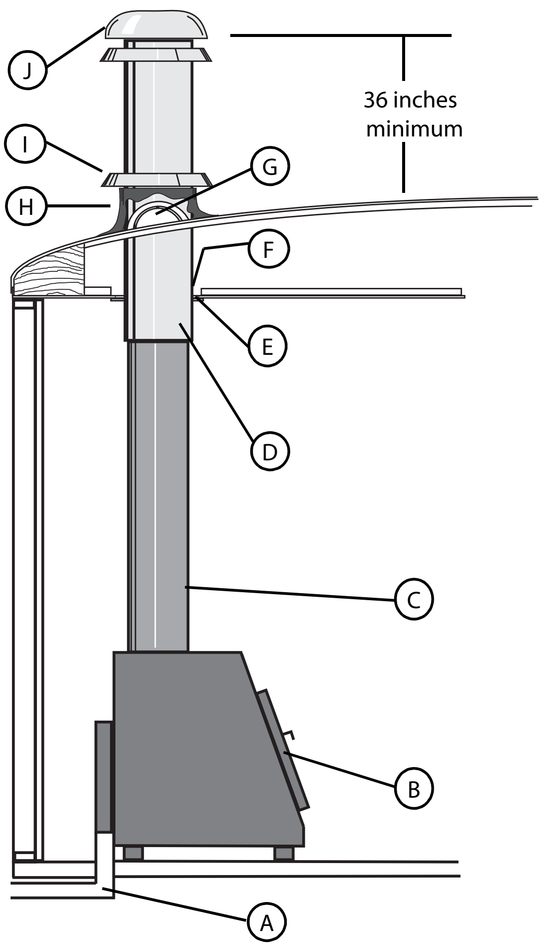
Combustion Air Inlets — Existing wood stoves—installed before current standards without a combustion air inlet from the outdoors into the firebox—should at least have an inlet on the floor near the stove. This inlet should use a medium-sized register (2 inches by 14 inches or 4 inches by 6 inches) and a sheet metal boot which goes all the way through the floor protector and floor or through a nearby wall. The inlet of the vent should be screened to exclude pests. The register should be closable, so it can be closed when the wood stove is idle. A square-to-round sheet metal boot should be used to go through the floor. A piece of flexible duct can connect this boot to an outlet in the skirting. Be sure to locate the outlet vent in the skirting on a side of the house that is sheltered from prevailing winds. A sheltered location will prevent wind gusts from forcing excess air into or pulling air out of the combustion air inlet. If the crawl space is vented, then the combustion air inlet need not go through the skirting but may terminate in the crawl space.

Chimneys — The chimney must extend above the roof at least 3 feet and be at least 2 feet above any nearby obstruction (within 10 feet) like an evaporative cooler.

Wood stoves can leak dangerous pollutants into the home if they do not exhaust all their combustion products. The flue pipe must have adequate draft. If you can smell wood smoke in a home, it's a sign of weak draft, inadequate combustion air, or inadequate home ventilation. Wood stove chimneys may need to be extended higher than the minimum standards to improve draft. Or, leaks in the chimney may need to be sealed to preserve the chimney draft.

Wood stove chimneys should be cleaned at least every heating season.

Figure 11-28 New Wood Stove Installation Requirements



A. Combustion air directly to airtight wood stove; B. Double-wall wood stove approved for mobile homes; C. Double-wall flue pipe directly to wood stove; D. Triple-wall or insulated double-wall pipe through roof cavity; E. Trim collar or thimble; F. 2 inches clearance from combustibles in roof assembly; G. Roof support bracket; H. Flashing; I. Storm collar; and J. Rain cap.

Chapter 12 Cooling Systems

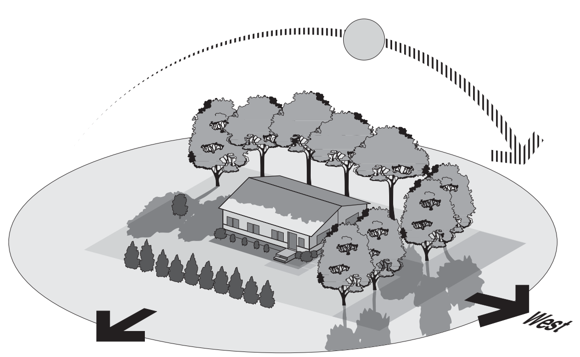
Summer comfort is determined by heat loss, heat gain, and heat production by our bodies. Air temperature and humidity are most important, but air movement, sunshine, clothing, activity level, and temperatures of surfaces around us also influence our comfort.

If you understand what makes you comfortable and if you begin using natural cooling methods, you won't need as much air conditioning.

Shading is the most effective strategy to control cooling costs. Solar heat falling on your home comprises more than one-half of the heat that requires removal by a cooling system. If you block this heat and prevent it from falling on your home, you may not need air conditioning.

Another effective way to improve comfort and reduce cooling costs is to use fans to promote ventilation with outdoor air during moderate weather and to circulate indoor air when the air conditioner is operating.

Figure 12-1 Shade Tree Placement



Shade trees on the home's south side shade the roof from overhead summer sun during the morning and early afternoon. Shade trees on the west shade the home during the afternoon when the sun is lower in the sky.

In moderate climates, shading, ventilation, and air circulation may provide all the cooling you need. In more humid climates, air conditioners are necessary to provide a high degree of comfort. In dry climates, evaporative coolers are effective and much less expensive to purchase and operate than air conditioners.

Figure 12-2 Percent of Solar Heat Blocked by Window Treatments

Shade Treatments for Single-Pane Glass

Sun Screen (indoors)	20-30%
Colored Venetian Blind	25-40%
Draperies (light colored)	40-55%
Opaque Rolling Shade (dark exterior)	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 exterior)	75-80%
Aluminum Louvered Sun Screen	80-85%
Awnings	50-90%

The percentage of solar heat blocked varies according to the shading device used.

Shading and Reflecting

Heat from the sun shining through windows and on roofs is a major reason for needing mechanical cooling systems. The most effective way to reduce solar heat is simply to block it, using: shade trees, vines and trellises, metallized window films, awnings, sun screens, and bright roof coatings.

Shade trees and trellised vines provide the most effective shading. They don't allow the sun's rays to reach the home and they create cool buffer zones near the home. For a detailed discussion of the advantages of landscaping, please refer to *Chapter 3* ***Landscaping***.

Effective shading can also be gained from reflective roof coatings, window films, interior window treatments, sun screens, awnings, low-e glass, and reflective glass.

Reflective Roofs and Walls

Dark colors are inappropriate for walls and roofs in hot climates, because they absorb too much solar heat. The exterior walls and roof should be reflective to reflect unwanted solar heat.

If you repaint your exterior walls, choose white or a very light color.

When you reroof your home, choose a reflective roofing or roof coating. The most common reflective coatings are asphalt-based coatings, mixed with aluminum particles and mineral fibers. They reflect about 60% of solar heat hitting the roof. These reasonably-priced asphalt coatings vary in quality, mainly due to the amount of aluminum particles in each five-gallon container. The better coatings, which are more expensive, contain more aluminum and are more reflective. Be sure to stir this asphalt/aluminum coating vigorously and often during its application.

Bright white latex rubber coatings reflect up to 75% of solar heat. These latex coatings are more dependent on proper surface preparation than asphalt coatings. The roof surface must be clean and dry before application. Some latex coatings require a primer coat.

Most large hardware stores and lumber yards carry both asphalt and latex roof coatings. Follow the manufacturer's instructions for surface preparation and application.

Interior Window Treatments

Interior window treatments with reflective surfaces—either metallized or bright white—can block solar heat effectively. Opaque roller shades with white surfaces facing the exterior repel about 80% of the solar heat entering the window. These roller shades block most of the light and all the view.

White venetian blinds and white slim shades (a smaller-scale venetian blind) repel 40% to 60% of the solar heat entering the window. These venetian blinds and slim shades also block most of the light and view.

If you want to retain some light or view, install roller shades made with metallized plastic window film. Like reflective films applied directly to glass, these metallized plastic roller shades can preserve the view and transmit some light, while blocking most of the heat.

Figure 12-3 Solar Transmittance

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	55-65% (standard)	75%
Double-Pane Low-E	45-50% (hot climate)	50%

Solar and visible transmittance for new window glass.

Figure 12-4 Trellis for Shading

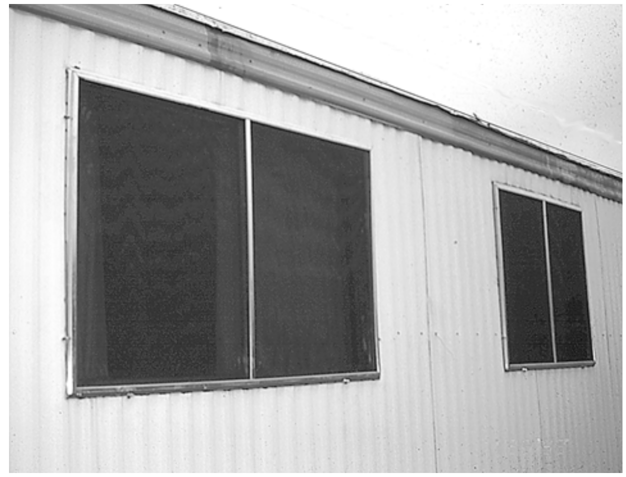
A trellis covered with climbing vines is a very effective shading device because it stops solar heat before it reaches the home.

Reflective Window Films

Metallized plastic window films (similar to those applied to automotive windows) can block 50% to 75% of the solar heat transmitted by single-pane glass.

A microscopic layer of metal on these films reflects solar radiation. Installed on the interior side of single-pane glass, reflective window films repel solar heat, cut glare, and reduce fading. The most effective films look like a mirror when viewed from outdoors during the daytime. Tinted films that color the glass are not as effective in blocking solar heat.

Figure 12-5 Sun Screens



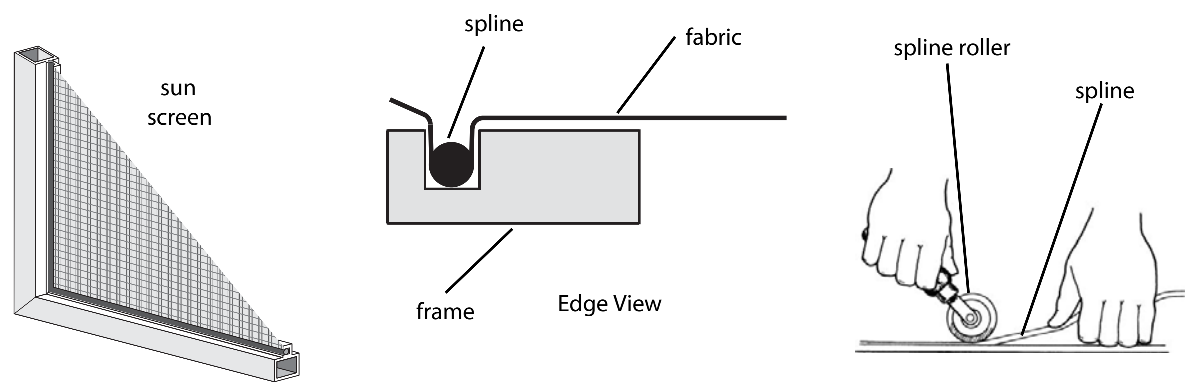
Installed on the window's exterior side, sun screens block 65% to 85% of solar heat.

An aluminum patio cover and a wall of large sun screens shades this patio area from the strong desert sun.

Because reflective window films block daylight in addition to solar heat, consumer acceptance has been slow. Newer films (sometimes called low-e films) recently introduced to the marketplace, transmit more light while blocking most of the heat. These low-e films also reflect heat back into the home in winter.

Window films may be installed for $3 per square foot or less. Installing reflective window film is a moderately difficult do-it-yourself project. These

Figure 12-6 Sun Screen Construction



Sun screens are constructed like insect screens. The fabric sun-screen material is stretched onto a metal frame and clamped in place by a plastic spline inserted in a track.

films—manufactured with removable protective layers—require careful placement and are very sensitive to dirt.

Unlike sun screens, reflective window films do not obstruct the operation of any kind of window.

Window films are probably the best shading method for unshaded sliding glass doors. Window films also work well for outwardly opening windows that wouldn't open if you installed an exterior sun screen.

Lower-quality window films may get cloudy or deteriorate because of intense sunlight, harsh cleaning fluids, or abrasion from cleaning by rough towels. Newer high-quality window films have a scratch resistant coating and can be easily cleaned with soapy water and a soft cloth.

Sun Screens

Sun screens are often the least expensive window-shading option that retains a full view through the window. Sun screens can be removed in winter to allow solar heating.

Most sun screens absorb 65% to 70% of solar heat before it enters the home. A different type of screen made of aluminum with tiny louvers absorbs about 85% of the solar heat. The aluminum, louvered sun screens are more expensive than standard sun screens.

Sun screens are made like insect screens, with aluminum frames that have a channel and with retaining splines. Sun screen fabric is available in a variety of colors.

Sun screens must be installed on the exterior side of a window to be effective. For all windows that open outwardly, such as awning windows or casement windows, sun screens should be installed on the movable sash. Sun screens are frequently used to shade east- and west-facing porches.

Sun screens, like window films, are not easy do-it-yourself projects. Professionally built and installed sun screens cost $2 to $4 per square foot. You can save 50% or more with home built and installed screen kits, but your final product may not last as long as a professionally-built sun screen.

Awnings

Awnings are expensive but popular in hot sunny climates, since they intercept solar heat before it gets to the window.

The three most important considerations in selecting and designing awnings are:

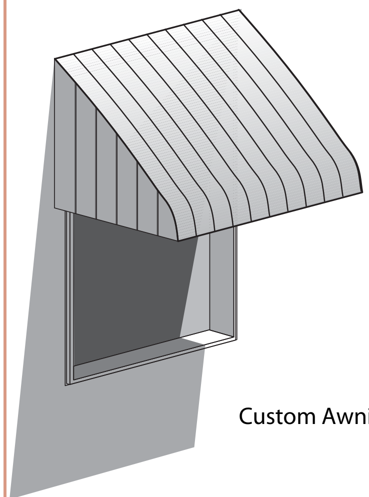
1. **Amount of shade desired.** The shade an awning produces is closely related to how far the awning drops down over the window. This distance is known as the drop of the awning.
2. **Importance of maintaining a view out the window.** Depending on their drop, awnings can cut off a significant portion of a window's view.
3. **Cost of the awning.** Custom-made awnings are more expensive than do-it-yourself awning kits or mass-produced awnings.

Awnings on a home's south side need a drop measuring 45% to 60% of the window height to block solar radiation from high in the sky. Awnings on the east and west need a drop of 60% to 75% in order to block solar radiation emanating from lower in the sky during morning and afternoon.

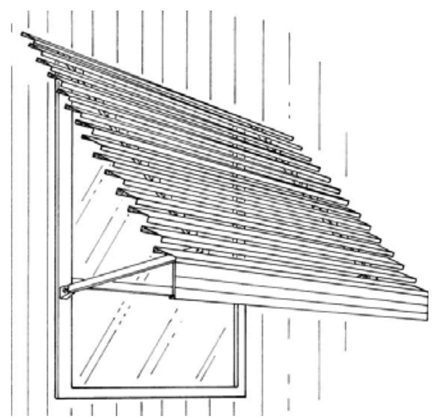
Custom-made awnings usually have sides which make them more effective at blocking a variety of the sun's angles throughout the day. Do-it-yourself awnings, lacking sides, are more effective if they are wider than the windows they shade. Some aluminum awnings are adjustable and can actually close completely (like a hinged lid), protecting the window from high winds.

Retractable awnings—although expensive—give maximum shade during hot weather while allowing sunshine and view during cooler weather. Some specialty awnings close over the window like a lid for protection from high winds. These protective awnings are particularly appropriate in the southeastern hurricane zones.

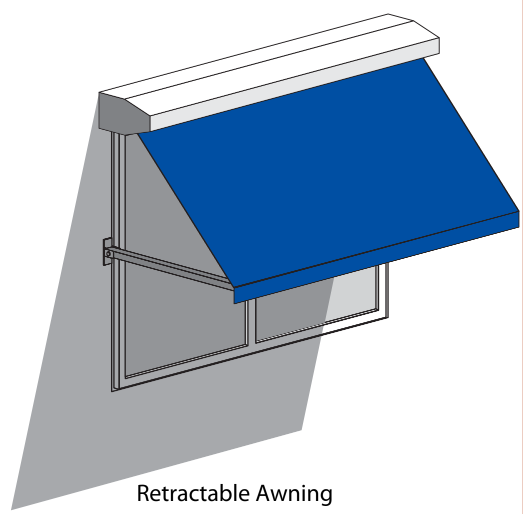
Figure 12-7 Awnings



Custom Awning with Sides



Do-it-yourself Slatted Awning



Retractable Awning

The most costly window shading device, awnings are also often the most effective.

Low-e Glass and Reflective Glass

A ***low-e*** coating of tiny metal flakes improves the thermal performance of double-pane glass in both summer and winter. In summer, low-e glass reduces the transmission of solar heat through the glass by about 30%. Glass with more metal flakes is called reflective glass; it's used as a single pane and it looks like a mirror from the outdoors.

In winter, the low-e coating helps insulate the glass. A low-e double-pane window insulates 30% better than a standard double-pane window and about 250% better than a single-pane window.

Low-e glass is a desirable feature in almost all climates. However, in hot climates, reflective single-pane glass may outperform low-e glass, since reflective glass blocks more solar heat.

If you're buying new windows, it pays to buy the most efficient ones you can afford. Energy benefits alone, however, don't justify the cost of replacing windows.

Air Circulation and Ventilation

Air circulation means moving indoor air to create a windchill effect. Ventilation means using cool outdoor air to remove accumulated solar heat and internally-generated heat—usually done during evening and night hours.

The cooling windchill produced by circulation fans allows about a 4°F increase in the thermostat setting—with no decrease in comfort—and saves 15% to 40% in air-conditioning costs.

Ceiling fans are probably the most effective air-circulation fans. Homes with adequate headroom should have ceiling fans in every room, if air-conditioning costs are high. Table fans and floor fans also do a excellent job of circulating air within the home, particularly for homes with low ceilings.

Figure 12-8 Oscillating Fans

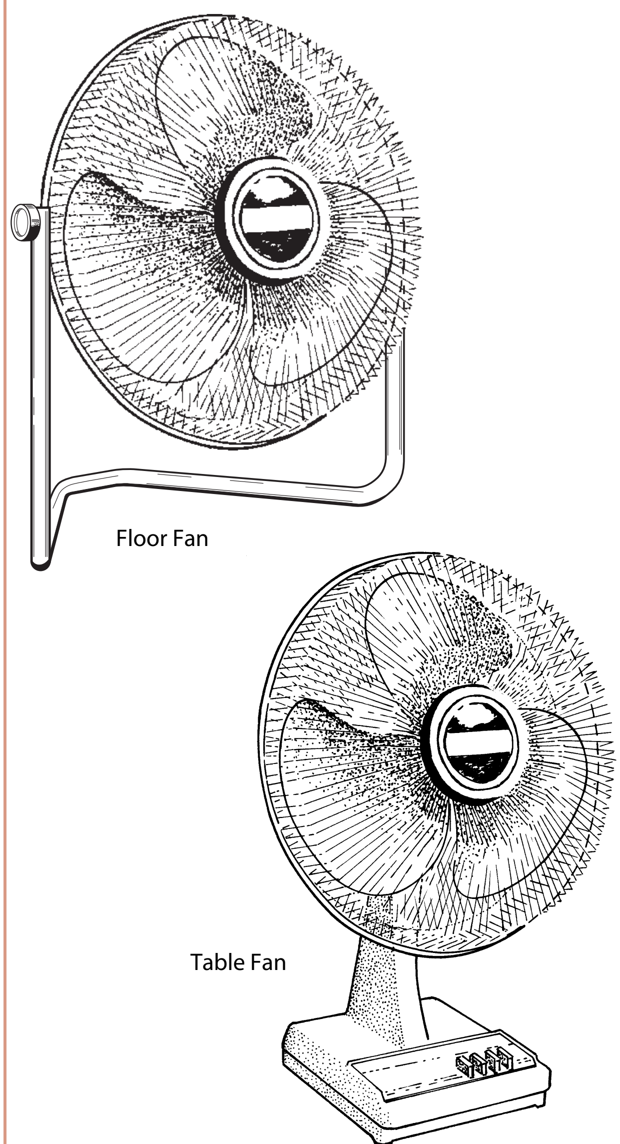
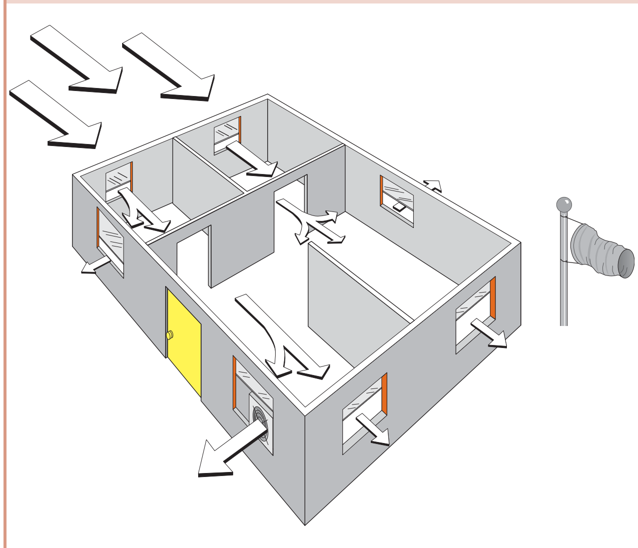


Table fans and floor fans are the most popular and cost-effective cooling devices. They cool people by creating a wind chill.

Ventilation can reduce your air-conditioning costs up to 50%. During mild weather, it can substitute for air conditioning. During hot weather months, ventilation can considerably reduce air-conditioning hours by flushing heat out of the home with cool (and free) nighttime air.

Figure 12-9 Nighttime Ventilation



A window fan aids the cool night breeze in flushing accumulated heat out of the home.

Windows facing into the prevailing wind are best for admitting outdoor air. Use window fans to push air out of the leeward side of the home—the side facing away from prevailing winds. Window fans can increase breezes or create a breeze when outdoor air is still.

Experiment with opening windows and positioning window fans in different rooms to see which arrangement works best. Try using smaller window openings for inlets and larger ones for outlets to increase the ventilating air's velocity. Remember that well-designed landscaping can help channel cooling breezes and create cool zones around the home.

