Chapter 8

SPECIAL TOPICS

Protection Against Decay and Termites

Wood used in conditions where it is always dry, or even where it is wetted briefly and then redries rapidly, does not decay. However, all wood and wood products used in construction are susceptible to decay if kept wet for long periods under temperature conditions favorable to the growth of decay organisms. Most of the wood used in a house is not subjected to such conditions. There are places where water can work into the structure, but such places can be protected. Protection is accomplished by methods of design and construction, by use of suitable materials, and in some cases by using treated material.

Wood is also subject to attack by termites and some other insects. Termites can be grouped into two main classes–*subterranean* and *dry-wood*. In northern states, subterranean termites are confined to scattered, localized areas of infestation (fig. 182). In several locations in the South the Formosan subterranean termite has recently (1966) been discovered. It is a serious pest because its colonies contain large numbers of the worker caste and cause damage rapidly. Though presently localized in a few areas, this species could spread to other areas. Controls are similar to those for other subterranean termites. Dry-wood termites are found principally in Florida, southern California, and the Gulf Coast States. They are more difficult to control but cause less serious damage than subterranean termites.

Wood has proved itself through the years to be a desirable and satisfactory building material. Damage from decay and termites has been small in proportion to the total value of wood in residential structures, but it has been troublesome to many homeowners. Moreover, changes in features of building design and use of new building materials call for a restatement of the basic safeguards to protect buildings against both decay and termites.

Decay

Wood decay is caused by certain fungi that can utilize wood for food. These fungi, like the higher plants, require air, warmth, food, and moisture for growth. Early stages of decay caused by these fungi may be accompanied by a discoloration of the wood. Paint may also become discolored where the underlying wood is rotting. Advanced decay is easily recognized because the wood has undergone definite changes in properties and appearance. In advanced stages of building decay, the affected wood generally is brown and crumbly but sometimes may be comparatively white and spongy. These changes may not be apparent on the surface, but the loss of sound wood inside is often reflected by sunken areas on the surface or by a "hollow" sound when the wood is tapped with a hammer. Where the surrounding atmosphere is very damp, the decay fungus may grow out on the surface–appearing as white or brownish growths in patches or strands or in special cases as vinelike structures.

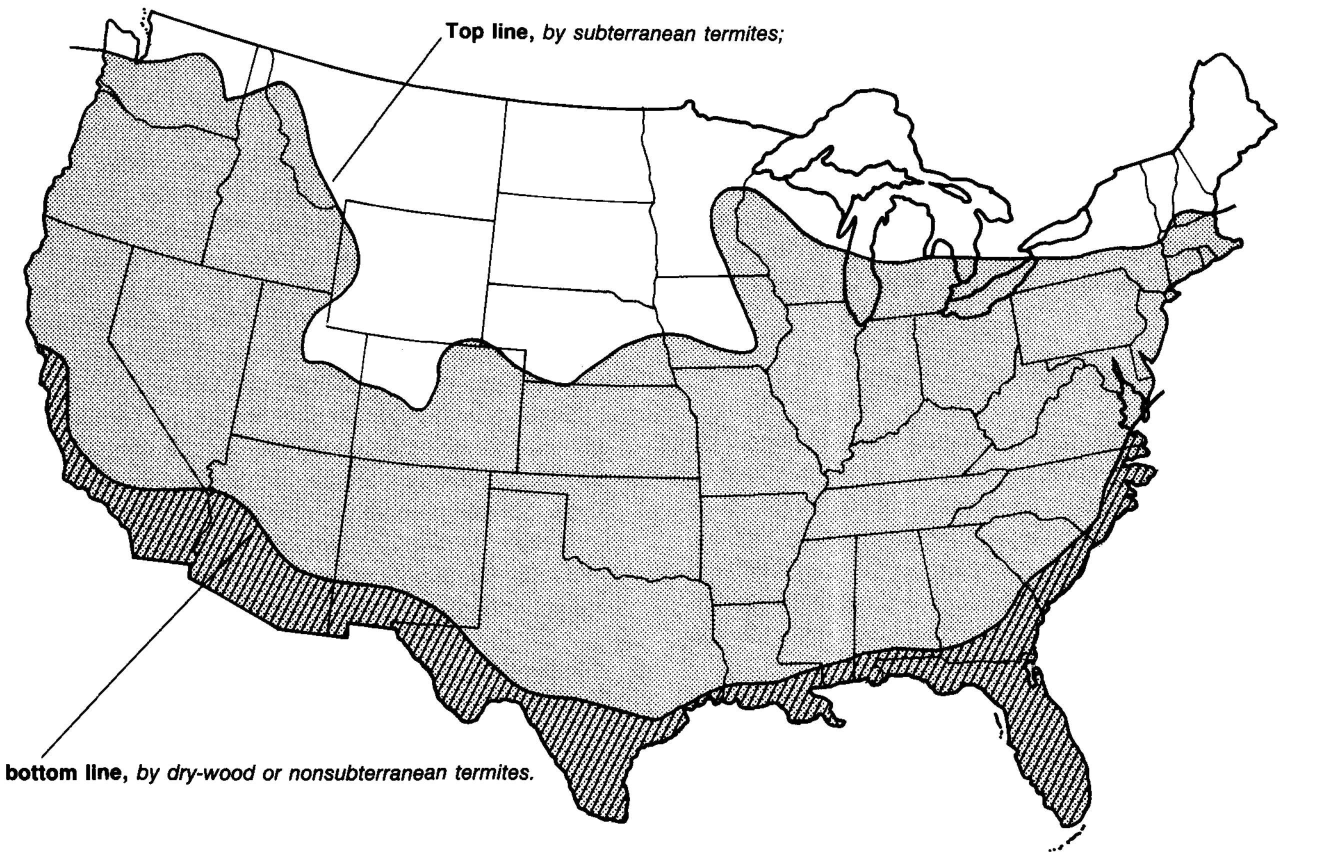
Fungi grow most rapidly at temperatures of about 70 to 85 °F. Elevated temperatures such as those used in kiln-drying of lumber kill fungi, but low temperatures, even far below zero, merely allow them to remain dormant.

Moisture requirements of fungi are within definite limitations. Wood-destroying fungi do not become established in dry wood. A moisture content of 20 percent (which can be determined with an electrical moisture meter) is safe. Moisture content greater than this is practically never reached in wood sheltered against rain and protected, if necessary, against wetting by condensation or fog. Decay can be permanently arrested simply by taking measures to dry out the infected wood and to keep it dry. Brown, crumbly decay, in the dry condition, is sometimes called "dry rot," but this is a misnomer. Such wood must necessarily have been damp when the rotting occurred.

The presence of mold or stain fungi should serve as a warning that conditions are or have been suitable for growth of decay fungi. Heavily molded or stained lumber, therefore, should be examined for evidence of decay. Furthermore, such discolored wood may not be entirely satisfactory for exterior millwork because it frequently has greater water absorptiveness than bright wood.

The natural decay resistance of all common native species of wood lies in the heartwood. When untreated, the sapwood of all species has low resistance to decay and usually has short life under decay-producing conditions. Of the species of wood commonly used in house construction, the heartwood of redwood and the cedars is classified as being highest in decay resistance. All-heartwood lumber is becoming more and more difficult to obtain, however, as increasing amounts of timber are cut from the smaller trees of second-growth stands. In general, when substantial decay resistance is needed in load-bearing members that are difficult and expensive to replace, wood appropriately treated with preservative is recommended.

Figure 182 – *Northern limits of termite damage in the United States:*



Subterranean termites

Subterranean termites are the most destructive of the insects that infect wood in houses. The chance of infestation is great enough to justify preventive measures in the design and construction of buildings in areas where termites are common.

Subterranean termites are common throughout the southern two-thirds of the United States except in mountainous and extremely dry areas.

One of the requirements for subterranean termite life is the moisture available in the soil. Termites become most numerous in moist, warm soil containing an abundant supply of food in the form of wood, scraps of lumber for example, or other cellulosic material. In their search for additional food (wood), they build earthen shelter tubes over foundation walls or in cracks in the walls, or on pipes or supports leading from the soil to the house. These tubes are from ¼ to ½ inch or more in width and flattened, and serve to protect the termites in their travels between food and shelter.