When using ventilation as a substitute for air conditioning, you may need to consider outdoor and indoor humidity. Removing moisture from humid air is an important function of an air-conditioning system. In humid climates, ventilation may introduce excessive moisture into the home. When the air conditioner is turned on, it may have to run longer to remove this moisture.

So, if air is very humid (70% relative humidity or above), wait until the outdoor air temperature is less than 65°F before shutting down the air conditioner and introducing cool evening air.

Air-Conditioning Principles

Air conditioners employ the same principles as refrigerators. An air conditioner cools your home with a cold indoor ***coil*** called the ***evaporator.*** A hot outdoor coil, called the ***condenser***, releases the collected heat outside.

The evaporator and condenser coils are similar to a car radiator—copper pipes surrounded by aluminum fins. Fans move indoor air through the evaporator coil and outdoor air through the condenser coil.

A fluid, called the ***refrigerant***, collects heat at the evaporator coil and releases it at the condenser coil. A pump, called the ***compressor***, forces the refrigerant through the two coils and through copper tubing connecting them together.

The evaporator removes water vapor from indoor air as it passes through the coil's fins. The cold evaporator condenses water from the humid indoor air and drains it away. This dries the air and makes it more comfortable.

Air-Conditioner Energy Ratings

If your air conditioner is more than 10 years old, it is likely inefficient. You could save 20% to 50% of air-conditioning costs by replacing it with a newer, more efficient model.

It is easy to compare energy consumption of various air conditioners. The ***Energy Guide Label***, listing an air conditioner's energy efficiency must remain on the air conditioner until it is sold. To determine energy efficiency for an existing air conditioner, find the model number and manufacturer from the nameplate. Contact a local dealer of that manufacturer's equipment and ask them to look up the efficiency rating for you.

Energy ratings of air conditioners are based on how many Btus of heat per hour the unit removes for each watt of power it draws. For central air conditioners, the efficiency rating is called the ***Seasonal Energy Efficiency Ratio*** or ***SEER***. For room air conditioners, it is called ***Energy Efficiency Ratio*** or ***EER***.

Central air conditioners are sized from 18,000 Btuh to 48,000 Btuh (1.5 ton to 4 ton). National appliance standards for central air conditioners require a SEER between 8.9 and 10.0, depending on when the unit was manufactured. There is a wide selection of units available with SEERs up to almost 17.

Room air conditioners are sized from 5500 Btuh to 14,000 Btuh. National appliance standards require room air conditioners built after January 1, 1990 to have an EER of 8.5 or greater. An EER of 10 is considered energy-efficient. Select a room air conditioner with an EER of at least 9.0, if you live in a mild cooling climate. Select one with an EER over 10, if you live in a hot climate.

Air conditioners with higher EERs or SEERs generally cost more, but the energy savings will return the initial investment several times during its life span. Buy the most efficient air conditioner you can afford, especially if you live in a hot climate or if your air-conditioning costs are high.

The most efficient air conditioners are listed by size and efficiency in the ***Consumer Guide to Home Energy Savings***, listed in the bibliography.

Using Air Conditioners

Setting the thermostat lower than necessary for adequate comfort leads to high energy costs. Set the thermostat to 76°F or higher, and when you leave, turn the thermostat to 82°F or higher. The air conditioner will run longer than usual when you return, but you'll save energy and money because the unit ran little, if at all, while you were gone.

Keep in mind that the air conditioner will cool no faster, if you set the thermostat to a lowerthan-desired temperature upon your return.

Residents with regular schedules of occupancy and vacancy can save money and improve comfort and convenience by using ***automatic thermostats***. Automatic thermostats combine a clock and a thermostat in order to control home temperatures automatically. (*See "Programmable Thermostats" on page 150.*)

Air-Conditioner Maintenance

Air-conditioner efficiency is directly related to routine maintenance. Well-maintained air-conditioning systems consume from 15% to 40% less energy than neglected air-conditioning systems.

The following routine maintenance tasks can be performed by a technician or a home owner. These general tasks should be performed on all air-conditioning systems. Additional maintenance relating to a specific type of air conditioning system is listed under that particular system.

- Cleaning or replacing filters regularly (every one-to-two months, depending on operating time)
- Cleaning the blower's fan blades (*See "Cleaning Blowers and Heat Exchangers" on page 156.*)
- Removing debris from around condensing units
- Cleaning condenser coils as often as necessary (dirt is usually visible)
- Cleaning evaporator coils and condensate pans every two-to-four years
- Straightening fins in evaporator and condenser coils

Evaporator coils located in the furnace can be very difficult to clean. If the technician has to remove the coil to clean it, the job can cost $300 or more. This is a good reason to be very diligent about changing filters.

Brush surface dirt from the coil with an old hair brush. Common household cleaners are usually adequate for removing the remaining dirt. Use special foaming cleaners for pushing dirt out of the recesses of coils if the dirt is deeply lodged. Caustic or basic cleaners, used by professionals, remove grease or mineral scale from evaporator coils. These caustic or basic cleaners are a last resort because they may corrode nearby ducts or metal in the coil. If you use strong cleaners, be sure to wear rubber gloves.

Remember: When cleaning any air-conditioning coil, remember not to bend the delicate metal fins with high-pressure water or vigorous scrubbing.

Air Conditioner Service

Air conditioner adjustments and repairs is strictly for professionals. Even then, many professionals don't know how to correctly install and service air-conditioning systems. The lack of consistency among air-conditioning technicians gives the consumer no guarantee that basic operating necessities—correct sizing, airtight ducts, the correct amount of refrigerant, and adequate airflow—are present in the air-conditioning system.

An expert professional service technician performs the following procedures to diagnose and service an air conditioner:

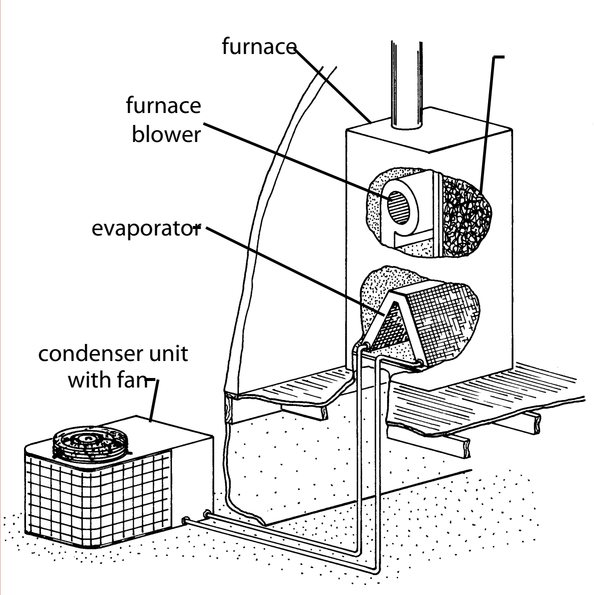
- Measures performance and efficiency;
- Verifies correct refrigerant ***charge,*** by measurement;
- Diagnoses and seals duct leakage (central only);
- Verifies adequate airflow, by measurement;
- Verifies correct electric control—especially that heating is locked out when the thermostat calls for cooling;
- Inspects evaporator and condenser coils for dirt;
- Inspects electric terminals—cleans and tightens connections and applies non conductive coatings, if necessary;
- Oils motors and checks belts for tightness and wear; and
- Checks level and tightness of thermostat, or installs automatic thermostat.

Central Air Conditioners

A ***central air conditioner*** is the most quiet and convenient way to cool a larger home. There are three types of central air-conditioning systems common to manufactured housing: ***packaged air conditioners, split-system air conditioners,*** and ***hybrid-split-system air conditioners.***

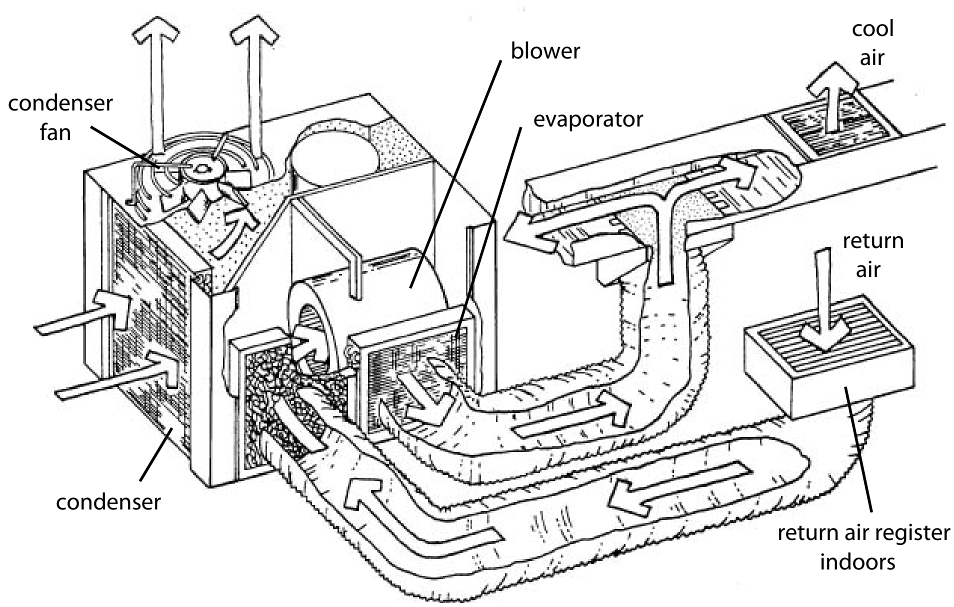
Central air conditioners have ***supply*** and ***return*** ducts that connect to a central air handler.

Figure 12-10 Split-System Air Conditioner



The evaporator is placed in the cooling coil compartment of the furnace. The condenser, compressor, and condenser fan are installed outdoors on a concrete slab.

Figure 12-11 Packaged Air Conditioner



Packaged air conditioners have their evaporator, condenser, and compressor in a cabinet located outdoors. Indoor air is circulated by a blower, enclosed in the same metal cabinet.

Packaged Air Conditioners

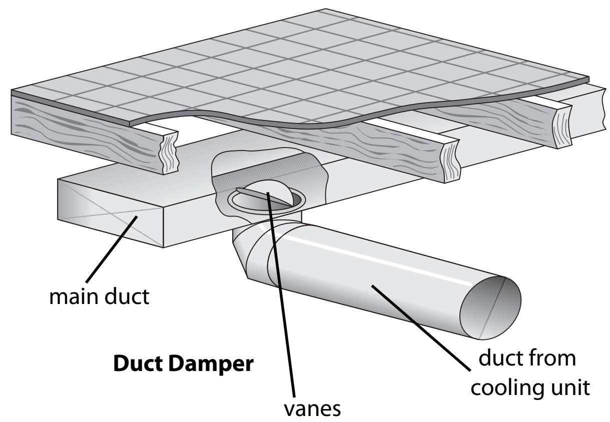
Packaged air conditioners (also called unitary air conditioners and self-contained air conditioners) have the compressor, condenser, and evaporator all in a single cabinet located outside the home.

A packaged air conditioner may also contain a gas furnace or some electric resistance heating coils. ***Return air*** from the home enters a large main return register, the travels through a filter and insulated duct and into the packaged air conditioner. The air conditioner's blower blows this air through the evaporator coil and into another insulated duct that is connected to the home's main duct and supply registers.

Packaged air conditioners for double-wide mobile homes use a Y-shaped fitting that splits the main supply duct (12-to-14-inch diameter) into two branches (10-to-12-inch diameters). These branches then connect to main ducts on each half of the double-wide home. The supply connections to the main duct are similar to those shown for evaporative coolers.

Some packaged air conditioners have no heating elements. Instead, these air conditioners share ducts with a furnace, installed indoors. These systems require dampers at the base of the indoor furnace and in the supply duct of the air conditioner. These dampers prevent cool air from blowing into the furnace closet, air that would waste energy or cause condensation and corrosion in the furnace.

Figure 12-12 Damper for Outdoor Cooling Units



When a packaged air conditioner or evaporative cooler shares ductwork with an indoor furnace, it must have a damper in the main duct. This damper prevents hot air from flowing into the cooling unit during the winter.

Packaged Air-Conditioner Dampers —

Packaged air conditioners need special dampers when they share ducts with a furnace installed indoors. **(The absence or malfunction of these dampers can cause severe energy waste.)**

The connection between the furnace and the main duct needs a damper that is positioned either automatically or manually for heating or cooling. Automatic dampers are now available for all furnaces. The automatic damper, installed in the cooling coil compartment, closes under pressure from the fan in the air conditioner and opens under pressure from the furnace fan. Older furnaces may have a louvered manual damper installed at the base of the furnace and positioned for either heating or cooling by a hand control. These dampers prevent cool air from filling the furnace compartment and rusting out the furnace during the cooling season, but won't prevent heated air from entering the packaged air conditioner outdoors during the heating season.

Preventing heated air from circulating through the air conditioner requires another damper inside the air conditioner or supply duct. Inspect the air conditioner by removing an access panel near the evaporator on a cold day when the furnace is operating and see if warm air from the furnace is flowing into the packaged air conditioner.

The one-way airflow dampers—preventing heated air from entering the air conditioner—are forced open by the air conditioner fan and they close by gravity. They're usually located where the insulated supply duct feeds into the main duct although some packaged air conditioners have a damper inside or attached to them.

See if the damper opens and closes by disconnecting the duct from the supply side of the packaged air conditioner or from the main duct. If the damper does not open and close smoothly, repair or lubricate it. If the damper isn't present, install a new one. If you can't repair or install a damper, then at least plug the insulated duct during the heating season to prevent the loss of this heated air. The return register for the packaged air conditioner in the home should also be plugged in the winter.

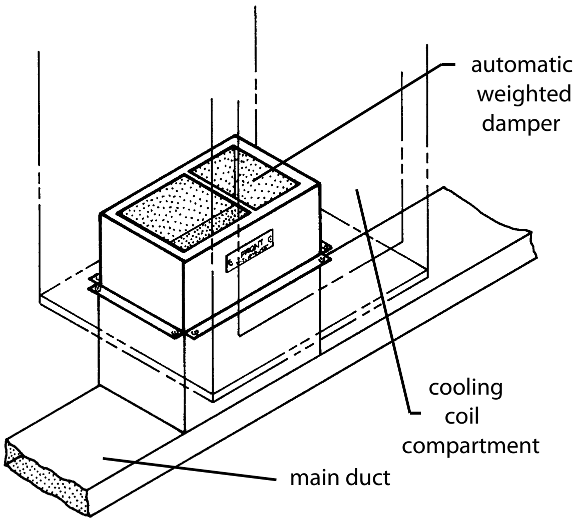
Packaged Air-Conditioner Maintenance —

Packaged air conditioners are less likely to have refrigerant-charge problems than split-systems because they are charged at the factory. However, duct leakage and blockage can be worse because of the flexducts that connect them to the home's main duct.

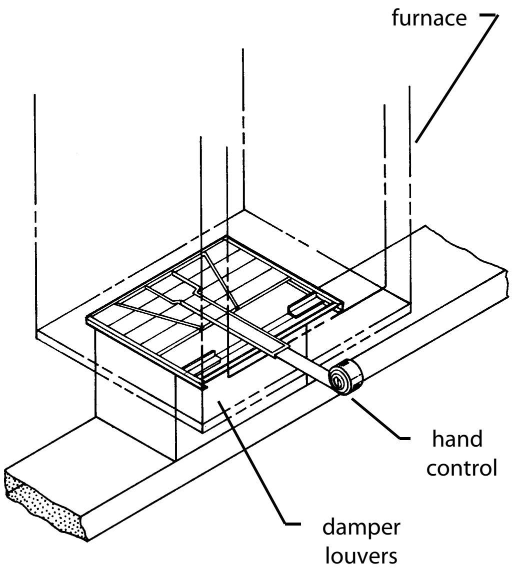
In wet climates, rust attacks the cabinets of packaged air conditioners. Rust holes can create excessive air leakage in the supply or return air. If the metal divider between the evaporator and condenser rust out, warm outdoor air mixes with cool indoor air circulating through the evaporator compartment.

Rust accelerates if the air conditioner cabinet sits directly on a concrete slab without spacers to provide an air space underneath. If your air conditioner sits directly on the slab, buy and install rubber spacers to hold the unit up off the slab.

Figure 12-13 Furnace Dampers Used with Packaged Air Conditioners



Automatic Damper



Manual Damper

These dampers, used with packaged air conditioners and ground-mounted evaporative coolers, prevent cooled air from entering the furnace. The manual damper is open during the heating season and closed during the cooling season. The automatic damper opens and closes automatically.

Rust often necessitates replacing the air conditioner, although you might salvage it by plugging holes in the cabinet with pop-riveted sheet-metal patches and sealing them with duct mastic.

The filter is usually located in the main return register. Clean or replace it every month or two during hot weather.

To clean the evaporator and condenser in a packaged air conditioner, first open the cabinet and brush the surface dirt off with an old hair brush. Then, spray the cleanser into both sides of the coils. And finally, rinse them with very light spray from a garden hose. Allow the unit to air dry, or mop and vacuum the water out.

Split-System Air Conditioners

Split-system air conditioners have the evaporator coil in the furnace cabinet to cool the indoor air and a condenser outdoors to get rid of heat collected by the evaporator. The condenser and the evaporator are connected by copper tubing to carry the refrigerant back and forth. The furnace blower pulls return air from the rooms into the furnace cabinet and forces it through the evaporator coil, through the main duct, and out the registers.

Split-System Air Conditioner Maintenance — The filters in split-system air conditioners are located in the furnace compartment. Fiberglass filters should be changed and foam filters cleaned every month or so of frequent air conditioner use. A clean filter will keep the evaporator coil clean longer. If your furnace doesn't have a filter, you can order a filter rack and filter from a local mobile home parts distributor or service company. Filters keep the evaporator clean, which is important for efficiency and because cleaning the evaporator is a messy time-consuming job.

The evaporator should be inspected at least every other year and cleaned if necessary. Here's how to clean the evaporator:

Step 1: Remove the access panel near the bottom of the furnace. Brush the surface layer of dust or lint off the coil gently with an old hair brush. With the surface layer gone, brush more deeply and vacuum the loose dust and lint.

Step 2: Spray household cleanser on the coil from both sides and wait for it to soften the dirt.

Step 3: Spray rinse water on the coil from a spray bottle. Watch to make sure that the evaporator's metal trough drains by looking to see water coming out of the drain hose. If the hose or trough is plugged, it must be unplugged or the trough and duct will remain wet and grow mold. After cleaning, put the access panel back on the cooling coil compartment and seal it with tape or caulking.

The condenser should also be cleaned annually. To clean, remove the grillwork that protects the coil on the outside. Brush the coil's outside with a hairbrush to remove surface dirt. Straighten bent fins. Spray cleaner into the coil from outside and then spray water gently through the coil from inside the cabinet to push dirt out the same way it came in.

Hybrid-Split-System Air Conditioners

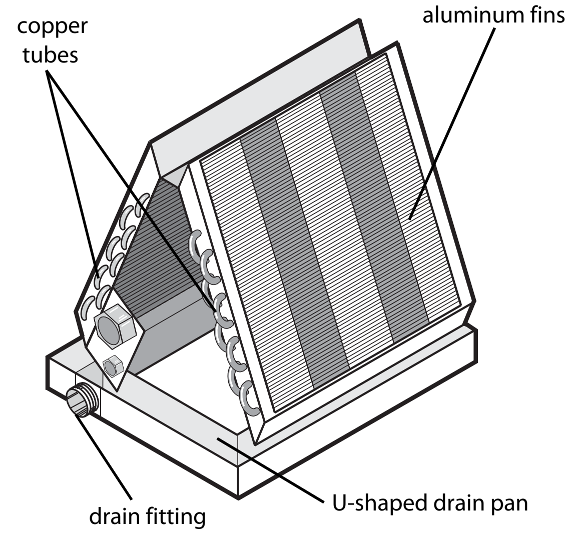
Hybrid-split-system air conditioners have an air handler that sits underneath the home or is attached to the floor. The air-handler contains a blower and the evaporator coil, both of which need to be cleaned every two to four years. It may also contain heating coils. The filter is usually located in the main return duct. The condensing unit is located outdoors like a standard split-system air conditioner. The maintenance procedures follow the general procedures listed above.

Central Air-Conditioning Airflow

Experts in the air-conditioning field say that nothing will compensate for low airflow through ducts except increasing airflow.

Obstructions in the distribution system like a dirty evaporator coil, duct dents, duct debris, and bent or dirty registers are major energy problems for central cooling systems. Good cooling efficiency is dependent on good airflow. There should be about 400 cubic feet per minute of airflow for each ton of air-conditioning capacity in order to achieve acceptable efficiency and performance. Less airflow may significantly reduce efficiency; more airflow may cause comfort problems.

Figure 12-14 A-Coil

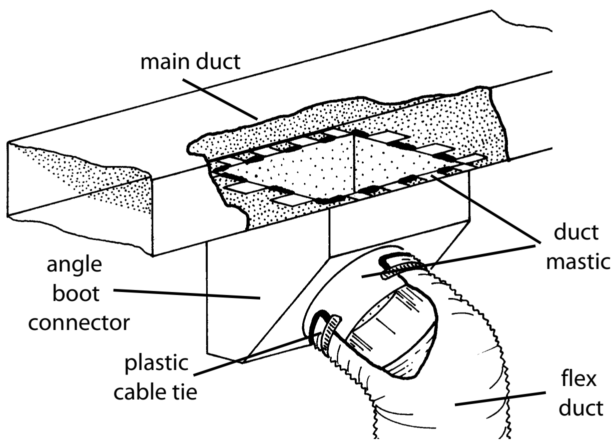


The evaporator coil of split-system air conditioners is an A-shaped panel of tubes and fins. A U-shaped pan under the bottom collects and removes water that condenses on the coil.

Service technicians can measure the airflow in the air-conditioning system to check if it is adequate in a variety of ways including: using an air speed meter, measuring air pressure in the ducts, and measuring temperature differences between the supply and return air.

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

Figure 12-15 Angle Boot Connection



This common fitting type is used to connect ductwork from external packaged air conditioners and to connect ground-mounted evaporative coolers to the main duct.

Air flowing out of every supply register must have an unobstructed path back to the furnace or air conditioner. Blockage in supply or return air ducts can pressurize portions of the home, increasing air leakage. Typical methods of improving free air return to a central return air register are cutting off the bottom of doors or installing louvered openings in doors. If you purchase a thicker carpet, be sure to maintain an inch or more clearance under interior doors.

Duct leaks are also very important and should be located and sealed as *Chapter 11* ***Heating***. Pay particular attention to sealing the boots that connect the registers with the main duct, because these are usually the areas with the most air leaks.

Duct leakage is a major problem in warm humid climates. Research by Florida Solar Energy Center (FSEC) found that effective duct repair can save 15% to 25% of cooling costs in manufactured homes located in hot humid climates.

Check the connections between flexducts and packaged air conditioners for leaks while the fan is operating, so you can feel the air leaks. If you feel leaks, disconnect the flexduct and re-seal it. Before slipping the inner polyethylene lining over the metal collar, coat the collar with $^{1}/_{4}$-inch of duct mastic. Clamp the inner liner to the collar with a plastic cable tie, and clamp the outer layer to the collar with another cable tie.

Some manufactured homes in southern climates have ducted return air. Check these return air ducts for leakage and obstructions as you would the supply air ducts. You can retrofit return air ducts if necessary to improve air distribution. (*See "Improving Air Distribution" on page 157.*)

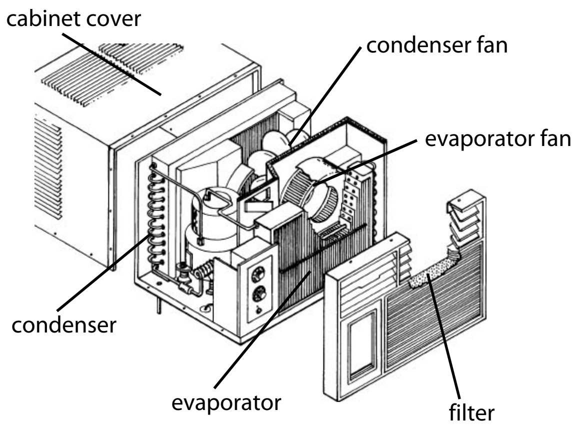
Room Air Conditioners

Room air conditioners save energy and money over central air conditioners by cooling specific rooms, instead of the whole house. Room air conditioners don't have energy-wasting ducts and they're smaller than central units, so they are less expensive to buy and operate. They require careful installation and should be supported by the window sill, not the window itself which might be damaged by the air conditioner's weight.

The cabinet of the room air conditioner contains the evaporator, the condenser, the compressor, controls, and all other parts. The evaporator and its fan face the indoors, and the condenser and its fan face the 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 back out through an unfiltered section of grille, also in the front cover. The heat, collected from indoors, is released into the outdoor air by the condenser and its fan.

Ceiling fans, table fans, and floor fans should be used to circulate air while room air conditioners are operating.

Figure 12-16 Room Air Conditioner



Located in a window or a hole in the wall, a room air conditioner contains the evaporator, condenser, compressor, and all other parts in a single cabinet. It has no supply and return ducts.

The National Electrical Code allows a room air conditioner drawing less than 7.5 amps to be plugged into any 15-amp or 20-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.

Room Air Conditioner Maintenance

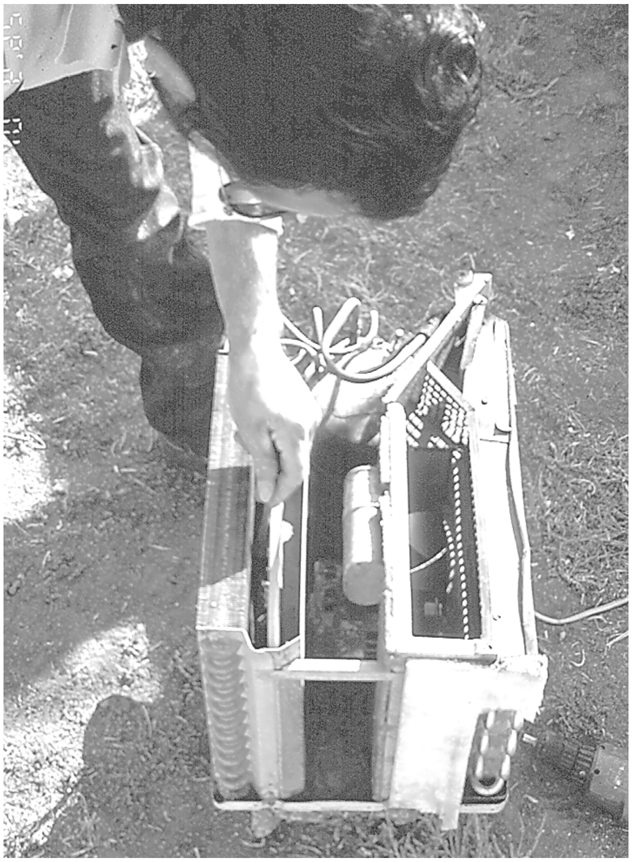
As with other air conditioners, keeping the filter and coils clean are the most important maintenance procedures. The filter is visible and easily removable from the front of the unit. Most filters are foam rubber designed to be cleaned with soap and water. In some models, the mechanical components slide out of the cabinet for cleaning and servicing. With others, you have to remove the unit from the window or wall to clean the coils.

Clean the coils by brushing them with an old hair brush, spraying them with cleanser, and then spraying them with clean rinse water. Try to keep the electrical components dry, and let the unit air-dry completely before using or storing it.

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

1. Seal thoroughly around the room air conditioner to prevent the infiltration cold air, if you plan to leave it in year round.
2. During the heating season, remove the room air conditioner, or cover it on the inside with plastic sheeting or an insulated removable box to prevent air leakage. Don’t cover the unit on the outside, unless it’s covered inside too, because warm moist indoor air infiltrating the unit from inside can cause condensation and rust.

Figure 12-17 Cleaning Room Air Conditioners



Here a technician brushes the interior side of the condenser (outdoor) coil, which is the side that collects most of the dirt. The evaporator (indoor) coil collects most of its dirt on the indoor side, making it easy to clean.

Evaporative Coolers

In the warm, dry climates of the western United States, ***evaporative coolers*** (also called swamp coolers) are a popular and energy-efficient way of cooling. Evaporative coolers use about one-quarter of the energy of air conditioners and cost about one-half as much to install. However, they don't work effectively in climates where the relative humidity remains above 40% during the cooling season.

Evaporative coolers blow the cool air into the home through a window, a hole in the ceiling, or through ducts. A large fan forces cool air into the house pushing warmer house air out through partially opened windows. The temperature of outdoor air, sucked into the cooler's cabinet, drops when water from the cooler's pads evaporates.

The evaporative cooler pulls outdoor air into its cabinet through absorbent pads dampened by water, which is pumped through distribution tubes. The distribution tubes are connected to a water pump that recirculates water from the cabinet's water reservoir. A float valve, connected to the home's water supply, keeps this reservoir supplied with fresh water to replace water evaporating from the pads.

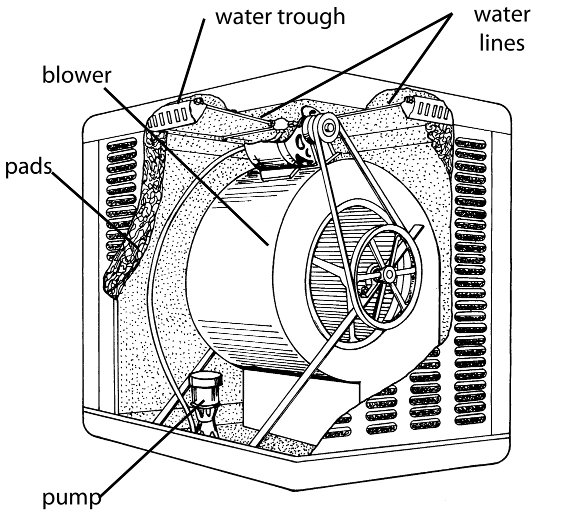
Evaporative coolers are rated by the cubic feet per minute of air they deliver to the home. Windows on the leeward side of the home are kept partially opened to provide one-to-two square feet of window opening for each 1000 cubic feet per minute of cooler capacity.

Evaporative Cooler Installation

Most evaporative coolers are roof-mounted. However, many experts prefer window- or ground-mounted units, because they are easier to maintain. The best place for an evaporative cooler is in the shade on the windward side of the home (side facing wind) because the wind aids the circulation of cooled air through the unit and into the home. The windward location also discourages recirculation of exhaust air from the house into the cooler.

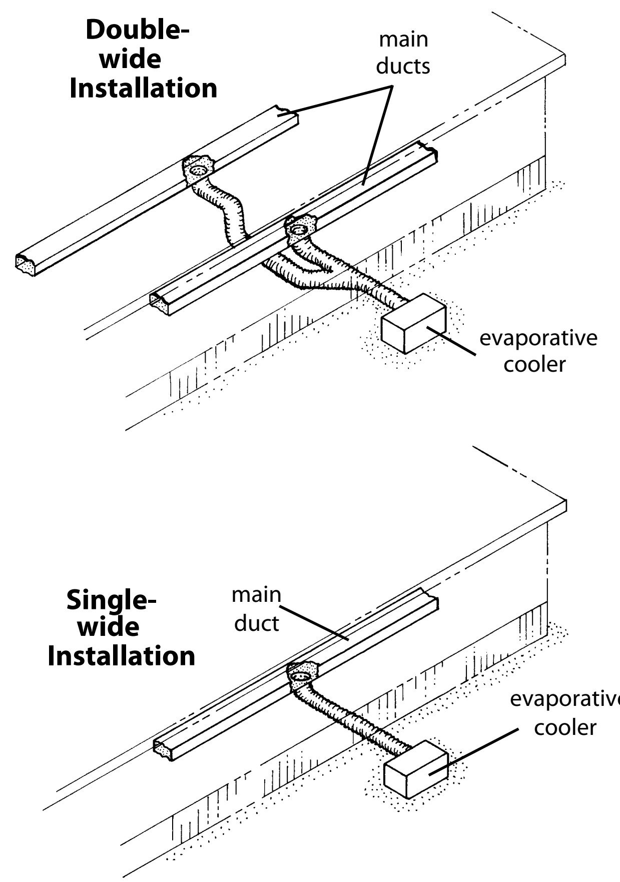
Select an horizontal-flow evaporative cooler for a window or concrete-pad installation. A flexible supply duct connects the cooler to the main duct of the home. Evaporative coolers require the same types of dampers used with packaged air conditioners (*See "Packaged Air-Conditioner Dampers" on page 175.*), to insure that heated air from the furnace isn't carried outdoors and moist cool air isn't delivered to the furnace.

Figure 12-18 Evaporative Cooler



Most evaporative coolers, used in mobile homes, are downflow units that are mounted on the roof. Today, many manufacturers encourage homeowners to install ground-mounted units because they are easier to service and provide better comfort.

Figure 12-19 Installation of Ground-Mounted Evaporative Cooler



These two illustrations show good installation practices for both ground-mounted evaporative coolers and packaged air conditioners. Ground-mounted evaporative coolers discharge air horizontally out of their sides.

Evaporative Cooler Maintenance

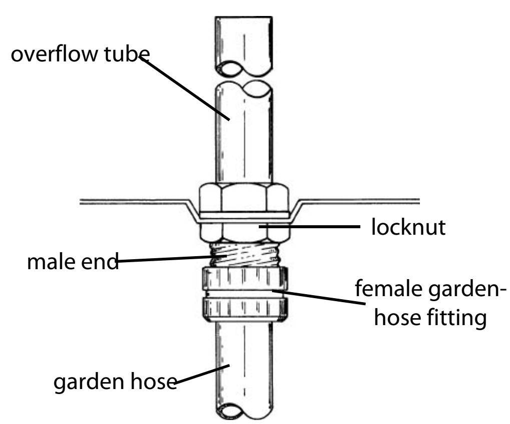
The more an evaporative cooler runs, the more maintenance it needs. An evaporative cooler may need routine maintenance several times during the cooling season and it will definitely need a major cleaning every season. As with air-conditioning systems, be sure to disconnect electricity to the unit before servicing.

Most problems with evaporative coolers are caused by neglect. In very hot climates where the cooler is operating much of the time, you should look at the pads, filters, reservoir, and pump as often as once a week.

Water quality is the single most important maintenance consideration Save yourself a lot of work and money by draining your reservoir regularly. There is a drain fitting on all coolers at the bottom of the unit connected to an overflow tube that controls the water level in the reservoir, like the overflow device in a toilet. After shutting off the water, connect a garden hose to this drain fitting; then unscrew the overflow tube to drain the reservoir. Remove scum, scale, and dirt, particularly near the intake area of the recirculating pump. Scrape and paint the reservoir with a waterproof coating, if it's rusty.

Replace the pads at least once every cooling season or as often as once every six weeks 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. If your unit has filters, they should be cleaned when the pads are changed or cleaned.

Figure 12-20 Drain Fitting and Overflow



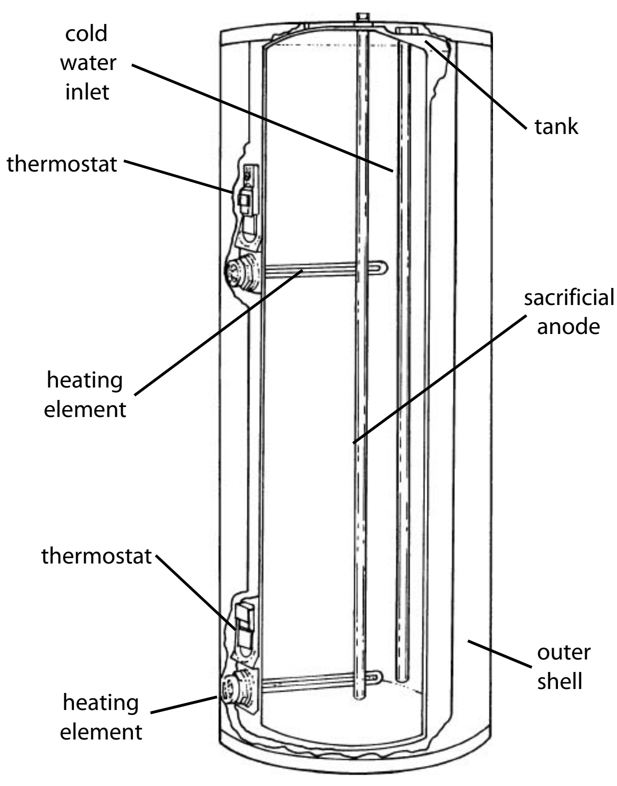
Evaporative cooler reservoirs are drained by fittings like this one. A garden hose is attached to the fitting's male end that protrudes from the cooler cabinet. Removing the overflow tube allows water to drain through this hose.

Check the fan blades for dirt and clean the fan. (*See "Cleaning Blowers and Heat Exchangers" on page 156.*) Remove scale and dust from the louvers in the cooler cabinet, and clean the holes in the water trough that distributes water to the pads. Inspect the blower belt for wear and tightness; the belt shouldn't move more than $^3/_4$ inch when you press on it. Also, check for leaks in the float valve when you turn the water back on.

CHAPTER 13 WATER HEATING SYSTEMS

The water heater in your mobile or manufactured home is a hard working and seldom appreciated device. Really, the only time most home owners think about the water heater is when it's malfunctioning or when it has failed. Maintaining your water heater and making energy improvements to the water heating system reduces energy costs and stretches the water heater's lifetime.

Figure 13-1 Electric Water Heater



Electric water heaters have either one or two heating elements, each with its own thermostat.

Water Heater Principles

The U.S. Department of Energy reports that 14% of the average home's energy costs go to heating water.

Natural gas, propane, or electricity provides heat for water heaters used in manufactured homes. Most water heaters are located in a closet adjoining the bathroom or kitchen, which is accessible only from outdoors through an exterior access door. However, many electric water heaters and gas, sealed-combustion water heaters are installed inside the home's living space.

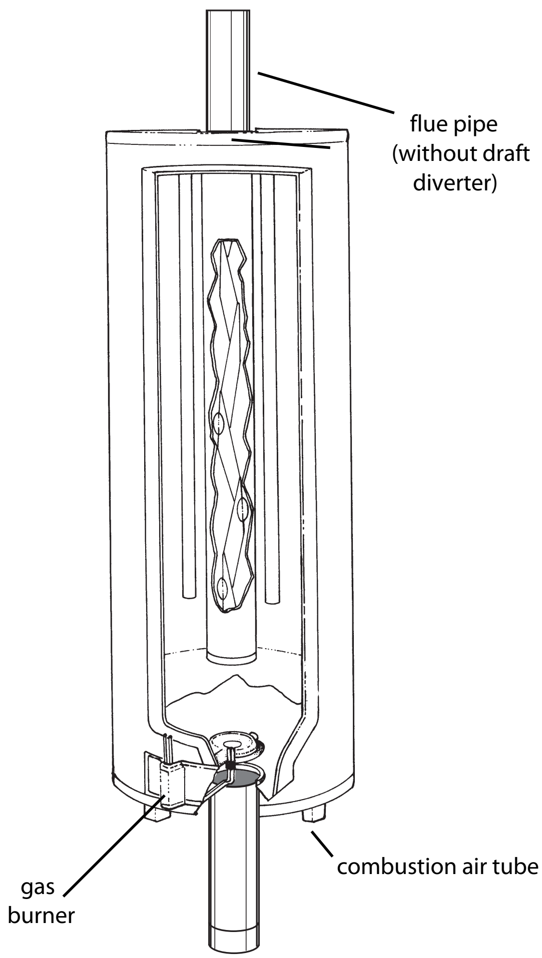
The water heater is composed of a tank, surrounded by an insulation layer and a metal jacket. The cold water flows through an inlet pipe—30-to-40 inches long— into tank's bottom. The hot water outlet is just a short piece of pipe that just barely penetrates into the tank.

Hot water floats to the top of the tank, while the coldest water settles to the bottom. During use, hot water is pushed out of the outlet at the top of the tank by cold water entering the bottom. The placement of inlet and outlet prevents a direct mixing of hot and cold water.

Each water heater has a ***sacrificial anode***. The sacrificial anode is a metal rod that gives water something to corrode instead of the tank. The anode hangs from a fitting on the tank's top. Each water heater also has a relief valve that opens to expel hot water or steam, if the pressure or temperature in the tank becomes dangerously high.

Water heaters heat 30-to-50 gallons of water, with 40 gallons being the most common size. Water heaters use energy in two ways: ***demand*** and ***standby***. Demand refers to the energy required to heat incoming cold water to the desired temperature. Standby is heat lost through the walls of the storage tank and piping while the hot water sits, waiting to be used.

Figure 13-2 Sealed-Combustion Water Heater



These expensive water heaters, which utilize outside combustion air, are necessary when a water heater must be installed within the living space.

Gas-Burning Water Heaters

Gas-burning (natural gas or propane) water heaters heat water from a burner located underneath the tank. A thermostat, mounted on an automatic gas valve near the tank's bottom, opens the gas valve when the water temperature falls and closes it when the temperature rises. This valve starts and stops the flow of natural gas or propane to the burner.

A metal ***flue*** (chimney) takes hot combustion gases up through the center of the tank, using them to further heat the water. On top of the tank, the flue has an opening called the ***draft diverter***. This diverter diverts down-drafts out of the flue and lets air into the flue to moderate excessive suction.

Gas-burning water heaters, designed for mobile homes, can be set to burn either natural gas or propane. A tag on the water heater should state which fuel it is equipped to burn. Each water heater is equipped with a conversion kit for switching between the two fuels. The kit contains a burner orifice, a pilot orifice, and a regulator screw. Burning propane in a water heater equipped for natural gas, or vice versa, is very dangerous and may result in a fire or serious malfunction.

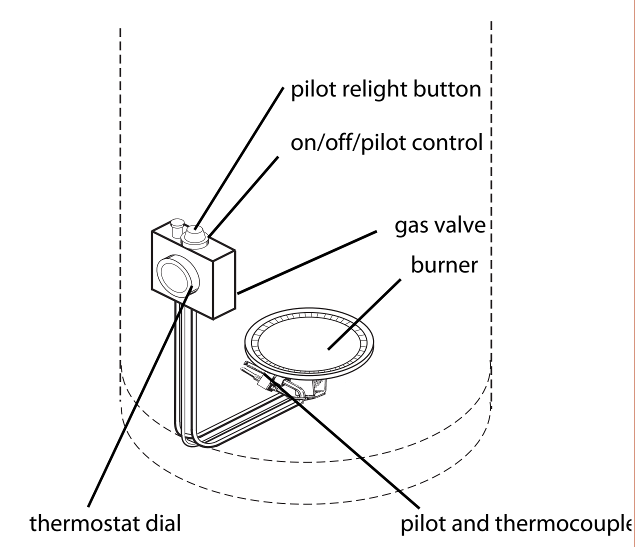
When replacing a natural gas water heater (or the water heater's gas valve), use a convertible gas/propane water heater (or gas valve), unless you're absolutely sure that your home will never move or change fuels in the future.

Open-Combustion Water Heaters — There are two types of natural gas or propane water heaters common in manufactured homes—***open-combustion water heaters*** and ***sealed-combustion water heaters***. Open-combustion water heaters use the air around them—in their closets—for combustion and for moderating their chimney draft. Sealed-combustion water heaters draw combustion air from outdoors.

Open-combustion water heaters are located in closets isolated from indoor air. The burner and the flue's draft diverter draw air from inside the closet. As combustion air enters through a vent in the ceiling, floor, or door of the closet, it replaces air exiting through the burner and draft diverter.

Often, this closet—supposedly sealed from indoors—is inadvertently connected by holes to the indoors. These holes contribute mightily to air leakage and pose potential air-quality and fire-safety problems. When replacing a water heater, line the water heater closet with sheetrock (which is fire-resistant) and seal the seams. Don't cover the combustion air inlet.

Figure 13-3 Gas Valve, Burner, and Thermostat



Pictured here is the gas-burning system of a gas water heater.