Because subterranean termites eat the interior of the wood, they may cause much damage before they are discovered. They honeycomb the wood with definite tunnels that are separated by thin layers of sound wood. Decay fungi, on the other hand, soften the wood and eventually cause it to shrink, crack, and crumble without producing anything like these continuous tunnels. When both decay fungi and subterranean termites are present in the same wood, even the layers between the termite tunnels are softened.

Dry-wood termites

In contrast to the subterranean tunnel-building termites, dry-wood termites fly directly to and bore into the wood. Dry-wood termites are common in the tropics, and damage has been recorded in the United States in a narrow strip along the Atlantic Coast from Cape Henry, VA, to the Florida Keys, and westward along the coast of the Gulf of Mexico to the Pacific Coast as far as northern California (fig. 182). Serious damage has been noted in southern California and in localities around Tampa, Miami, and Key West, FL. Infestations may be found in structural timber and other woodwork in buildings, and also in furniture, particularly where the surface is not adequately protected by paint or other finishes.

Dry-wood termites cut across the grain of the wood and excavate broad pockets, or chambers, connected by tunnels about the diameter of the termite's body. They destroy both springwood and the usually harder summerwood, whereas subterranean termites principally attack springwood. Dry-wood termites remain hidden in the wood and are seldom seen, except when they make dispersal flights.

Safeguards against decay

Except for special cases of wetting by condensation or fog, a dry piece of wood stays dry and never decays if it is placed off the ground under a tight roof with wide overhang. It is a good precaution to design and construct a house to comply with these conditions of "umbrella protection." The use of dry lumber in designs that keep the wood dry is the simplest way to avoid decay in buildings.

Most of the details regarding wood decay have been included in earlier chapters, but they are given here as a reminder of their relationship to protection from decay and termites.

Untreated wood should not come in contact with the soil. It is desirable that the foundation walls have a clearance of at least 8 inches above the exterior finish grade, and that the floor construction has a clearance 18 inches or more from the bottom of the joists to the ground in basementless spaces. The foundation should be accessible at all points for inspection. Porches that prevent access should be isolated from the soil by concrete or from the building proper by metal flashing or aprons (fig. 183).

Exterior steps and stair carriages, posts, wall plates, and sills should be isolated from the ground by concrete or masonry. Sill plates and other wood in contact with concrete near the ground should be separated from the concrete by a moistureproof membrane, such as heavy roll roofing or 6-mil polyethylene. Girder and joint openings in masonry walls should be big enough to assure an air space around the ends of these members.

Design details. Surfaces like steps, porches, door and window frames, roofs, and other projections should be sloped to promote runoff of water. Noncorroding flashing should be used around chimneys, windows, doors, or other places where water might seep in. (See section on flashing and other sheet metal in chapter 4.) Roofs with considerable overhang give added protection to the siding and other parts of the house. Gutters and downspouts should be placed and maintained to divert water away from the buildings. Porch columns and screen rails should be shimmed above the floor to allow quick drying or posts should slightly overhang raised concrete bases.

Exterior steps, rails, and porch floors exposed to rain need protection from decay, particularly in warm, damp parts of the country. Pressure treatment of the wood provides a high degree of protection against decay and termite attack. In geographic areas where the likelihood of decay is relatively small, on-the-job application of water-repellent preservative by dipping or soaking has been found to be worthwhile. The wood should be dry, cut to final dimensions, and then dipped or soaked in the preservative solution. Soaking is the best of these nonpressure methods, and the ends of the boards should be soaked for a minimum of **3** minutes. It is important to protect the end grain of wood at joints, because this area absorbs water easily and is the most common infection point. These treatments work because they provide a treated layer near the wood surface. Any saw-cut made after treatment will expose unprotected wood. Let treated wood dry for several days before painting or staining.