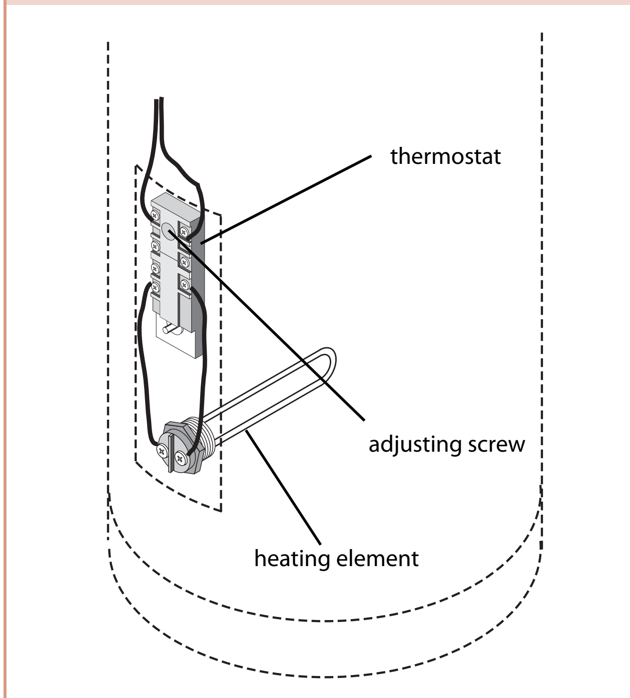
Sealed-Combustion Water Heaters —

Sealed-combustion water heaters, designed for safety in relatively airtight homes, can be installed anywhere indoors. Like any combustion appliance located within the manufactured home's living space, the sealed-combustion water heater draws combustion air from outside and vents combustion by-products outside. Their sealed burners draw air directly from the crawl space through a pipe.

Electric Water Heaters

An electric water heater is usually wired for 240 volts and has one or two electric elements, each with its own thermostat. In two-element water heaters, the element at the bottom of the tank is the ***standby element*** which maintains the whole tank at its minimum thermostat setting. A water heater loses heat through its shell. The standby element adds heat to maintain the minimum setting, so a full tank of hot water is available on demand.

Figure 13-4 Electric Heating Element with Thermostat



The thermostat and heating element of an electric water heater.

The element at the top of the tank is the ***demand element.*** This element heats water at the top of the tank, if necessary, to provide quick recovery of usable hot water during times intensive hot water consumption.

If either the standby element or the demand element becomes too hot, an overload switch trips and must be manually reset. If this overload switch trips regularly, find out why the element is overheating. The element is generally removed to inspect for damage or a coating of scale.

Electric water heaters have less standby heat losses than natural gas or propane water heaters. They do not have a flue pipe running up the center of the tank as do natural gas water heaters. Airflow in the flues of natural gas or propane water heaters continuously carries away some of the tank's stored heat.

However, since electricity is considerably more expensive than natural gas or propane, many people prefer natural gas or propane for heating their water.

Water Heater Maintenance

The purchase, operation, and replacement of water heating equipment is expensive. Regular maintenance and energy-efficient retrofits are very good investments for home owners.

Mobile home residents should help maintain their hot water heating system. Residents can perform the following regular inspection, maintenance, and energy improvements:

- Check faucets, water heater tank, and piping for leaks.
- Remove all flammable material from near the water heater.
- Set water temperature at 120°F.
- Measure the shower's flow rate. Install a low-flow shower head, if the flow is excessive.
- Install pipe insulation on the hot-water supply water pipe from the water heater to the faucet or shower.
- Increase tank insulation to at least R-15—more, if possible.
- Drain water from the water heater once a month. This will remove some of the sediment that collects at the tank's bottom reducing the tank's storage capacity and leading to premature failure.

Mobile home residents may want to hire the following maintenance and repair services from a professional:

- Repair all water leaks.
- Every water heater has a pressure and temperature relief valve that expels hot water or steam, if the pressure or temperature in the tank becomes dangerously high. This relief valve is connected to a pipe draining underneath the home. If you notice this relief valve expelling water, try setting the water temperature lower as described above. If that doesn't work, have it inspected by a qualified professional.
- Clean the sediment out of the water heater tanks every 3-to-5 years.
- The sacrificial anode in a water heater is a metal rod that gives water something to corrode instead of the tank. For soft water, replace the sacrificial anode every 3 years. For hard water, replace the sacrificial anode every 5 years. Replacement will likely triple the life of the tank.
- If the floor of the water heater is sagging or water damaged, drain the tank, disconnect the electricity or natural gas, remove the tank, and repair the floor as part of a comprehensive maintenance or replacement project.
- For natural gas or propane water heaters, check for correct draft (chimney suction). Also, check for carbon monoxide—a poisonous gas indicating poor combustion. Correct the combustion problem if carbon monoxide is found.

Setting Hot Water Temperature

Electric water heaters have thermostats you adjust by turning a setscrew or knob. On gas-burning water heaters, you turn a temperature dial located near the bottom of the tank on the gas valve.

Measure the hot water temperature at the farthest water faucet from the tank. Mark the current thermostat setting on the thermostat or its dial.

The temperature at the faucet should be around 120°F. If the temperature is higher than 120°F, turn the thermostat down. Draw 20 gallons of hot water, wait an hour, and then measure the temperature again. Keep adjusting until you're within a few degrees of 120°F.

If the home has a dishwasher, set the thermostat at 130°F unless the dishwasher has its own built-in water-heating booster.

If you have wrapped a water heater with additional insulation, do not set its thermostat above 130°F.

Preventing and Removing Water-Heater Sediment

Sediment (waterborne dirt) and scale (dissolved minerals that precipitate in a hot water) frequently settle to the bottom of a water heater's tank.

In electric water heaters, scale flakes settle in the tank's bottom and cling to electric elements. Sediment burns out the tank's bottom electric element as it builds up and surrounds the element.

In gas-burning water heaters, sediment wastes energy by insulating water from the burner. Sediment also overheats the steel tank, shortening its life.

Signs of heavy sediment include: noise in natural gas or propane water heaters, bottom-element burnout in electric water heaters, and odors in both types.

Since the cold-water dip tube discharges water straight down, the tank's insides directly underneath it are kept sediment-free. Instead, sediment collects around the edge of the tank's domed (concave) bottom.

If you let the sediment accumulate to two inches or more, flushing with the existing drain valve can partially remove it. Most drain valves, however, don't allow adequate flow for flushing because their opening is too small. Consider installing a larger drain valve—a $^3/_4$-inch ball valve works well as a replacement because its larger opening permits more flow.

Plumbers remove scale by pouring a mild-acid cleaning solution into an emptied tank to dissolve the scale. A plumber may also remove the elements of electric water heaters and soak them in the same cleaning solution, brushing them gently to remove scale. More complete instructions on removing sediment from water heaters is found in ***The Water Heater Workbook*** by Larry and Susan Weingarten found in the Bibliography.

Newer dip tubes—available as replacements or as options on new water heaters—are curved at the bottom to cause the incoming water to swirl around the bottom edge of the tank, dislodging sediment. These curved dip tubes, combined with more effective drain valves, remove most sediment as long as you flush the tank every month or so.

Water Hardness and Sediment — Water hardness—the concentration of scale-producing minerals—is measured in grains per gallon. Expect scale to collect in the tank when your water has a hardness level greater than 10 grains per gallon.

Hard water at 160°F can deposit 9-to-10 times as much scale as hard water at 120°F. If a water heater's thermostat is set too high, reducing its temperature to 120°F will help control mineral buildup and will markedly decrease the water heater's energy consumption.

Water softening—a mineral filtering chemical process—will also help reduce scale, but the salt medium that captures minerals must be rinsed with clean water to recharge it as often as once a month. Water softening adds salt which may be a health problem for persons with high blood pressure. And, the salt in softened water accelerates corrosion.

Preventing Water Heater Corrosion

As discussed, more waterborne minerals means more scale. However, less minerals usually means more acidic and corrosive water—minerals dull the water's acidity. As with sediment, corrosion will be reduced if you keep the water heater's temperature to around 120°F.

The sacrificial anode in a water heater is a metal rod that gives water something to corrode instead of the tank. If the anode is badly corroded, water will attack the tank. If you have soft water, replace the sacrificial anode every 3 years. If you have hard water, replace the sacrificial anode every 5 years. Replacement will likely double or triple the life of the tank. With functioning sacrificial anodes, a standard water heater should last at least 30 years.

You can buy a nipple with an auxiliary anode attached to insert in the hot water outlet. Or, replace the existing anode—installed in another port in the water heater. The exact procedure for removing anodes and replacing them is found in ***The Water Heater Workbook*** by Larry and Susan Weingarten found in the Bibliography.

Energy Conservation and Water Heating

Even though water heating is usually between 10% and 20% of total energy costs, it gives a home owner good opportunities for noticeable energy savings. Water heater insulation and hot water pipe insulation reduce heat losses and cost little. Low-flow shower heads are one of the most cost-effective retrofits proposed in this book. Selecting a energy-efficient new water heater is crucial to minimizing energy use and cost throughout its lifetime.

Insulating Water Heater Tanks

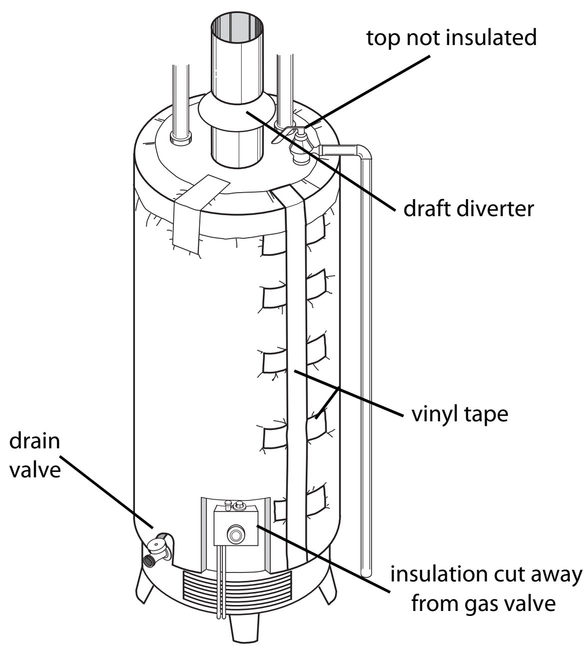
Water heater insulation is one of the surest and best energy conservation measures. Money spent on water heater insulation can repay itself in less than a year.

Water heaters rarely have an enough insulation surrounding them—usually only a couple inches of fiberglass, R-7 at most, between the tank and its outer steel shell. A total R-value between R-15 and R-35, depending on the cost of fuel, is ideal.

A study of 220 homes by the Bonneville Power Administration found average savings of 730 Kwh per year from wrapping electric water heaters. This represents actual dollar savings of about $73 per year (figured at $0.10 per kilowatt-hour).

Energy technicians commonly install vinyl-faced fiberglass insulation (3-to-6-inches thick) over the exterior shell of tank-type water heaters. The blanket's seam is sealed with vinyl tape. But, the tape alone won't hold the insulation permanently without some strapping. The insulation is strapped to the tank with long plastic cable-ties or wire.

Figure 13-5 Tank Insulation for Gas Water Heater



Insulation is not installed on top of the heater or near the burner and control.

Most insulation facings are combustible. To protect the facing from heat and to avoid interfering with the function of the water heater's parts, observe the following:

1. For natural gas water heaters, cut the insulation and its facing to allow 3 inches clearance from the heater's burner-access panel at the bottom of the water heater. Don't insulate gas-burning water heaters on top. Their flue's high temperature and the insulation's possible interference with the draft diverter could create fire hazards.
2. For electric water heaters, you can completely cover the heater's sides and top. But, cut flaps in the insulation at the electric elements' access panels to allow easy access for maintenance or adjustment.

Some argue that the pressure-and-temperature (p&t) relief valve should not be insulated for safety reasons. Others argue that the p&t relief valve and drain valve are important energy losses and that it's not unsafe to insulate them.

Insulating Water Heater Closets

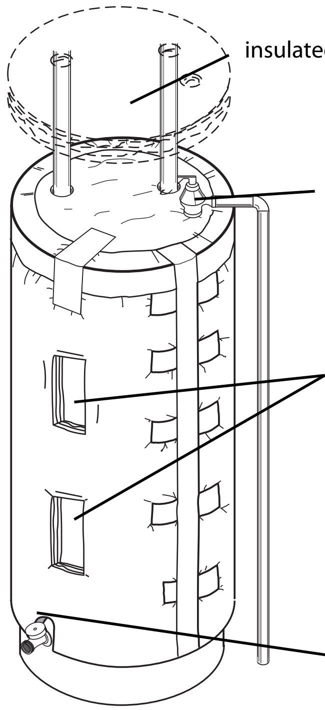
If there isn't room to insulate the water heater inside its closet, you can insulate the walls and doors of the closet itself. However, this probably won't save as much energy as installing the insulation directly on the tank. Use fiberglass batts or foam insulation to insulate the closet's door and walls. Staple the fiberglass insulation in place. Use screws or nails with enlarged heads (available at hardware stores) to fasten the foam insulation so that the heads do not penetrate the soft insulation.

Insulating Hot Water Pipes

Pipe insulation slows heat conduction through the water distribution pipes. Pipe insulation also reduces heat losses from convecting hot water which rises into nearby pipes, cools, and then returns to the tank. Insulating exposed water pipes can reduce standby losses saving $5 to $15 per year. Insulated pipes deliver water 2°F to 4°F warmer than un-insulated pipes. This allows a lower water heater temperature setting and lower natural gas or electricity bills.

Polyethylene foam or neoprene foam pipe sleeves are most commonly used to insulate hot water pipes. Pipe sleeves should be taped, wired, or clamped with a cable tie every foot or so; to secure them to the pipe. Pipe sleeves can be mitered together at 90° and 45° bends.

Figure 13-6 Electric Water Heater Insulation



Insulation is often cut away at the element access panels and, for safety, at the pressure/temperature relief valve.

Matching the inside diameter of the pipe sleeve to the outside diameter of the pipe is important for a snug fit. Copper pipe and plastic pipe are $^1/_8$-inch larger in outside diameter than their nominal size—for example $^1/_2$-inch copper or plastic pipe has an outside diameter of $^5/_8$ inch. Galvanized steel pipe is $^1/_4$-inch larger in outside diameter than its nominal size—for example, $^3/_4$-inch galvanized steel pipe has an outside diameter of 1 inch.

Low-Flow Shower Heads

Low-flow shower heads are one of the most cost-effective energy conservation devices for any home. Low-flow shower heads with a maximum flow rate of 2-to-3 gallons-per-minute will save considerable energy and water, while still providing a comfortable shower.

Measure the shower flow rate using a gallon milk jug and a watch. An energy- and water-saving flow rate of 3 gallons-per-minute or less will fill a gallon container in about 20 seconds. If the container fills in 16 seconds or less, consider replacing the shower head with a more efficient one.

There are two general types of low-flow shower heads, aerating models and laminar-flow models. Aerating models mix air with the water coming out of the small holes in the shower head. This forms a misty spray.

Laminar-flow shower heads are recommended for damp climates, because aerating shower heads create more steam and may put too much moisture in the air. Laminar-flow shower heads don't mix water and air at the nozzle. Instead, they form distinct individual streams of water.

Buying a New Water Heater

Since May of 1980, all new water heaters sold in the U.S. must have an Energy Guide Label which can not be removed before sale. The Energy Guide Label is intended for comparison shopping. It doesn't precisely predict operating cost. It does feature: the water heater's estimated yearly operating cost, a bar scale comparing its operating costs with those of similar models, and a table for estimating specific operating costs for your regional energy prices.

Before you purchase any new water heater, check the insulation of various models. Conventional water heaters have a thermal resistance (R-Value) of only R-4 to R-8. Better water heaters are more heavily insulated, with R-12 to R-16.

Consider buying water heaters with curved dip tubes, double sacrificial anodes, and advanced interior tank coatings. A water heater with these features will last at least 30 years, compared to the 7-to-10 years of most under-maintained conventional water heaters.

The American Council for an Energy-Efficient Economy lists the most efficient water heaters in their annual guide, ***The Consumer Guide to Home Energy Savings.*** (*See "Bibliography" on page 227.*)

The extra cost of a better water heater will save enough energy to return your investment in one year or less!

Figure 13-7 Water Heater Energy Label

Water Heater ELECTRIC

First hour rating 55 **Models(s)** 31656

ENERGYGUIDE

Estimates on the scale are based on national average ELECTRICITY **rate** $. 0804 PER KILOWATT HOUR

Only models with first hour ratings of 48 TO 55 GALLONS **are used in the scale**

Model with lowest energy cost $428

$458
THIS MODEL

Model with highest energy cost $562

WHEN THIS MODEL IS OPERATED IN 5500 WATT MODE: THE FIRST HOUR RATING IS 62 GALLONS THE ESTIMATED YEARLY COST IS $459

Your cost will vary depending on yuor local energy rate and how you use the product. The energy cost is based on U.S. Government standards test.

How much will this model cost you to run yearly?

	Yearly cost
Estimated yearly cost shown below	
Cost per KILOWATT HOUR $.04	
$.06	
$.08	
$.10	
$.12	
$.14	

Ask your salesperson or local utility for the energy rate (cost per KILOWATT HOUR **) in your area.**

IMPORTANT. Removal of this label before consumer purchase is a violation of federal law (42 U.S.C. 6302)

Try to buy the most energy-efficient water heater available.

Chapter 14 Plumbing Systems

This chapter provides general information about plumbing systems for mobile or manufactured homes. Topics covered include: plumbing components, troubleshooting, and basic repairs.

Plumbing Components

Plumbing consists of supply pipes, drain pipes, fittings, and plumbing fixtures like sinks and tubs. Supply pipes bring water into the home, and drain pipes carry soiled water away to a septic tank or sewer. Fittings join pipe together.

Most mobile home supply and drain piping is made of plastic. Polybutylene plastic pipe and fittings make up the most common supply piping system for manufactured housing. Polyvinyl chloride plastic is the most common type of drain piping and fittings.

Some homes have piping of flexible copper tubing with flared fittings. Copper piping and fittings are the most reliable type of supply but cost more and require more skill to install. And, some much older mobile homes have galvanized iron pipe with threaded fittings.

Parts for plastic, galvanized iron, and flexible copper piping are available at most hardware stores and mobile home suppliers.

Supply Pipes

As mentioned, the most common supply pipe and fittings for manufactured housing are made of polybutylene. These polybutylene supply pipes are easy to repair and install. Common polybutylene pipe inside diameters are $^3/_8$ inch, $^1/_2$ inch, and $^3/_4$ inch. The outside diameter is $^1/_8$ inch larger than the inside diameter, just like copper pipe. Polybutylene pipe can be used with polybutylene barbed fittings, brass barbed fittings, or polybutylene compression fittings. Copper water pipe can use polybutylene compression fittings and polybutylene pipe can use brass compression fittings since copper and polybutylene have this same dimensions.

Fittings

Fittings that join any type of pipe together are classified by function. An ell turns the pipe at a 45° or 90° angle. A coupling joins two pipes in a straight line. A tee joins three pieces of pipe together. A shut-off joins pipe in a straight line or at a 90° angle and provides a way to shut off water supply to a part of the system.

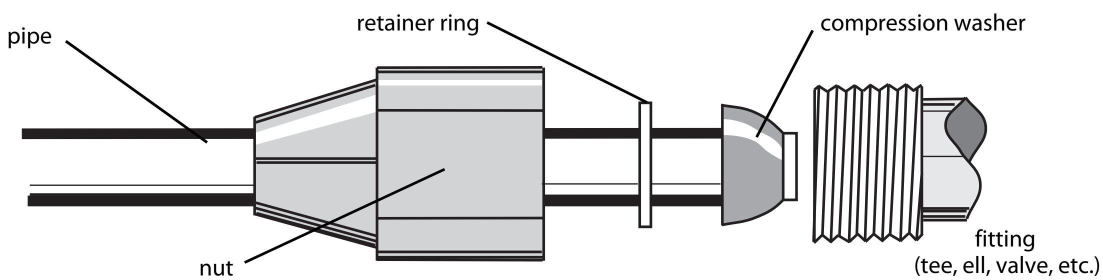
Fitting joints are described as male or female, depending on whether they slip inside (male) or outside of (female) the joint.

Adapters are fittings that change from one size or type of pipe to another. Adapters are described by the type of pipe and size that the fitting adapts to and from.

The majority of fittings used with polybutylene pipe are also made of polybutylene. However, since these fittings sometimes crack when subjected to highly chlorinated water, some manufacturers use copper and nylon fittings with polybutylene pipe.

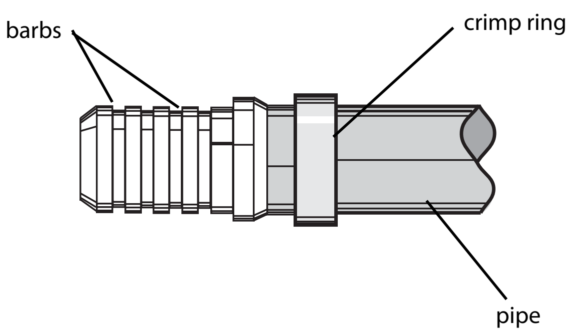
There are two distinct designs for fittings used with polybutylene pipe: barbed fittings and compression fittings. For either, you need to know the pipe's inside diameter pipe size to buy the correct fitting.

Figure 14-2 Compression Fitting



Compression fittings for polybutylene supply pipe are preferred by do-it-yourselfers, because they are easy to connect.

Figure 14-1 Barbed Fitting



The barbed fitting's crimp ring clamps the pipe to the fitting. This slightly deforms the pipe, forming a watertight and mechanically strong joint.

Barbed Fittings — Barbed fittings, which require a special tool for crimping, are used by plumbers. They find the barbed fittings slightly less expensive and more reliable than compression fittings.

A barbed fitting slips inside the pipe. Then, a copper or aluminum crimp ring slips over the end of the pipe and fitting. A special tool crimps the ring, tightly clamping the pipe to the barbed fitting.

A stainless steel hose clamp may be used for emergency repairs on barbed fittings. However, the clamp and pipe need to be gently heated, so that the clamp will deform the softened pipe onto the barbed fitting, to form a watertight seal.

Compression Fittings — Most do-it-yourselfers use compression fittings. All that is needed for their installation is a hacksaw to cut the pipe, and an adjustable wrench to tighten nuts on fittings.

The compression fitting has four major parts: nut, retainer ring, compression washer, and fitting. The pipe with the nut, retainer ring, and compression washer already in place, slips into the fitting. As the nut is tightened, the compression washer is squeezed into the space between the fitting and the pipe. This forms a tight seal. The retainer ring bites into the pipe and prevents it from slipping out of the fitting.

Drain Pipes, Traps, and Vents

Drain pipes and drain fittings rarely fail. If they do, they are easily repaired with standard plastic fittings from any hardware store.

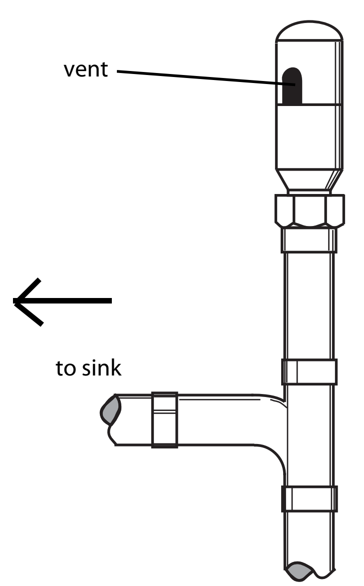
Drain piping is $1^1/_4$-to-4 inches in diameter. Polyvinylchloride plastic is the most common type of drain piping. PVC plastic drain pipe and fittings are joined by a special cement and may require a special cleaning compound. Follow the directions on the cement and cleaner containers.

Plumbing fixtures in mobile homes, such as sinks and bathtubs, must have traps. Traps are U-shaped pipes that remain filled with water to prevent sewer gases from entering the home.

In addition to traps, plumbing fixtures must have vents. Plumbing vents allow air into drain pipes, preventing water flowing in the drain pipes from creating a suction that siphons water out of the traps. Air comes from the vent's opening on the roof or under a sink. When a vent is plugged, draining water siphons the trap and sewer gases can enter the home. You can detect the siphoning of water out of the traps if you hear a gurgling noise comes from the drain while water is draining from a fixture.

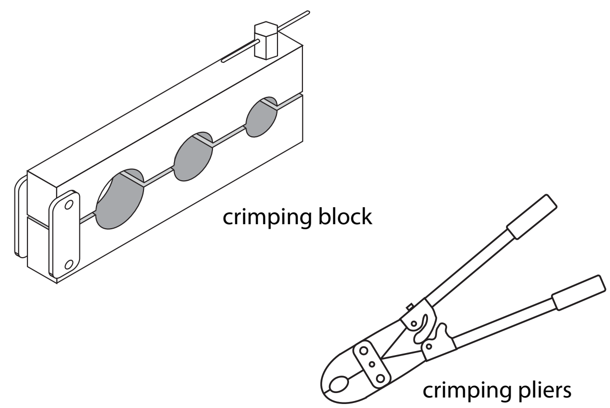
Spiderwebs or other debris can clog a rooftop plumbing vent. Running a plumbing snake down the vent will usually unplug it. Vents installed under sinks are one-way air valves that let air into the pipes but not out. If these vents fail, you may smell sewer gases in the home. Replacing the vent will usually cure the problem.

Figure 14-3 Drain Vent



These one-way plumbing vents are often used in manufactured housing to avoid having to run vent piping through the roof. They allow air into the pipes, but they don't allow sewer gases out (unless they malfunction).

Figure 14-4 Crimping Tools



These tools are used to crimp the crimp rings of barbed fittings. The crimping block is less expensive than the crimping pliers, but the pliers are faster and more convenient.

Another possible cause of sewer gas smell is plumbing vents on the roof. In some cases, the vent pipe can spill sewer gas into the home from the hole in the roof through which it passes. Sometimes, the hole in the roof is considerably larger than the pipe (this gap doesn't leak due to the rain cap covering the vent). If the roof cavity leaks air into the furnace closet, the furnace blower can suck vented sewer gas into the roof cavity and into the home.

To correct this problem: Remove the rain cap on the roof; seal between the roofing and the pipe; and replace the rain cap. Or, extend the vent stack on the roof and use a roof jack—a watertight roof fitting—and roof sealant to waterproof the penetration. Also, refer to *Chapter 5* ***Air Leakage*** for suggestions how to seal air leaks in the furnace closet.

Plumbing Leaks

Plumbing leaks waste water and energy. Leaking water deteriorates building parts by dissolving adhesives and corroding metals. Leaks also provides water for pests like fungus or termites.

If you see stains near plumbing fixtures or notice water near pipes, fittings, or fixtures, find the leak and repair it.

Supply and drain plumbing should be checked for leaks whenever a new home is moved and installed. Manufacturers recommend testing the supply water system with 100 pounds per square inch air pressure (psi). The system should hold 100 psi of air for 15 minutes after being disconnected from the air compressor by an air shut-off valve.

A mobile home's water heater must be isolated during such a test or it may suffer damage from the high pressure. The water heater's inlet and outlet piping can be temporarily connected together to accomplish this.

Find the leaks by listening for hissing noises. Fix the leak by tightening or replacing fittings or pipes. Repeat the test and look for other leaks.

The drain system can be leak-tested by filling the sinks, bathtubs, and toilets, and then marking the level after plugging the main sewer with a cap. The fixtures should maintain that water level for half an hour.

If the level in the fixtures goes down, search for dampness along the course of the home's drain piping. Wipe the wet pipes with a towel and follow the water to its source. Then, cut out the leaking section and replace it with new pipes and fittings.

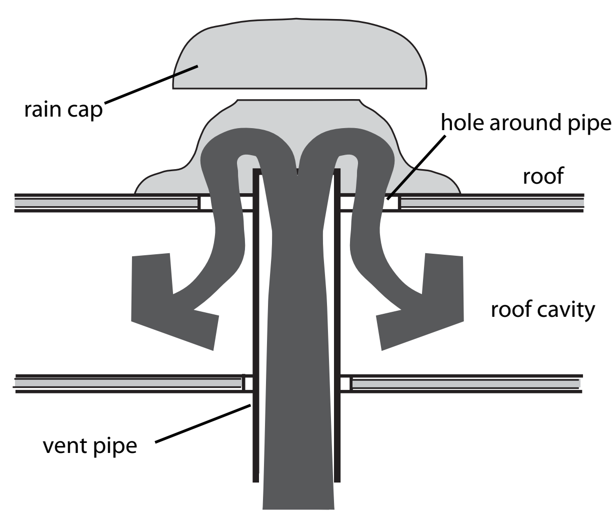
The anti-siphon valve on a built-in dishwashers may fail and leak. This valve, located on the drain hose running from the dishwasher to the drain, prevents drain water from returning to the supply and contaminating it. If you see wetness near the dishwasher, remove the anti-siphon valve and temporarily replace it with tubing and hose clamps. If this temporary procedure stops the leak, then replace the anti-siphon valve. If possible, install a slightly larger capacity valve.

Spigots on bathtubs can be a source of water damage. If there is no drip edge on the spigot, water flow or leakage through the spigot sometimes clings to the bottom of the spigot and flows back toward the wall of the tub enclosure. These spigots should be replaced with new ones having drip edges of at least $^1/_4$ inch.

Joints in the tub enclosure, especially around the spigot and valves, should be sealed with silicone caulking as often as necessary to avoid water getting behind the tub or shower enclosure.

Washers on bathtub and sink faucets should be replaced whenever the faucet leaks. Any book on home plumbing will provide necessary details about repairing faucets.

Figure 14-5 Drain Vent Backdrafting



Sewer gases can be drawn into the home, if the furnace fan creates a vacuum in the roof cavity as a result of air leaks in the furnace closet.

Freeze Protection for Pipes and Fittings

Heat tape is the most common and economical kind of freeze protection for pipes and fittings. Some home owners do use light bulbs and small electric space heaters to thaw pipes or keep pipes thawed during very cold weather. If you use space heaters or light bulbs for this purpose, keep flammable materials away from them to avoid starting a fire.

Do not use lightweight, thermostatically-controlled heat tape. This heat tape has caused many fires in mobile homes. Use only shielded self-regulating heat tape, rated specifically for mobile or manufactured housing. Carefully follow installation instructions that accompany this shielded heat tape.

Chapter 15 Electrical

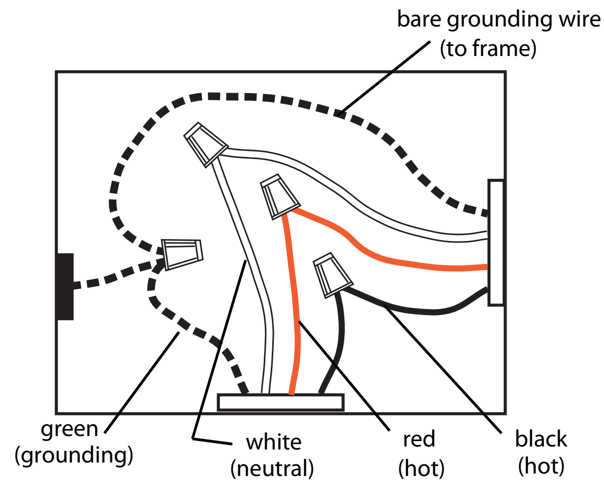
This chapter provides general information about a mobile or manufactured home's electrical system.

The electrical system of a mobile home consists of: service wires; electric meter; feeder wires; one or two main switches; a main service panel box with circuit breakers or fuses; branch circuits; and the home's wires, receptacles, and fixtures. The brief descriptions below are not intended as a code or instructional manual.

The most authoritative book for specific electrical information on a mobile home is its factory installation manual. If this manual is not available, the Manufactured Housing Institute's ***Model Manufactured Home Installation Manual*** is a good reference (*See "Bibliography" on page 227.*). The ***National Electrical Code's*** Article 550 is an accepted standard for mobile home electrical systems.

Flaws in a home's electrical system can cause fire or serious injury. Be safe: Make sure that a qualified electrician makes all the necessary inspections, connections, and repairs of your mobile home's electrical system.

Figure 15-1 Junction Box



In older homes, the feeder cable is sometimes spliced under the home in a junction box. Junction boxes, like this one, are often used as a crossover connection between the sections of multi-section homes.

Service Equipment and Feeder Wires

Main service wires, either underground or overhead, come from the utility company's transformer. These three wires, two "hot" wires and one "neutral" wire, attach to terminals on the utility's side of the electric meter. A terminal is a clamp made of conducting metal for joining a wire to a switch or electric device.

The meter plugs into the meter base like a cord's plug goes into a receptacle. The main switch is often housed in the same metal box as the meter and its base. The meter and a main switch are usually located on a utility pole, a ground pedestal, or attached to one of the home's outside walls.

Attached to the house side of the electric meter are the feeder wires. The feeder wires are two hot wires (red and black), a neutral wire (white), and an equipment grounding wire (green). These wires are either part of a cable or are collectively carried in a metal conduit or pipe.

The feeder wires run from the meter and main switch into the home's service panel box. In modern homes, these wires are continuous. In older homes, the feeder wires may be terminated in a plug or a junction box connecting the service panel box to the electric meter.

The main switch will likely be marked with the service capacity of the system in amps. Older mobile homes had service equipment rated at only 50 amps. Modern manufactured homes usually have a 200 amp service.

These black and red feeder wires are connected to the hot bus bars in the panel box. A bus bar is a large electrical terminal for connecting many wires together. The white neutral feeder wire is connected to the neutral bus bar.

Branch and Appliance Circuits

Branch circuits are systems of cable, 3-prong receptacles, and light fixtures. Cable is an insulated sheath containing two or more wires. Appliance circuits are circuits that serve a single appliance like a furnace, air conditioner, electric range, or electric dryer.

Each branch circuit is protected by a circuit breaker or fuse, attached to the panel box's bus bars. Circuit breakers or fuses prevent the circuit's wire from carrying too much electrical current. When a circuit breaker trips or a fuse blows, the home owner should investigate the cause of the circuit overload. Perhaps too many portable appliances are connected in a particular area of the home—often the kitchen.

If a circuit breaker on a circuit fails, or if a fuse blows, its replacement must match the branch circuit wire used in the home—15 amps for older homes, 20 amps for newer homes.

A ***short circuit*** is a circuit with no load. Electricity flows violently from the hot wire to the neutral or some other grounded conductor. Your body is a grounded conductor because you conduct electricity and you are connected to the ground by your feet. Short circuits in appliances are particularly dangerous in the kitchen and bathroom because possible wetness can provide an excellent electrical connection between your feet and the ground.

In newer homes, circuits in the kitchen and bathroom are protected by special circuit breakers or receptacles called ground-fault-circuit interrupters (GFCI). These GFCIs will trip, interrupting the circuit, if they detect electricity flowing in its grounding wire. Electricity flows in a grounding wire only when there's a short circuit.

Many manufacturers and electricians prefer to use GFCI receptacles instead of GFCI circuit breakers because the former are less expensive. A GFCI receptacle installed as the first receptacle on a circuit, protects the whole circuit. If it is too sensitive and interrupts power inappropriately, that affects the whole circuit.

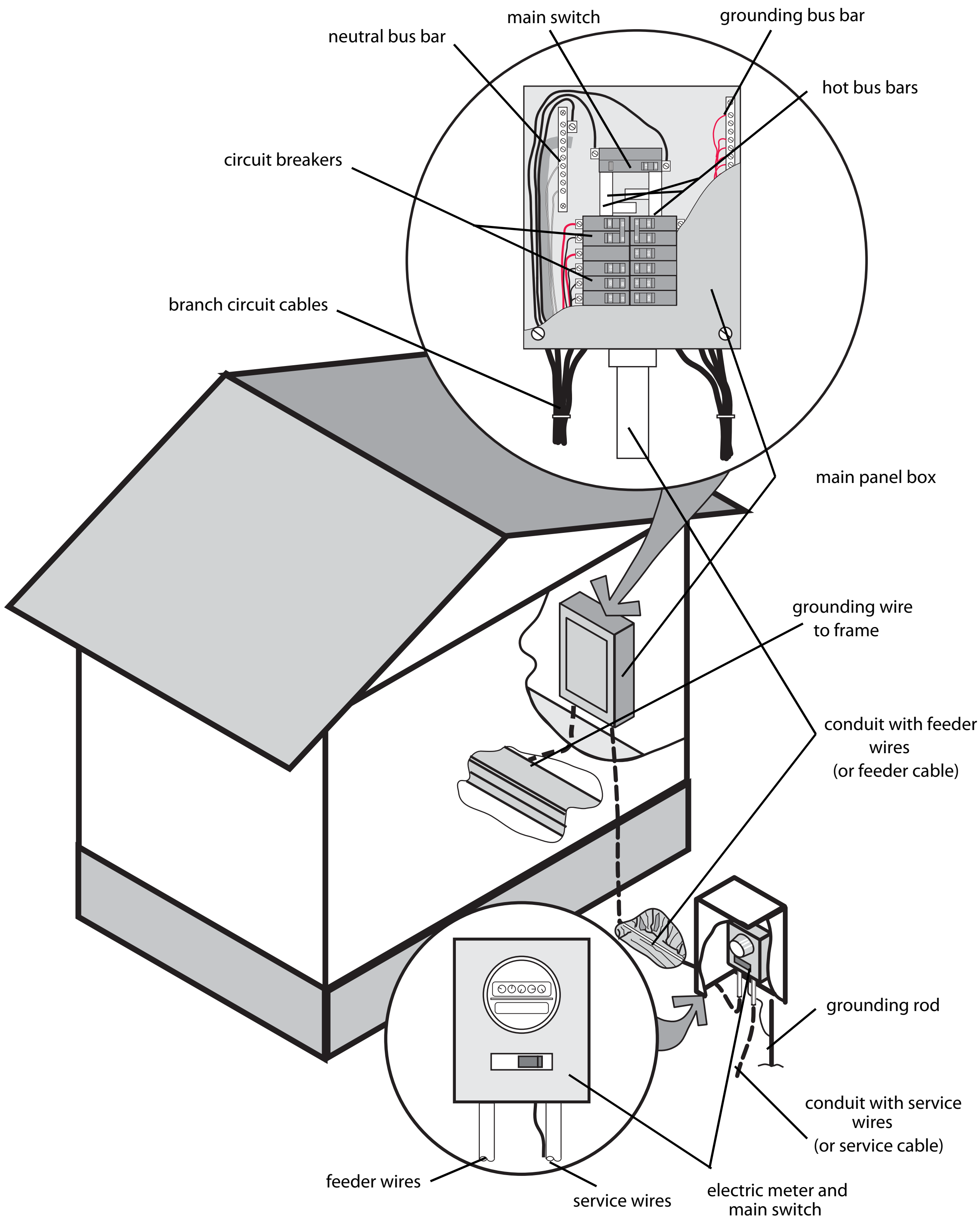
The black wire in a branch circuit cable is the hot wire which carries the electric current. The white wire is the neutral wire that gives the current a place toward which to flow. And, the bare copper wire is the grounding wire which carries stray electricity away in the event of a short circuit.

Neutral wires in branch circuits must be connected only to: 1. Neutral wires in fixtures and outlet; and 2. The neutral bus bar in the service panel box.

Sometimes a neutral wire is accidentally connected to a hot wire somewhere in the system. This can happen at an outlet, for example. If the hot and neutral wires were reversed, the white wire would be unwittingly connected to the dark-colored receptacle terminal and the black wire connected to the light-colored terminal. This reversal is dangerous. If you notice mild shocks from metal parts of the home or other irregularities, have the system tested.

A circuit tester is used to detect faulty wiring. They are available at most hardware stores.

Figure 15-2 Modern Electrical Service



Today's manufactured homes have at least 100 amps of service capacity. Many have underground service and feeder wires.

Grounding

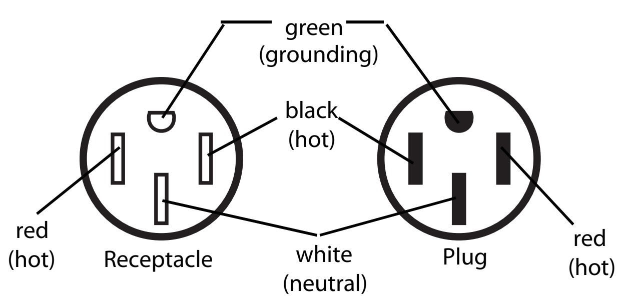
Home electrical systems use the ground or earth in two ways. The first is to ground the neutral feeder wire. The ground or earth is electrically neutral and provides a kind of vacuum that draws electricity from the hot wires towards the ground through home's electrical devices.

The second way electrical systems use the ground is for grounding equipment. The equipment grounding wire is the bare wire connected to:

1. Each grounding terminal of a receptacle;
2. Each metal electrical box (including the main panel box);
3. The mobile home chassis;
4. Ducts;
5. Metal roofing;
6. Metal siding; and
7. Metal plumbing.

Ideally, all metal parts are safely grounded. If they become electrically charged, electricity will flow harmlessly into the ground.

Figure 15-3 50-Amp Receptacle and Plug



Older mobile homes often use a 50-amp plug from the house and a matching receptacle from the meter to feed electricity to the home.

Double-wide homes should have a jumper wire or strap for electrically connecting the steel frames together. These usually bare copper wires, which connect the metal parts of the home together electrically, are clamped to the grounding bus bar of the main panel box. This grounding bus bar is itself electrically connected to the metal panel box. Both are connected to a bare grounding wire. This grounding wire fastens to a copper grounding rod with an approved mechanical clamp. The grounding rod is driven into the ground or buried in the ground near the meter.

This network of equipment grounding connections gives stray electricity from accidental short circuits an easy and safe path for flowing into the ground. Lacking this path, this stray electricity might flow to ground through some unlucky person.

Testing

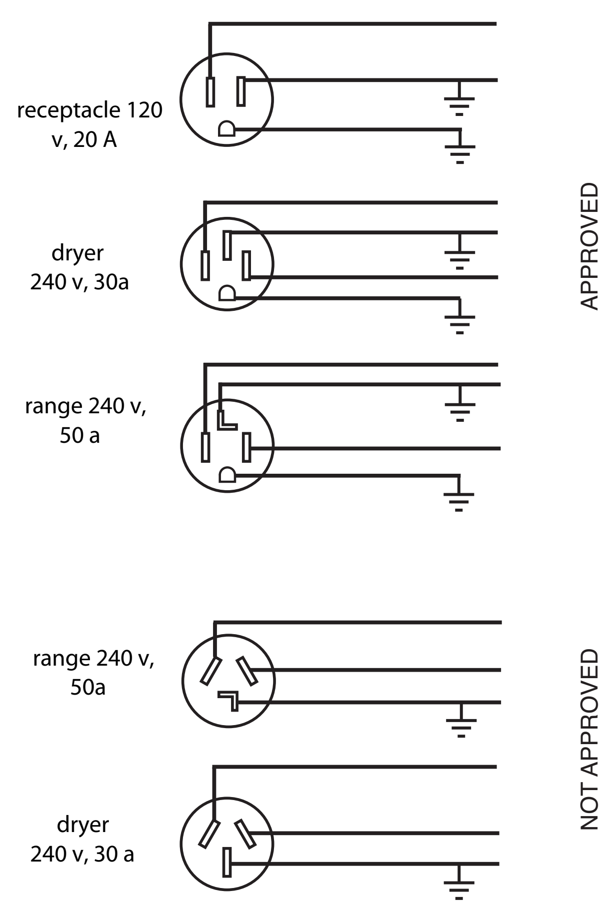
Professional electricians perform the following tests to ensure the safety of a mobile home's electrical system:

1. With the main switch off, electricians test for continuity (electrical connection) between each hot and neutral wire in the service box with the grounding bus bar. There should be no continuity between hot or neutral wires and the grounding bus bar. The electricians use a continuity tester, a small battery-powered flashlight that lights up when its terminals are attached to two metal surfaces that are connected together electrically.
2. Using the continuity tester electricians check metal electrical boxes, metal ducts, the home's metal chassis, metal siding, roofing, and pipes for continuity to ground. The electrician should find that these parts are connected to ground. As mentioned above, the metal parts are connected together electrically at the factory and should be grounded through the grounding bus bar in the service panel box.
3. Electricians insert a circuit tester into each receptacle to check hot, neutral, and grounding connections. This circuit tester indicates whether the grounding receptacle is connected to ground. This test is performed with the power on.
4. Electricians ensure that ground fault circuit interrupters (GFCIs) are connected to all

bathroom and outdoor circuits. They test the GFCIs by pushing a button on the device that trips a circuit breaker.

5. Electricians check for power at all outlets and fixtures. This test can be performed with the power on, using a circuit tester and a 120-volt test light or a light bulb. Or, this test can be performed with the power off, using a continuity tester. During this test, all light switches are tested for operation.

Figure 15-4 Branch and Appliance Circuit Receptacles



The most common types of receptacles found in homes are for outlets, ranges and dryers. Older dryer receptacles had only 3 wires, but 4-wire receptacles have been standard since the 1970s.

Electrical Safety Precautions

The following simple precautions will help manufactured home owners, service technicians, and electricians evaluate the electrical safety of mobile or manufactured homes.

1. Have your electrical system tested if you notice irregularities. Ask the electrician to read the testing section above.
2. Do not use lightweight, thermostatically-controlled heat tape. This heat tape, used to prevent pipe freezing, has caused many fires in mobile homes. Use only shielded heat tape rated specifically for mobile or manufactured housing. Carefully follow all installation instructions that accompany this shielded heat tape.
3. Do not use lightweight extension cords for electric space heaters, irons, or other heating devices. These extension cords, sometimes called lamp cord, were designed for lights. If inappropriately used for heating devices that draw more power than lights, these cords will overheat.
4. Remember that electric space heaters and room air conditioners use most of the capacity of a single circuit. Although they may be able to share with a lamp or radio, electric space heaters and room air conditioners should not share a circuit with other appliances like toasters and refrigerators.
5. Always use screw terminals of receptacles, not the easy-connect holes in the back of the receptacle. The easy-connect holes don't provide enough surface contact for a satisfactory wire-terminal connection.
6. The main service panel box should be clearly marked with the areas of the home protected by each circuit breaker or fuse. Adults and older children should know the location of the main electrical switch and the location of circuit breakers or fuses for various branch

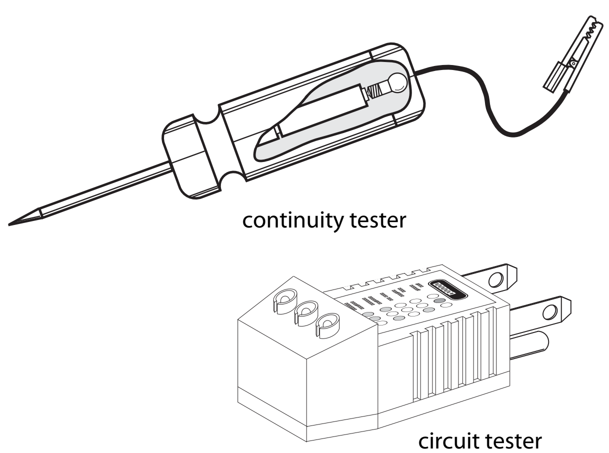
circuits. This knowledge will help them disconnect power in the event of an emergency—a flood, for example.

Aluminum Wiring

Some older mobile homes have aluminum wiring, a wiring that is not nearly as safe as copper.

Aluminum wiring may corrode as it ages. It may expand and contract enough to loosen its connections. Corroded aluminum wire may also reach dangerously high temperatures when connected to large loads like space heaters.

Figure 15-5 Testing Devices



The circuit tester tests, with the power on, for the correct connection of the hot, neutral, and grounding wires. The continuity tester tests, with the power off, whether or not a complete circuit exists.

If you have aluminum wiring, an electrician can recondition it. The electrician should shut off the power and inspect wire ends at the terminals of lights, switches, outlets and appliances. If the wire is loosely attached to the terminal, he or she tightens the screw. If the wire end is coated with a white powdery aluminum corrosion, the electrician should clean it with fine sandpaper. If the end is brittle so it breaks when bent, he or she should strip a new end. The wire end and terminal is coated with anti-corrosion creme.

If you plan to keep your home permanently, you might consider having it rewired. An electrician could easily pull new wire through the ceiling. New wiring could be installed in walls during reinsulation with siding removed.

Appendices

Glossary

Air changes at 50 pascals (ACH50) - The number of times that the complete volume of a home is exchanged for outside air when a blower door depressurizes the home to 50 pascals.

Air barrier - Part of the building assembly that is designed to stop airflow between indoors and outdoors.

Air changes per hour - A measurement of how many times each hour the home's volume is exchanged for outdoor air through cracks and holes in the shell or through ventilation.

Air handler - A metal box containing a large fan. The same box may house heating or cooling coils or both.

Air infiltration barrier - A woven plastic sheet that stops almost all the air traveling through a building cavity, while allowing moisture to pass through the cavity.

Anchor - A rod, screwed or driven into the ground or set in concrete for tying a manufactured home down. The anchor is attached to the home by straps or cables.

Amp - A unit of measurement of the flow of electrical current.

ASHRAE - The American Society of Heating, Refrigeration, and Air Conditioning Engineers.

Backdraft damper - A damper, installed near a fan, that allows air to flow in only one direction.

Batten - Narrow strips of wood or plastic used to cover seams in walls and ceilings.

Belly board - See Rodent barrier.

Belt rail - A piece of 3/4" thick lumber fastened to wall, floor, or ceiling framing at right angles across the framing members to provide extra strength and a fastening surface for siding, roofing, or flooring.

Bimetal element - A metal spring, lever, or disc made of two dissimilar metals that expand and contract at different rates as the temperature around them changes. This movement operates a switch in the control circuit of a heating or cooling device.

Blower door - A device composed of a fan, a removable panel, and gauges used to measure and locate air leaks.

Blowing wool - Insulation packaged in bags and intended to be blown into attics, walls, and floors.

Blowing machine - A machine with a powerful fan used to blow insulation through a tube into a building. It also has an agitator to break up the insulation which is compressed in bags.

Blown fiberglass - Loose-fill fiberglass blown through a blowing machine and hose into a building cavity.

Boot - A duct section that connects between a duct and a register or between round and square ducts.

Bowstring truss - A truss shaped like a bow, made of lightweight wood framing, used to support a mobile home roof.

Branch circuit - An electrical circuit used to power outlets and lights within a home.

Branch duct - A supply duct that branches off the main duct.

Building cavities - The spaces inside walls, floors, and ceilings between the interior and exterior sheeting.

Cable tie - A plastic belt that ties cable together, also used to clamp insulated flexduct to metal duct.

Cellulose insulation - Insulation made from newspaper or wood waste and treated with a fire retardant, packaged in bags for blowing.

CFM50 - The number of cubic feet per minute of air flowing through the fan housing of a blower door when the house pressure is 50 pascals (0.2 inches of water). This figure is the most common and accurate way of comparing the airtightness of buildings that are tested using a blower door.

CFMn - The number of cubic feet of air flowing through a house from indoors to outdoors during typical, natural conditions. This figure can be roughly estimated using a blower door.

Chassis - The steel trailer that carries the weight of the mobile home.

Chimney effect - The rising of air caused by temperature-derived weight differences in air.

Circuit breaker - A device that disconnects an electrical circuit from electricity when it senses an overload of current in the circuit.

Cladding - The covering over a building framework like siding, roofing, or flooring.

Combustion air - Air that chemically combines with a fuel during combustion to produce heat and flue gases, mainly carbon dioxide and water vapor.

Condenser - The outdoor heat-transfer coil of an air conditioner that heats outdoor air when the refrigerant, inside it, condenses and releases heat.

Conduction - Heat flow through a solid object by vibration from molecule to molecule.

Countersink - A cone-shaped hole drilled by a special bit to allow a flat-head wood screw to sit at or below the surface of the material where it is installed.

Crossmember - A structural steel piece that connects the main beams of a mobile home.

Crossover duct - A duct connecting the plenums and duct systems of the two halves of a double-section mobile home.

Density - The weight of a material divided by its volume, measured in pounds per cubic foot.

DOE - The United States Department of Energy.

Draft booster - A small fan that helps to move combustion air into the firebox and combustion products out.

Edge spacer - The spacing device between two panes of glass in a double-pane window.

Environmentally sensitive - A person who is highly sensitive to pollutants, often because of overexposure, is said to be environmentally sensitive.

Evaporative cooler - A device for cooling homes in dry climates that cools the incoming air by humidifying it.

Evaporator - The indoor heat-transfer coil of an air conditioner that cools the surrounding air as the refrigerant inside the coil evaporates and absorbs heat.

Fan control - A bimetal thermostat that turns the furnace blower on and off as it senses the presence of heat.

Feeder wires - The wires connecting the electric meter and main switch with the main panel box indoors.

Fender washer - A large washer with a small hole that prevents a screw head from pulling through a soft material through which the screw is attached.

Fiberboard - A soft sheeting used for ceilings and underbellies of mobile homes, available in white or a sturdier asphalt-impregnated black.

Fiberglass batts - Fiberglass insulation packaged in slabs 16-to-24 inches wide and 3-to-12 inches thick with or without a paper or foil facing used to insulate between framing in manufactured housing.

Fiberglass blanket - Fiberglass insulation 1-to-6 inches thick and 3' to 6' wide used for insulating over framing in manufactured housing.

Fill tube - A plastic tube—1-to-3 inches in diameter—connected to the end of a blower hose and inserted into a closed building cavity.

Flashing - Sheet metal or other material used to seal around penetrations on a roof.

Flue - The chimney close to the furnace.

Foamboard - Plastic foam insulation manufactured most commonly in 4-by-8 foot sheets in thicknesses of 1/4-to-3 inches.

Footing - The part of a foundation system that actually transfers the weight of the building to the ground.

Footing base - The piece of ground underneath the footing which is compacted to provide adequate support.

Framing - The structural pieces of the home's framework like wall studs, floor joists, and trusses.

Frost line - The maximum depth of the soil where water will freeze during the coldest weather.

Gable - The triangular end wall of a sloping roof.

Gypsum board - A common interior sheeting material for walls and ceilings made of gypsum rock powder packaged between two sheets of heavy building paper. Also called sheetrock, gyprock, or gypboard.

Heat anticipator - A very small electric heater in a thermostat that causes the thermostat to turn off before room temperature reaches the thermostat setting so that the house does not overheat from heat remaining in the furnace and ducts after the burner shuts off.

Heat rise - The number of degrees of temperature increase that air is heated as it is blown over the heat exchanger. Heat rise equals supply temperature minus return temperature.

High limit control - A bimetal thermostat that turns the heating element of a furnace off if it senses a dangerously high temperature.

House pressure - The difference in pressure between the indoors and outdoors as measured by a gauge on the blower door when the blower door is operating.

House-type door - An inwardly opening door hung on butt hinges.

HUD Code - The U.S. Department of Housing and Urban Development's standards for new manufactured homes, known as the Manufactured Home Construction and Safety Standards.

Humidistat - An automatic control that switches a fan, humidifier, or dehumidifier on and off.

I-beam - One of two steel beams shaped like 'I's that provide the main support for the mobile home and which are the main structural parts of the chassis or trailer.

Infiltration - The inflow of outdoor air into the indoors which is accompanied by an equal outflow of air from indoors to the outdoors.

J-rail - The metal strip that clamps a metal mobile-home roof down to the siding around the perimeter of the roof and also acts as a miniature rain gutter.

Jalousie windows - Windows that have multiple horizontal panes that allow the whole area of the window to be used for ventilation.

Jamb - The finished side or top piece of a window or door opening.

Joist - A horizontal wood framing member that supports a floor or ceiling.

Low-e - Low emissivity: used to describe energy-efficient glass and coatings that make the glass reflect heat.

Main beam - One of two steel beams shaped like 'I's that provide the main support for the mobile home and which are the main structural parts of the chassis or trailer.

Main panel box - The service box containing a main switch, and the fuses or circuit breakers located inside the home.

Manifold - A section of pipe with multiple openings.

Marriage wall - The joint between two sections of a double-section or triple-section home.

Mastic - A thick creamy substance used to seal seams and cracks in building materials.

Microclimate - A very localized climatic area, usually of a small site or habitat.

Mil - One one-thousandth of an inch.

Mobile home door - An outwardly opening door hung in a metal frame.

NREL - The National Renewable Energy Laboratory.

Open-combustion - A combustion device that takes its combustion air from the surrounding room air is called open-combustion.

Orifice - A hole in a gas pipe where gas exits the pipe to be mixed with air in a burner before combustion in a heating device.

Outrigger - A triangular piece of structural steel that connects to the main beam and stretches to the outside edge of the wood floor for support.

Outward clinching staple - A staple driven by a special staple gun that will stitch belly paper together without wood backing (also called "stitch stapler").

Packaged air conditioner - An air conditioner, installed outdoors, that contains both the evaporator and the condenser and often heating equipment. It is connected to the home by supply and return air ducts.

Particle board - A board sold in 4-by-8 foot sheets, made of pressed sawdust, used for mobile home flooring.

Pascal - A unit of measurement for small air pressures caused by blower doors and wind.

Perm - A measurement of how much water vapor a material will let pass through it per unit of time.

Pier - A short column of masonry or steel that provides support between the footing and the main beam.

Pilot light - A small gas burner and flame used to light the main burners of a gas appliance.

Plate - A piece of lumber installed horizontally to which vertical studs in a wall frame are attached.

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

Plumb - At a right angle to the earth's surface. Absolutely vertical.

Polybutylene - A plastic used for supply pipes in many mobile homes.

Polyethylene - A common plastic used for vapor barriers and ground moisture barriers.

Polyvinyl chloride - A plastic used for moisture resistant flexible film and drain piping.

Polystyrene - Rigid plastic foam insulation, usually white, blue, or pink in color.

Prime window - The main window installed on the outside wall. Not to be confused with a storm window.

Putty tape - A tape made of a stiff caulking material, used to seal windows, doors, and siding.

R-value - A measurement of resistance to conduction heat flow. Single-pane windows have an R-value of about 1 and insulation materials have R-values of 2-6 per inch of thickness.

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

Refrigerant - A special fluid used in air conditioners and heat pumps that heats air when it condenses from a gas to a liquid and cools air when it evaporates from a liquid to a gas.

Register - A louvered vent in the floor or ceiling connected to ducts for heating and cooling.

Relay - An automatic, electrically-operated switch.

Retrofit - An energy conservation measure that is applied to an existing building. Also means the action of improving the thermal performance or maintenance of a building.

Return air - Air circulating back to the furnace from the house to be heated by the furnace and supplied to the rooms.

Rim joist - The outermost joist around the perimeter of the floor framing.

Rodent barrier - A rigid or flexible material that protects the bottom of the floor from animals at the home site and road dirt during transport. Same as underbelly material.

Roof cap - Insulation and roofing installed directly over the existing roof of the mobile home.

Roof-column-support piers - The pier and footing under a column that supports a large section of roof—over a large family room, for example.

Room air conditioner - A unitary air conditioner installed through a wall or window which cools the room by removing heat from the room and releasing the heat outdoors.

Rough opening - The opening created by the framing in a wall for a door or window.

Rumble washer - A gasketed washer for fastening metal roofing to trusses to stop rumbling noise.

Sash - A movable or stationary part of a window that frames a piece of glass.

Sealed-combustion - Used to describe a combustion appliance like a furnace or water heater that draws combustion air from outdoors and has a sealed exhaust system.

Seasonal energy efficiency ratio (SEER) - The number of btus per hour an air conditioner removes per watt of power. Used for rating efficiency of air conditioners.

Service wires - The wires coming from the utility transformer to the service equipment at the home.

Sequencer - A bimetal switch that turns on the elements of an electric furnace in sequence.

Service equipment - The electric meter and main switch usually located outside the home.

Service wires - The wires coming from the utility transformer to the service equipment at the home site.

Shading coefficient - A decimal describing how much solar energy is transmitted through a window opening. Clear glass is 1 and shaded glass is a decimal number less than 1.

Sheathing - A structural cladding, attached to the framing underneath siding and roofing of a building, that strengthens or insulates the walls or roof.

Sheetrock - Gypsum interior wallboard used to produce a smooth and level interior wall surface and to resist fire. See also Gypsum board.

Shell - The exterior walls, floor, and roof assembly of a mobile home. The building parts that actually separate the indoors from the outdoors.

Short circuit - A dangerous malfunction in an electrical circuit where electricity is flowing through conductors and into the ground without going through an electric load like a light or motor.

Siding - The very outer decorative layer of wood, metal, plastic, or masonry material covering exterior walls.

Sill - The bottom horizontal piece of a window or door frame.

Site - A location for setting up a mobile home.

Skirting - Weather-resistant framing and sheeting used to enclose the crawl space of a mobile home.

Snap-disc thermostat - A thermostatic switch for a furnace fan or high limit that is operated by a heat-sensitive disc which snaps between concave and convex shapes.

Solar transmittance - The percent of solar energy admitted by a window. Used to measure a window's resistance to summer heat gain.

Solenoid - A magnetic operator for a switch or valve.

Spline - A strip that, when inserted into a groove, holds a screen or plastic film in place on a frame.

Split-system air conditioner - An air conditioner that has the evaporator coil in the furnace and the condenser outdoors.

Spot ventilation - Ventilation by an exhaust fan at the source of pollution.

Stitch stapler - An outward clinch stapler used for fastening paper and cloth underbelly material to cloth or paper patches.

Strike plate - The metal plate attached to the door jamb that the latch inserts into upon closing.

Strongback - A beam used as a stiffener usually in a roof or floor.

Stud - A vertical wood framing member of a wall.

Stuffer - A flat flexible plate used to stuff insulation into wall cavities.

Supply air - Air that has been heated or cooled and is then moved through the ductwork and out the supply registers of a home.

Termination bar - A metal strip that clamps the rubber roof membrane at the edge of the roof and wall in a rubber roof installation.

Thermocouple - An electric generator fueled by the pilot light that allows gas to flow if the pilot light is lit and stops gas flow if the pilot is extinguished.

Thermostat - A heat-sensitive switch for operating heating and cooling systems.

Threshold - The narrow raised sections of floor directly under doors which help to seal doors from air leakage and dust.

Tie-downs - Straps or cables attaching the home to ground anchors.

Trim - Decorative wood that covers cracks around window and door openings and at the corners where walls meet floors and ceilings. Sometimes called molding.

Truss - A lightweight, rigid framework designed to be stronger than a solid beam of the same weight.

Transformer - An electrical device that changes voltage used in heating control circuits.

U-value - The R-value's inverse used to rate windows.

Underbelly - The bottom part of the mobile home floor as viewed from underneath the floor in the crawl space.

Vapor barrier - A material that blocks the passage of water vapor.

Vapor diffusion - The flow of water vapor through materials going from a wetter area to a drier area.

Ventilated walls - Wall systems in mobile homes that were intentionally vented to the outdoors to remove moisture.

Visible transmittance - The percent of visible sunlight admitted by a window.

Weatherization - The process of reducing energy consumption and increasing comfort in buildings by improving energy efficiency of the building.

Weatherstripping - Flexible gaskets, often mounted within rigid metal strips for limiting air leakage through windows and doors.

Webbing - A reinforcing fabric used with mastics and coatings to prevent patches from cracking.

Weep holes - Holes drilled for the purpose of allowing water to drain out of an area in a building where it has accumulated.

Whole-house ventilation - Ventilation provided for the entire home by fans and vents.

A-1 Suggestions for Moving Mobile Homes

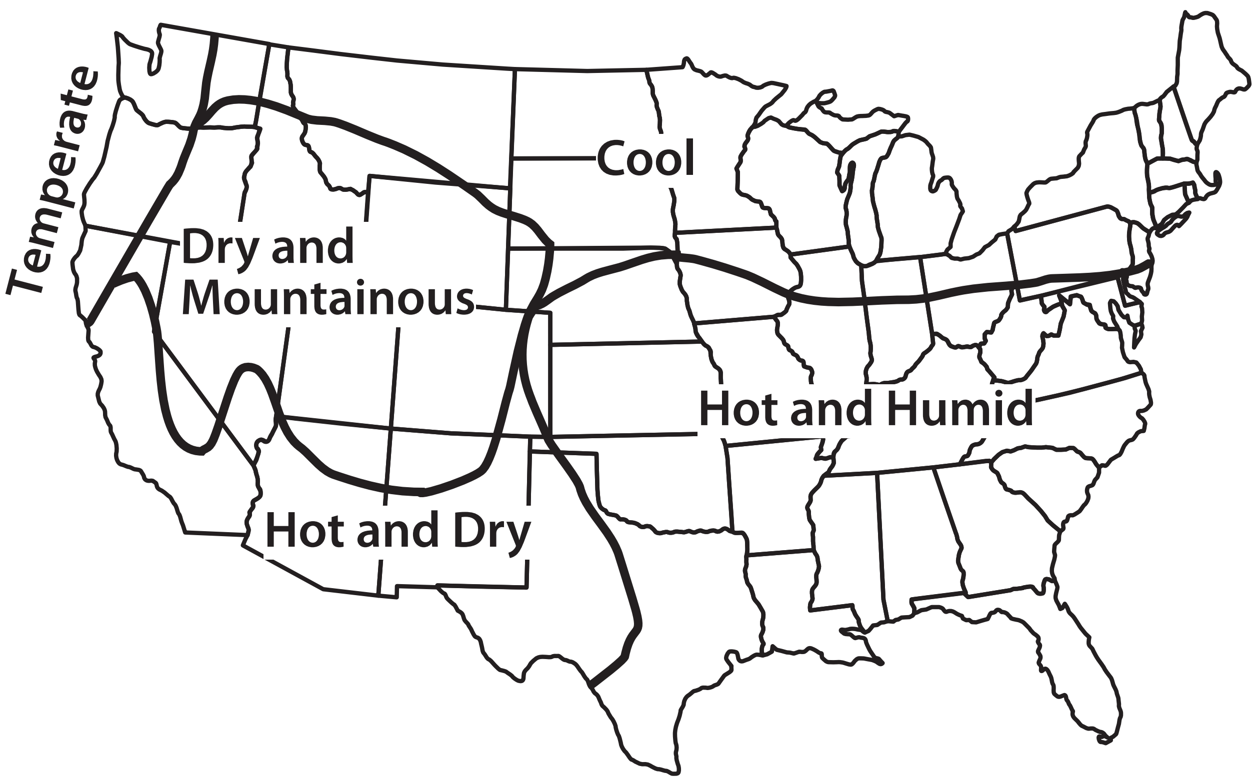
1. Mobile homes are not designed to be moving vans. All major furniture and appliances should be removed from the home and shipped separately. Appliances like water heaters, furnaces, and built-in kitchen ranges, that were shipped with the home originally, need not be removed.
2. Heavy items like books and dishes should be packed in boxes and moved separately. Any lightweight furnishings that are moved with the mobile home should be located near the hitch or axle.
3. Your home should have the same number of axles as were originally present. Moving the home with fewer axles could bend the frame or cause tires to blow out.
4. Check tire pressure and condition. Make sure that the bearings in the axle are packed with grease. Send at least two spare tires in good condition with the home.
5. Drain the water heater and make sure that it will not move. If necessary, strap the water heater to the wall of its compartment.
6. Remove swamp coolers and other unsecured roof protrusions. Check all roof fittings to ensure that they won't blow off in transit.
7. Remove the top of the toilet tank. Place it in a safe location where it will not break.
8. Install a furring strip along the first row of asphalt shingles on the roof.
9. Make all necessary repairs to prevent wind from tearing the underbelly.
10. Remove the skirting, number skirting panels, and tie them together for shipment.
11. Disconnect anchors and secure loose strapping.
12. Close, lock, and wire doors shut, so they can't pop open in transit.
13. Tape all drawers and cabinet doors shut.
14. Place wedges under both sides of interior doors to prevent them from swinging back and forth during transport.
15. Have gas lines, oil lines, electrical service, and air conditioning ducts disconnected by qualified service persons.
16. Cover halves of double-section homes with reinforced polyethylene sheeting. Carefully fasten the sheeting inside and outside. Bridge large gaps with lumber so that the sheeting will not flap excessively and tear. Provide support for roofs over spans where they aren't supported by interior walls. Install cross bracing to prevent the rectangular open side from tilting into a parallelogram.
17. Have all the preparation work you can do completed before the mover arrives.
18. Arrange for trip insurance either through the mover or through your local insurance agent.
19. Make sure that all necessary site work and foundation construction work is completed before the home is delivered to its new site.
20. Mobile or manufactured homes with roofs that have been added after the home's original installation should not be moved.
21. Check tires, wheels, and brakes on the home's axles to make sure they are road-worthy.

A-2 Maintenance Tips

1. Interior wood finishes can be restored by: 1. Cleaning them with soap and water; 2. Drying the walls; and then 3. Treating the paneling and trim with an oil that protects and polishes the wood. Lemon oil or linseed oil work well for this purpose, as do products that both clean and polish furniture.
2. Scratches and gouges in paneled walls can be filled and disguised by using colored putties or crayons, available in lumber yards or hardware stores.
3. Waxing tile and linoleum floors protects them from water and makes them easier to clean.
4. Water condensation and odors can be reduced by opening windows and doors during mild weather to thoroughly ventilate the home.
5. Metal sidings should be washed and waxed, like automotive finishes, to preserve their finish and appearance. Most dirt can be removed by spraying the siding with water on a warm day, especially if the siding is waxed. Don't spray cold water on hot siding in the summer. If the home has been recently moved or if the wind drives dirt into the walls of the home, you may have to use mild soap and a soft brush to remove dirt. Oil and grease can be removed with an automotive polishing compound, but be careful not to remove too much paint.
6. Bare aluminum siding must be treated with a special primer before painting. For steel siding, rust must be sanded down to bare metal and primed with an automotive primer before painting.
7. Metal roofs should be coated with a reflective coating to prevent solar heat from degrading the waterproofing on the roof and overheating the home during summer months. Once a year, sweep, scrub, or hose off metal roofs to remove dirt and enhance reflectivity.
8. Exterior seams around penetrations in the building envelope are a main area of water leakage. If you remove exterior fixtures, like roof vents and windows, be sure to have the appropriate sealants (putty tape, caulking, roof cement, etc.) ready when you reinstall or replace these fixtures. Apply caulking to the edge of all seams to prevent water penetration.
9. Gouges and scratches in white fiberboard ceilings can be covered with chalk or white acrylic latex caulk. Holes and cracks in ceilings should be filled and sealed to prevent heated or cooled air from the living space from escaping. Ceiling smudges can be removed with an art gum eraser.
10. After you are sure that the source of the water damage is repaired, water stains in white fiberboard or sheetrock can be repainted. First, paint the area with a mild bleach solution (1 part bleach to 4 parts water) to kill mold and other microbes and to whiten the area. Wait until the area dries, then paint it.
11. Dark surfaces or dirty surfaces on walls and roofs absorb more solar heat than light and shiny surfaces. If you want to stay cool in the summer: Paint, wax, and wash your walls and roof. Keep your home shiny and reflective.
12. If you have an air conditioner, keep it clean. Minimize dirt deposits on its condenser coils—avoid stirring up dirt, dust, leaves, or other debris around the air conditioner.

A-3 Regional Cooling Solutions

Cooling Regions



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°F 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 dryer 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%).

Zone 3 - Hot and Dry

Air temperatures can exceed 100°F during heat waves in this region. Relative humidity is very low—usually less than 40% 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% 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

Summer temperatures average in the 70°Fs, although temperatures can climb into the 90°Fs 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 be 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.

A-4 Foundation Design Reference

H-1 Approximate Weight of Components of a Manufactured Home

Component	Weight (lbs)	lbs/sq.-ft
Home	14,000-32,000	13-25
Contents	24,000-40,000	40
Snow Load	0-60,000	0-60
Total Design Weight	**38,000-132,000**	**53-125**

G-1 *The maximum weight of the home, which the foundation must support, is the sum of the home's weight, the weight of its contents, and the snow load prescribed for the region where it is located. This information is for a single section.*

H-2 Approximate Weight-Bearing Capacity of Soils

Soil Type	Weight-Bearing Capacity (PSF)
Rock	20,000
Hardpan or Very Compacted Soil	10,000
Firm Sand and Gravel	8000
Loose Sand or Gravel	4000
Firm Silt and/or Fine Sand	2500
Firm Clay	1500
Loose Silt/Clay	1000

G-2 *A pocket penetrometer, sold at engineering supply outlets, is the best tool for measuring the weight-bearing capacity of soil. However, you can estimate the weight-bearing capacity of the soil in pounds per square foot (psf) using this table, if you know the type of soil.*

H-3 Minimum Sizes for Square Footings

Footing Capacity	Soil Capacity 1000 PSF	1500 PSF	2000 PSF	4000 PSF
1000	12 x 12	10 x 10	8 x 8	6 x 6
2000	17 x 17	14 x 14	12 x 12	8 x 8
3000	21 x 21	17 x 17	15 x 15	10 x 10
4000	24 x 24	20 x 20	17 x 17	12 x 12
5000	27 x 27	22 x 22	19 x 19	13 x 13
6000	29 x 29	24 x 24	21 x 21	15 x 15
7000	32 x 32	26 x 26	22 x 22	16 x 16
8000	34 x 34	28 x 28	24 x 24	17 x 17
9000	36 x 36	29 x 29	25 x 25	18 x 18
10000		31 x 31	27 x 27	19 x 19
12000		34 x 34	29 x 29	21 x 21
14000			32 x 32	22 x 22
16000	Reinforced, designed footings		34 x 34	24 x 24
18000				26 x 26

G-3 *This table gives the dimensions of the minimum square-shaped footing for the weight it needs to support. The weight that a footing must support is specified by the manufacturer.*

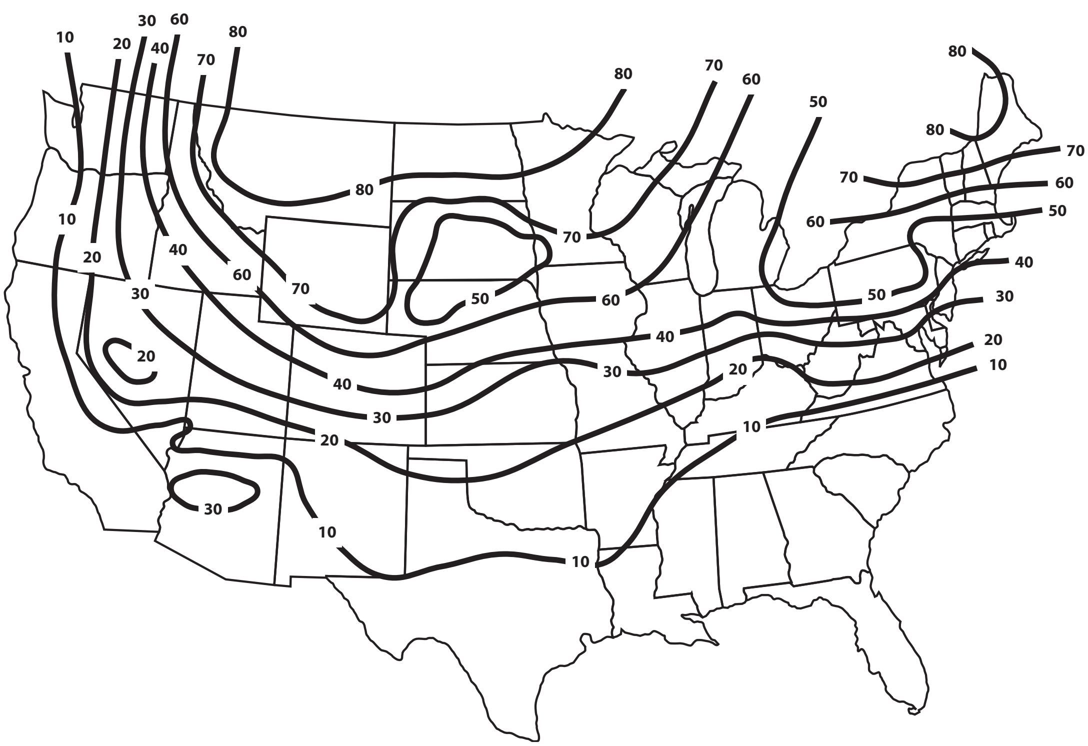
Foundation Design Reference (Cont.)

H-4 Pier/Footing Types and Characteristics

Type of Pier/ Footing	Spacing	Capacity Range Per Pier/Footing	Applicability
Frame Without Perimeter	8′	3000-6000 lbs.	Single and double-section homes in central and southern regions.
Frame and Perimeter	8′	1500-4000 lbs.	Usually required in northern and mountain regions. Often required by manufacturer for multi-section homes.
Marriage Wall	10′ 20′	2000-5000 lbs. 3500-10,000 lbs.	Required on all multi-section homes.
Roof Support Column	As needed	7000-18,000 lbs.	Required under marriage wall at specific locations on ends of large spans in open rooms.

***G-4** The weight that a footing and pier must support is specified by the manufacturer for the 4 different kinds of pier/footing combinations. The amount of weight each footing must carry depends on the weight of the home, its contents, the snow load in the region, and the location of the pier/footing. Home furnishings like pianos and water beds require extra pier/footings directly beneath them.*

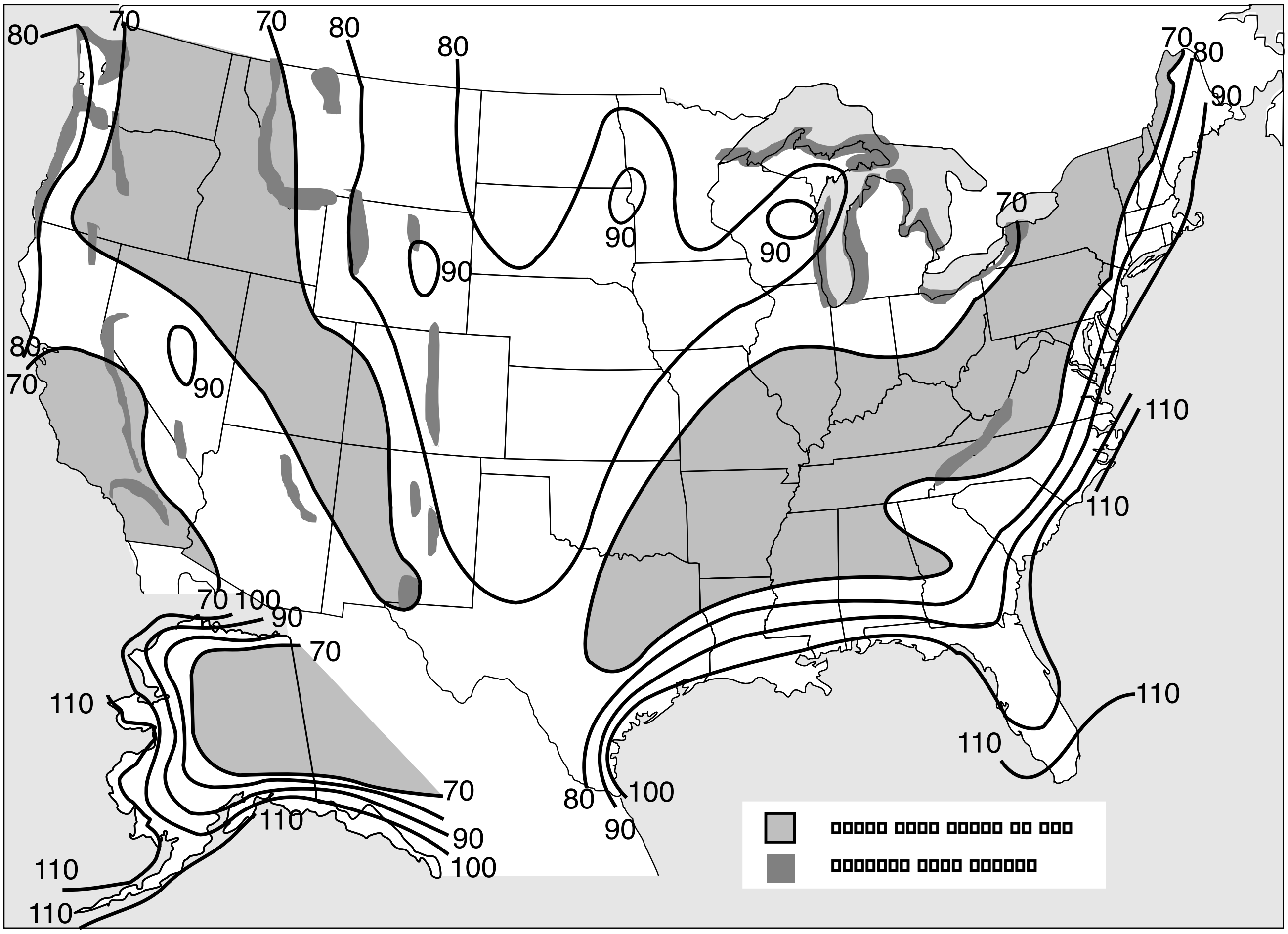
H-5 Maximum Frost Penetration Map



***G-4** The weight that a footing and pier must support is specified by the manufacturer for the 4 different kinds of pier/footing combinations. The amount of weight each footing must carry depends on the weight of the home, its contents, the snow load in the region, and the location of the pier/footing. Home furnishings like pianos and water beds require extra pier/footings directly beneath them.*

A-5 Wind Speed and Anchoring Requirements

These recommendations assume that anchors rated for 4725 pounds are installed as recommended by the anchor manufacturer.



H-1 *Locate the design wind speed for your area and see the table below for number of vertical and horizontal tie-downs.*

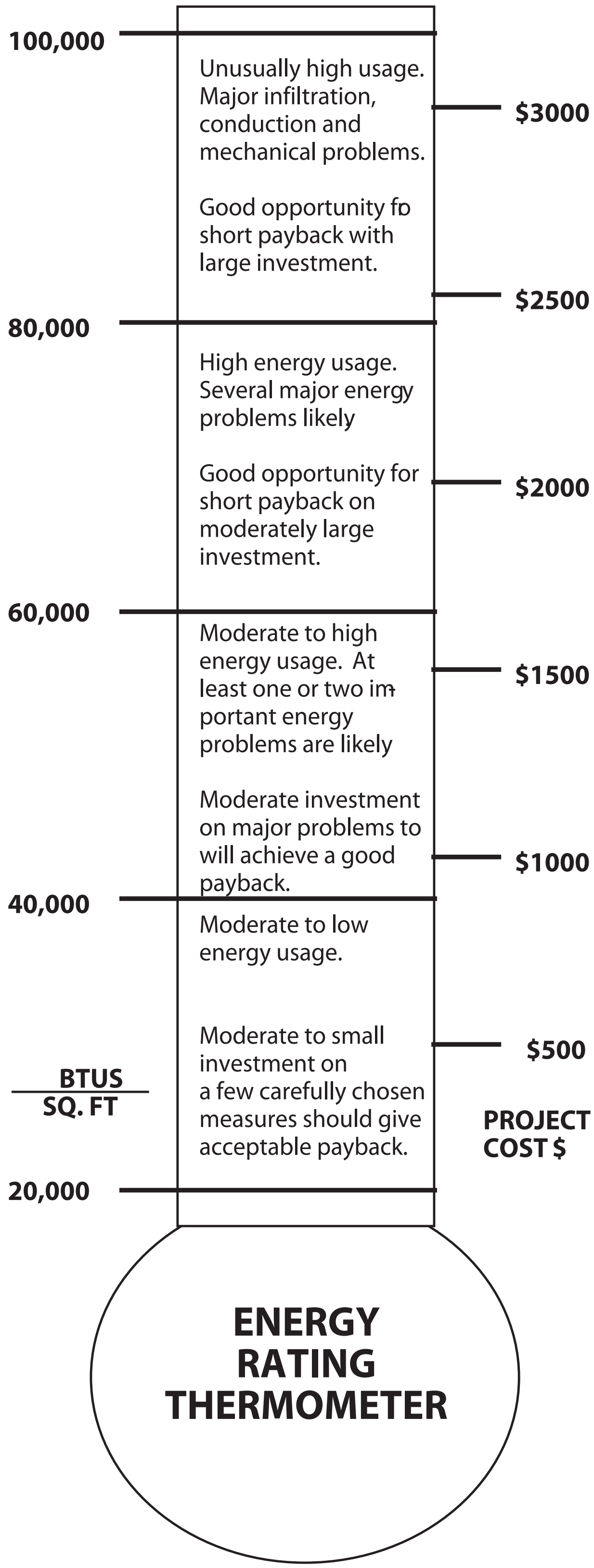
Number of Anchors and Ties per Side

Wind Speed (m.p.h.)	30-to-50 feet long		50-to-60 feet long		60-to-70 feet long	
	# frame ties	# overtop ties	# frame ties	# overtop ties	# frame ties	# overtop ties
70	3	2	4	2	4	2
80	4	3	5	3	5	3
90	5	4	6	4	7	6
100	6	5	7	5	8	6
110	7	6	8	6	10	7

H-2 *The number of over-the-top and frame ties required to secure a mobile home depends on length, design wind speed, tie-down strength, and anchor holding power. Double-wide homes need only frame ties.*

From Civil Defense Bulletin # TR75

A-6 Mobile Home Energy Rating



HOW TO USE THE ENERGY RATING THERMOMETER

The numbers on the left of the energy rating thermometer represent the number of Btus per square foot of floor space used each year in a mobile home. The numbers on the right represent the amount you can spend economically on energy conservation projects with a reasonable cost-recovery period (about 7 years).

To determine your cost limitations, plug your energy usage and square footage into the energy rating formula to calculate the amount of Btus per square foot of floor space used to satisfy the mobile home's annual energy needs.

Energy Rating Formula

$$\frac{\text{number of units / yr x Btus / unit}}{\text{square feet of floor space}} = \text{Energy Rating (Btus / square foot / yr.)}$$

Example:

A 14 x 70 mobile home using 89 mcf of natural gas per year.

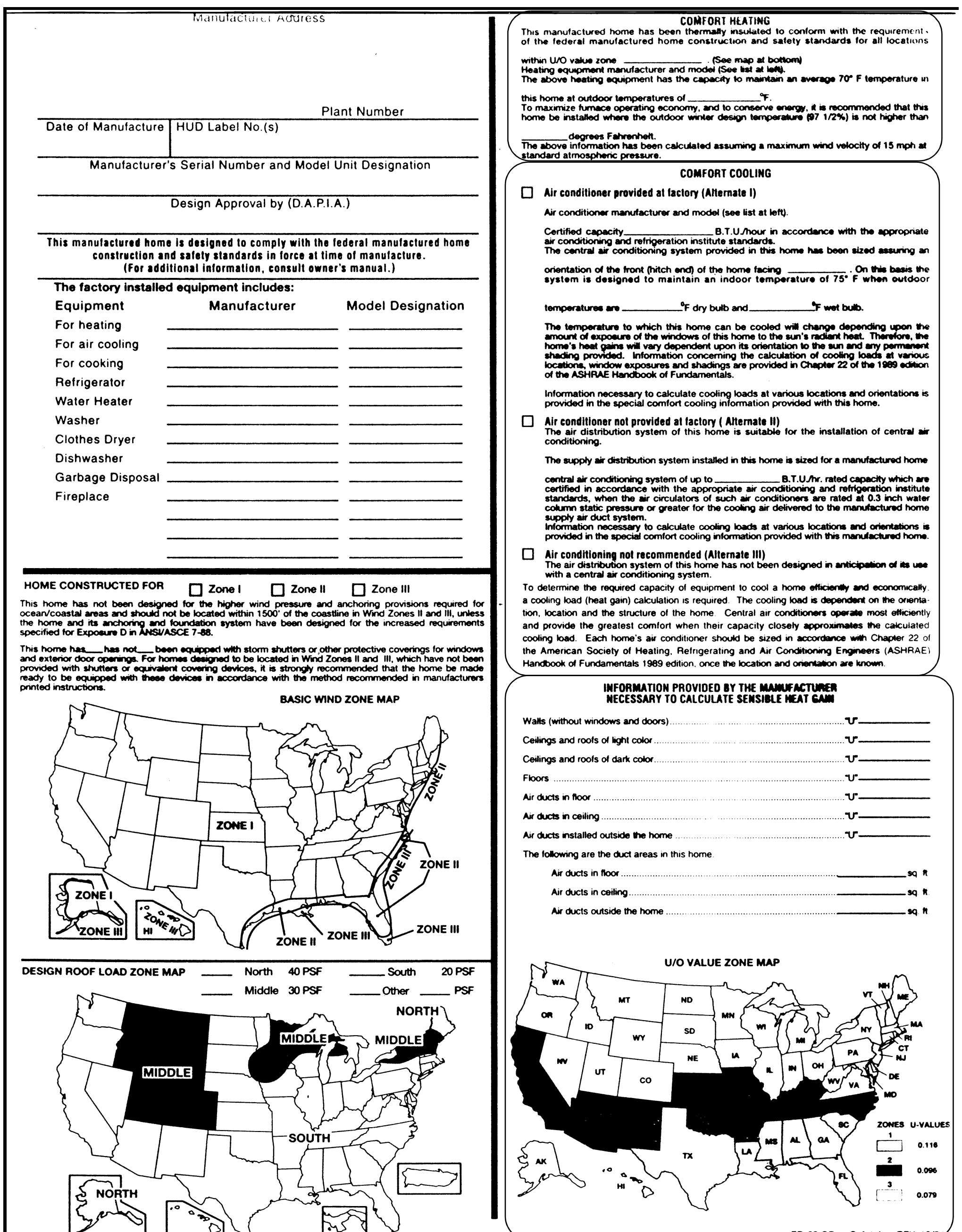
Number of units per year = 89
Btus per unit = 980,000
Square feet of floor space = 14 x 70 = 980

$$\frac{89 \times 980{,}000}{980} = 89{,}000 \text{ Btus / sq.ft./ yr}$$

Btu Contents of Fuels

Fuel	Btus	Unit
Natural Gas (mcf)	980,000	mcf
Fuel Oil (gal.)	138,000	gallon
Electricity (kwh)	3412	kWh
Propane (gal.)	95,500	gallon
Hardwood	24,000,000	cord
Softwood	17,000,000	cord
Wood Pellets	17,000,000	ton

A-7 Understanding Compliance Certificates


Manufacturer Address

Plant Number

Date of Manufacture | HUD Label No.(s)

Manufacturer's Serial Number and Model Unit Designation

Design Approval by (D.A.P.I.A.)

This manufactured home is designed to comply with the federal manufactured home construction and safety standards in force at time of manufacture. (For additional information, consult owner's manual.)

The factory installed equipment includes:

Equipment	Manufacturer	Model Designation
For heating		
For air cooling		
For cooking		
Refrigerator		
Water Heater		
Washer		
Clothes Dryer		
Dishwasher		
Garbage Disposal		
Fireplace		

HOME CONSTRUCTED FOR ☐ Zone I ☐ Zone II ☐ Zone III

This home has not been designed for the higher wind pressure and anchoring provisions required for ocean/coastal areas and should not be located within 1500' of the coastline in Wind Zones II and III, unless the home and its anchoring and foundation system have been designed for the increased requirements specified for Exposure D in ANSI/ASCE 7-88.

This home has____has not____ been equipped with storm shutters or other protective coverings for windows and exterior door openings. For homes designed to be located in Wind Zones II and III, which have not been provided with shutters or equivalent covering devices, it is strongly recommended that the home be made ready to be equipped with these devices in accordance with the method recommended in manufacturers printed instructions.

BASIC WIND ZONE MAP

DESIGN ROOF LOAD ZONE MAP ____ North 40 PSF ____ South 20 PSF ____ Middle 30 PSF ____ Other ____ PSF

COMFORT HEATING

This manufactured home has been thermally insulated to conform with the requirements of the federal manufactured home construction and safety standards for all locations within U/O value zone ________. (See map at bottom)

Heating equipment manufacturer and model (See list at left).

The above heating equipment has the capacity to maintain an average 70° F temperature in this home at outdoor temperatures of ________°F.

To maximize furnace operating economy, and to conserve energy, it is recommended that this home be installed where the outdoor winter design temperature (97 1/2%) is not higher than ________degrees Fahrenheit.

The above information has been calculated assuming a maximum wind velocity of 15 mph at standard atmospheric pressure.

COMFORT COOLING

☐ **Air conditioner provided at factory (Alternate I)**

Air conditioner manufacturer and model (see list at left).

Certified capacity________B.T.U./hour in accordance with the appropriate air conditioning and refrigeration institute standards.

The central air conditioning system provided in this home has been sized assuring an orientation of the front (hitch end) of the home facing ________. On this basis the system is designed to maintain an indoor temperature of 75° F when outdoor temperatures are ________°F dry bulb and ________°F wet bulb.

The temperature to which this home can be cooled will change depending upon the amount of exposure of the windows of this home to the sun's radiant heat. Therefore, the home's heat gains will vary dependent upon its orientation to the sun and any permanent shading provided. Information concerning the calculation of cooling loads at various locations, window exposures and shadings are provided in Chapter 22 of the 1989 edition of the ASHRAE Handbook of Fundamentals.

Information necessary to calculate cooling loads at various locations and orientations is provided in the special comfort cooling information provided with this home.

☐ **Air conditioner not provided at factory (Alternate II)**

The air distribution system of this home is suitable for the installation of central air conditioning.

The supply air distribution system installed in this home is sized for a manufactured home central air conditioning system of up to ________B.T.U./hr. rated capacity which are certified in accordance with the appropriate air conditioning and refrigeration institute standards, when the air circulators of such air conditioners are rated at 0.3 inch water column static pressure or greater for the cooling air delivered to the manufactured home supply air duct system.

Information necessary to calculate cooling loads at various locations and orientations is provided in the special comfort cooling information provided with this manufactured home.

☐ **Air conditioning not recommended (Alternate III)**

The air distribution system of this home has not been designed in anticipation of its use with a central air conditioning system.

To determine the required capacity of equipment to cool a home efficiently and economically, a cooling load (heat gain) calculation is required. The cooling load is dependent on the orientation, location and the structure of the home. Central air conditioners operate most efficiently and provide the greatest comfort when their capacity closely approximates the calculated cooling load. Each home's air conditioner should be sized in accordance with Chapter 22 of the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) Handbook of Fundamentals 1989 edition, once the location and orientation are known.

INFORMATION PROVIDED BY THE MANUFACTURER NECESSARY TO CALCULATE SENSIBLE HEAT GAIN

Walls (without windows and doors) .... "U" ________

Ceilings and roofs of light color .... "U" ________

Ceilings and roofs of dark color .... "U" ________

Floors .... "U" ________

Air ducts in floor .... "U" ________

Air ducts in ceiling .... "U" ________

Air ducts installed outside the home .... "U" ________

The following are the duct areas in this home

Air ducts in floor .... ________ sq ft

Air ducts in ceiling .... ________ sq ft

Air ducts outside the home .... ________ sq ft

U/O VALUE ZONE MAP

Comfort Heating: Tells you the lowest outdoor temperature at which your heating system will heat your home to 70°F.

Heating design temperature: When engineers design heating systems they choose the outdoor temperature exceeded 97.5% of the time for each particular region. The heating design temperature is the highest one where the installed furnace should be used. The heating design temperature for Helena, Montana is -17°F; for Spartenburg, South Carolina it's 18°F. If you moved a home from Spartenburg to Helena the furnace would be too small.

Cooling design temperatures: Engineers use two temperatures to design cooling systems: "design dry bulb" which measures heat and "design wet bulb" which measures humidity. Like heating design temperatures, they are exceeded only 2.5% of the time. Houston which is humid has design temperatures of 95°F dry bulb and 77° wet bulb. Tucson which is dry has design temperatures of 102°F dry bulb and 66°F wet bulb. (These temperatures are listed only for homes with built-in air conditioning.)

Certificate courtesy of www.hud.gov

Wind-load zone and roof-load zone for which your home is designed. It's OK if the home is over-designed for its region—for example a home designed for the middle zone (roof-load) could be located in the south zone.

U/O zone map tells you the thermal zone your home was designed for and the conductance ("U") of its walls, floors, and ceilings.
To find the "R" value divide the number "1" by the "U" value listed here.

A-8 Household Appliance Electrical Usage

Appliance	Annual kWh
Heating and Cooling	
Room air conditioner	500–2000
Two-and-one-half ton central air conditioner	2000–8000
Five ton central air conditioner	4000–12,000
Evaporative Coolers	200–2000
8-foot electric baseboard heater	750–2000
Electric furnace	6000–16,000
Furnace fan	300–900
Hot water circulator	250–700
Heat recovery ventilator	400–1100
General Appliances	
Engine block heater	50–400
Clothes dryer	400–1500
Computer	50–350
Ceiling fan	20–50
Whole house fan	60–200
Television, color (solid state)	100–400
Television cable box	40–160
Television off-cycle energy	10–40
Video cassette recorder	15–40
Hair blow-dryer	8–16
Hand iron	10–100
Heat lamp	10–25
Lighting (average total)	200–2000
Vacuum cleaner	20–80
Water heater (1–3 people)	2500–6000
Water heater (3–6 people)	4000–8000
Water heater (15 gallon)	2000–3500
Water bed	1000–2000
Hot tub heating (indoor 300–500 gallons)	1500–3000
Hot tub heating (outdoor 300–500 gallons)	3000–8000
Hot tub circulation	1000-2500
Pool circulator	1100–4000
Well pump	250–500
Clothes washers	80–200
Hot wash, cold rinse	1200–1700

Appliance	Annual kWh
Warm wash, cold rinse	600–1000
Cold wash, cold rinse	70–160
Water cooler with hot water	600–900
Kitchen Appliances	
Refrigerator/freezer	
20-year-old manual defrost	1300
20 year-old side-by-side, frost-free	1400–1900
10-year-old	800–1100
New ENERGY STAR qualified	400–540
Freezer	
20-year-old upright, frost-free	1400–2000
20-year-old chest, manual defrost	1100–1300
10-year-old chest	600–800
New ENERGY STAR qualified	370–430
Range (with oven)	200–800
Dishwasher	100–600
Broiler	20–100
Coffee maker	80–200
Microwave oven	100–250
Roaster	20–80
Slow cooker	40–150
Toaster	15–50
Toaster oven	50–300

Assembled from utility studies and utility company information sources.

A-9 Energy Project Summary

The tables on these two pages summarize and list the energy projects discussed in this book. The energy projects are listed in order of priority, payback period, and level of difficulty. Labor is

*Level of Difficulty	*Equipment
1. Expert Technician	A. Unique equipment
2. Skilled Technician	B. Rental Equipment
3. Skilled Homeowner	C. Specialized Tools
4. Average Homeowner	D. Ordinary Tools

	Project	Method/Material	Section	Difficulty/ Equip. *	Payback Period
Cold Climate	Sealing air leaks	Blower-door-guided air sealing	5.2	2A	0.5–1 yr.
	Water heating	Wrap water tank	13.3.1	4D	0.5–1 yr.
		Low-flow showerhead	13.3.4	4D	0.5–1 yr.
	Heating system	Seal duct leaks	11.3.1	3D	0.5–1 yr.
		Change or clean filters	11.4.1	4D	0.5–1 yr.
		Clean blower	11.4.2	3D	0.5–1 yr.
		Tune oil furnace	11.1.3	2A	0.5–1 yr.
		Adjust furnace blower	11.2.3	2D	0.5–1 yr.
		Automatic thermostat	11.2.5	2D	1–2 yrs.
	Roof insulation	Roof cavity insulation	10.4.2	3B	3–6 yrs.
		Rooftop insulation	10.4.3	2D	10–20 yrs
	Floor insulation	Blow or install batts	7.3.2	2C	3–7 yrs.
	Wall insulation	Blow-in of stuff fiberglass	8.3	2C	4–8 yrs.
		Remove siding and install batts	8.3.4	3D	6–10 yrs.
	Storm windows	Interior, movable or fixed	9.2.2	2D	4–10 yrs.
	Landscaping	Windbreaks	3.5	4D	7–12 yrs
Temperate Climate	Sealing air leaks	Blower-door-guided air sealing	5.2	2A	0.5–1 yr.
	Water heating	Wrap water tank	13.3.1	4D	0.5–1 yr.
		Low-flow showerhead	13.3.4	4D	0.5–1 yr.
	Heating system	Seal duct leaks	11.3.1	3D	0.5–1 yr.
		Change or clean filters	11.4.1	4D	0.5–1 yr.
		Clean blower	11.4.2	3D	0.5–1 yr.
		Tune oil furnace	11.1.3	2A	0.5–1 yr.
		Adjust furnace blower	11.2.3	2D	0.5–1 yr.
		Automatic thermostat	11.2.5	2D	1–2 yrs.
	Cooling system	Seal duct leaks	11.3.1	3D	0.5–1 yr.
		Clean filters/blower	11.4	3D	0.5–1 yr.

Project	Method/Material	Section	Difficulty/ Equip.	Payback Period	
	Adjust freon charge	12.3.4	1A	0.5–1 yr.	Cold Climate
	Adjust airflow	12.3.4	1A	0.5–1 yr.	
Passive cooling	Ventilation and air circulation	12.2	4D	0.5–1 yr.	
Automatic thermostat	Heating/cooling	11.2.5	2D	1–2 yrs.	
Roof insulation	Roof cavity insulation	10.4.2	3B	3–6 yrs.	
	Rooftop insulation	10.4.3	2D	10–20 yrs	
Floor insulation	Blow or install batts	7.3.2	2D	3–7 yrs.	
Wall insulation	Blow-in of stuff fiberglass	8.3	2C	4–8 yrs.	
Landscaping	Windbreaks	3.5	4D	8–14 yrs	
	Vines and shade trees	3.4	4D	4–10 yrs.	
Storm windows	Interior, movable or fixed	9.2.2	3D	6–12 yrs.	
Shading	Sun screens, window films, and awnings	12.1	2D	5–20 yrs.	
Sealing air leaks	Blower-door-guided air sealing	5.2	2A	0.5–1 yr.	Temperate Climate
Water heating	Wrap water tank	13.3.1	4D	0.5–1 yr.	
	Low-flow showerhead	13.3.4	4D	0.5–1 yr.	
Passive cooling	Ventilation and air circulation	12.2	4D	0.5–1 yr.	
Cooling system	Seal duct leaks	11.3.1	3D	0.5–1 yr.	
	Clean filters/blower	11.4	3D	0.5–1 yr.	
	Adjust freon charge	12.3.4	1A	0.5–1 yr.	
	Adjust air flow	12.3.4	1A	0.5–1 yr.	
Heating system	Seal duct leaks	11.3.1	3D	0.5–1 yr.	
	Change or clean filters	11.4.1	4D	0.5–1 yr.	
	Clean blower	11.4.2	3D	0.5–1 yr.	
	Tune oil furnace	11.1.3	2A	0.5–1 yr.	
	Adjust furnace blower	11.2.3	2D	0.5–1 yr.	
Landscaping	Vines and shade trees	3.4	4D	2–6 yrs.	
Shading	Sun screens	12.1.4	2D	5–20 yrs.	
	Window films	12.1.2	2D	4–8 yrs.	
	Awnings	12.1.5	2D	7–14 yrs.	
Roof insulation	Roof cavity insulation	10.4.2	3B	4–10 yrs.	
	Rooftop insulation	10.4.3	2D	6–18 yrs	

A-10 Indoor Air Pollutants

	Pollutant	Health effects and victims	Exposure limit
Dust	**Asbestos**	Lung cancer, asbestosis, mesothelioma. Smoking greatly increases risk of asbestos-related lung cancer. *Victims:* Asbestos workers.	No safe level. (EPA) 0.1 fiber/cc (OSHA 8 hr.) 1 fiber/cc (OSHA 30 min.)
Dust	**Biological particles**	Allergies, asthma, infectious diseases, toxic effects. *Victims:* Occupants of buildings with moisture problems.	No established limits.
Dust	**Combustion particles**	Decreased lung function, cancer. *Victims:* Smokers, wood stove users, city dwellers.	EPA/ASHRAE Limits 50 µg/m³ (continuous) 150 µg/m³ (8-hr.) 15,000 µg/m³ (8-hr. OSHA)
Dust	**Lead**	Damage to kidneys, nervous system, and red blood cells. *Victims:* Toddlers who ingest lead dust hand-to-mouth; demolition and renovation workers who breathe lead dust.	1.5 µg/m³ (EPA and ASHRAE 3-month exposure limit)
Dust	**Radon progeny**	Lung cancer. *Victims:* Long-time occupants of buildings with high radon levels.	4 pCi/l (EPA) 2 pCi/l (ASHRAE)
Gases	**Carbon monoxide**	Decreased reaction time and work capacity; chest pain and exacerbation of existing respiratory problems; headaches, nausea; asphyxiation, brain damage, coma, and death in high concentrations. *Victims:* Occupants of buildings with CO from combustion appliances and tobacco smoke.	9 ppm (EPA 8-hr.) 35 ppm (EPA 1-hr.) 200 ppm (Instantaneous OSHA)
Gases	**Formaldehyde**	Irritant, allergen, and possible carcinogen. Exacerbates existing respiratory problems. *Victims:* New home occupants, smokers, occupants of recently remodeled buildings.	0.1 ppm (ASHRAE continuous) 1 ppm (OSHA 8-hour)
Gases	**Nitrogen dioxide**	Retards pulmonary function in children and possibly in adults. Animal studies suggest decreased immune capacity. *Victims:* Occupants of buildings with combustion gases in indoor air.	100 µg/m³ or 0.08 ppm (EPA/ASHRAE continuous)
Gases	**Volatile organic compounds**	Respiratory irritants. Damages nervous system, cardiovascular system, kidneys, and liver. Many VOCs are carcinogens. *Victims:* New home occupants, workers using solvents, wood stove users, smokers.	Varies according to particular VOC compound.
Mixtures	**Environmental tobacco smoke**	Carcinogen. Irritates mucous membranes. Chronic and acute cardio-pulmonary effects in children. *Victims:* Occupants of buildings with indoor smoking.	Wood and tobacco smoke contain carbon monoxide, nitrogen dioxide, formaldehyde and VOCs. See above for limits.
Mixtures	**Wood smoke**	Acute respiratory illness. Chronic lung disease. *Victims:* Residents of wood-heated buildings and towns with many wood stoves.	EPA/ASHRAE Particulate Limits 50 µg/m³ (continuous) 150 µg/m³ (8-hr.) 15,000 µg/m³ (8-hr. OSHA)

Symptoms and sensory detection	Sources
Symptoms: No immediate symptoms. *Sensory detection:* Workers must be able to recognize asbestos and activities that raise asbestos dust.	Asbestos cement; pipe, furnace, and boiler insulation; ceiling and floor tiles; shingles and siding; vermiculite insulation.
Symptoms: Allergies, asthma, fevers, eye irritation, nose and throat irritation, and skin irritation. *Sensory detection:* moldy smell and visual detection.	Plants, animals, and humans; pillows, household dust; damp materials; standing water; humidifiers, evaporative coolers, air conditioners, water heaters.
Symptoms: Respiratory and eye irritation. *Sensory detection:* No odor. Fine black soot collects on horizontal surfaces over time.	Combustion appliances, tobacco smoke.
Symptoms: Decreased coordination and mental abilities. *Sensory detection:* By chemical test only.	Lead-based paint, outdoor lead dust from lead-containing gasoline, lead-using activities like soldering, stained-glass work, handling wheel weights, and lead-acid batteries.
Symptoms: No acute effects. *Sensory detection:* Colorless and odorless. Detection by specialized radon test equipment only.	Soil and rock, well water; some building materials.
Symptoms: Headaches, nausea, breathlessness, dizziness, tiredness, flu-like symptoms, chest pain in cardio-pulmonary disease sufferers. *Sensory detection:* Colorless and odorless, but usually accompanied by other combustion gases that have odor.	Gas cook stoves; unvented gas or kerosene heaters; fireplaces and wood stoves; gas and oil furnaces, boilers, and water heaters; tobacco smoke.
Symptoms: Eye, nose, and throat irritation; respiratory irritation; wheezing; coughing; fatigue; and skin rash. *Sensory detection:* Sharp, pungent odor. Presence of new building materials, paint, varnish, carpet, furnishings, and draperies.	Particle board, plywood, drywall; cabinetry and furniture; carpet and drapery fabrics; tobacco smoke.
Symptoms: Drowsiness; headache; respiratory irritation; eye, nose, and throat irritation; and labored breathing. *Sensory detection:* Odorless, colorless. Detection by chemical or electric device only.	Gas cook stoves; gas or oil heaters and water heaters; wood stoves; fireplaces; unvented gas and kerosene heaters; vehicle exhaust; tobacco smoke.
Symptoms: Eye, nose, and throat irritation; fatigue; weakness; skin rash; depression; irregular heartbeats; muscle twitching and convulsion; poor coordination; memory loss; and headache and nausea. *Sensory detection:* Some VOCs have a solvent smell; also presence of tobacco smoke and wood smoke.	Tobacco smoke; kerosene heaters; wood-burning stoves and fireplaces; perfumes and hair sprays; furniture polish; cleaning solvents; hobby and craft supplies; carpet; glues and adhesives; sealants, paints, varnishes, and stains; wood preservatives; dry-cleaned clothes; moth repellents; air fresheners; automotive products; and plastics.
Symptoms: Eye, nose, and throat irritation; respiratory irritation; headache; nausea; dizziness; appetite loss; and asthma aggravation. *Sensory detection:* Tobacco smoke odor.	Tobacco smoking.
Symptoms: Eye, nose, and throat irritation; respiratory irritation; headache; nausea; dizziness. *Sensory detection:* Wood smoke odor.	Wood-burning stoves, fireplaces.

A-11 Businesses and Organizations

Organizations:

American Association of Retired Persons
601 E Street NW, Washington, DC 20049
202-434-2277 • www.aarp.org

American Council for an Energy-Efficient Economy
1001 Connecticut Ave, Ste 801, Washington, DC 20036
202-429-8873 • www.aceee.org

GFA Management
PO Box 47024, Indianapolis, IN 46247
317-351-2547 • mfdhousing.com/gfa/

Loomis and Associates
1701 Quincy St., Naperville, IL 60540
800-853-7119 • mobilehomeadvantage.com

Manufactured Housing Institute
1745 Jefferson Davis Hwy, Arlington, VA 22202
703-413-6620 • www.manufacturedhousing.org

Manufactured Housing Resources
PO Box 9, Nassau, DE 19969
302-645-5552 • www.george-porter.com

National Conference of States on Building Codes & Standards, Inc.
505 Hunter Park Dr, Ste 210, Herndon, VA 22076
703-437-0100 • www.ncsbcs.org

National Foundation of Manufactured Home Owners, Inc.
161 Franciscan Drive, Daly City, CA 94014
415-992-7470

National Renewable Energy Laboratory (NREL)
1617 Cole Boulevard, Golden, CO 80401
303-231-1000 • www.nrel.gov

U.S. Department of Housing and Urban Development, Manufactured Housing Division
451 Seventh Street SW, Washington, DC 20410
202-755-7420 • www.hud.gov

Manufacturers of Equipment:

American ALDES Ventilation Corporation
4537 Northgate Court
Sarasota, FL 34234-2124
941-351-3441 • www.americanaldes.com

Unitary Products Group
5005 York Dr.
Norman, OK 73069
877-874-7378

Coleman/Evcon Industries
800-231-4822 • www.colemanac.com

Empire Comfort Systems
918 Freeburg Ave., Belleville, IL 62222-0529
800-851-3153 • www.empirecomfort.com

Nordyne Corporation
PO Box 46911, St. Louis, MO 63146-6911
314-878-6200 • www.nordyne.com

Tamarack Technologies
P.O. Box 963, Buzzards Bay, MA 02532
800-222-5932 • www.tamtech.com

Toyotomi USA
604 Federal Rd., Brookfield, CT 06804
203-775-1909 • ww.toyotomiusa.com

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