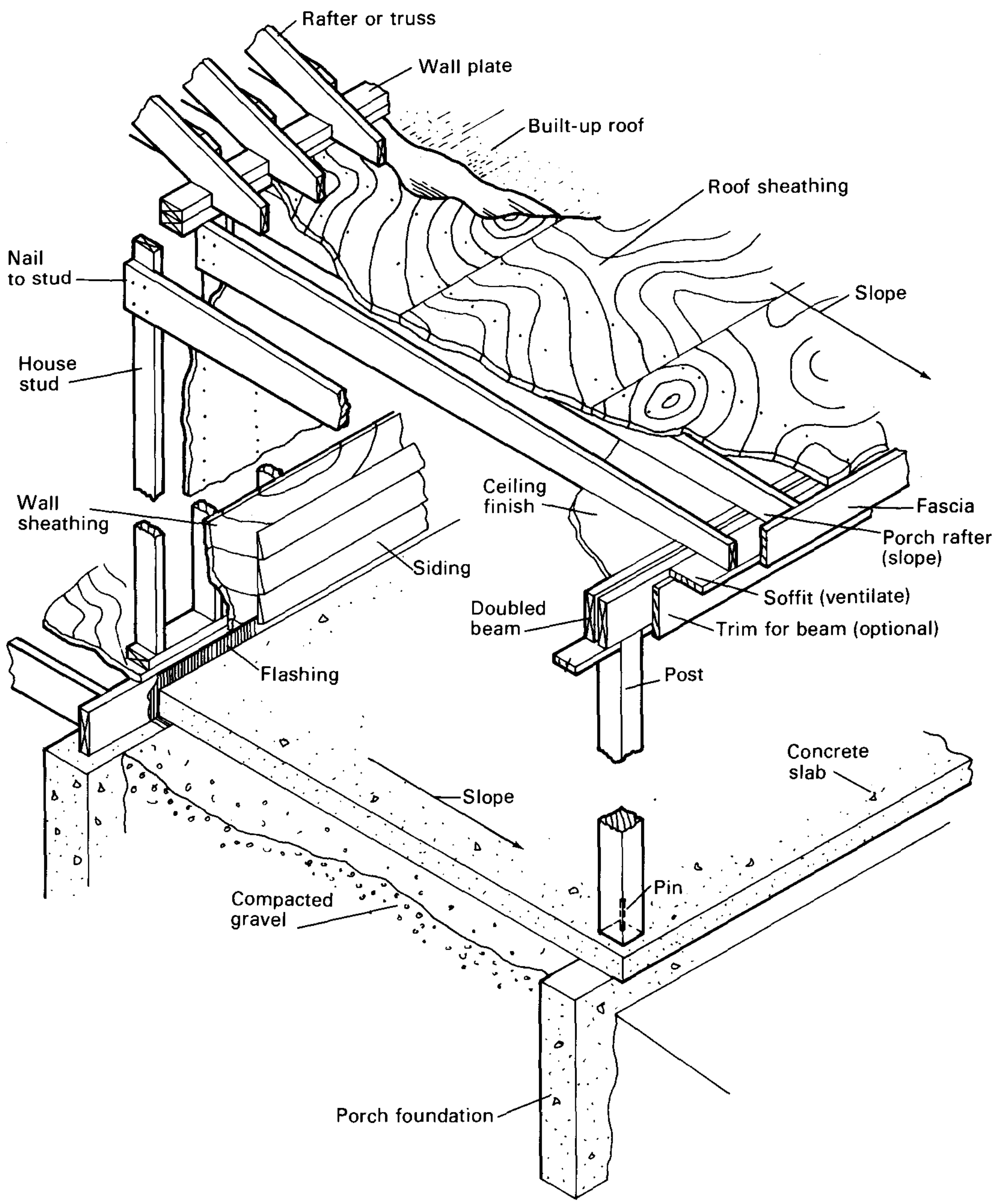
Remember, water-repellent treatments are only effective for wood used above ground.

Green or partially seasoned lumber. Construction lumber that is green or partially seasoned should be avoided; it may be infected before it comes to the job site with one or more of the staining, molding, or decay fungi. Such wood may contribute to serious decay both in the structural frame and exterior parts of buildings. If wet lumber must be used, or if wetting occurs during construction, the wood should not be fully enclosed or painted until thoroughly dried.

Water vapor from the soil. Crawl spaces of houses built on poorly drained sites may be subjected to high humidity. During the winter when the sills and outer joists are cold, moisture condenses on them and, in time, the wood absorbs so much moisture that it is susceptible to attack by fungi. Unless this moisture dries out before temperatures become favorable for fungus growth, considerable decay may result. However, the decay may progress so slowly that no weakening of the wood becomes apparent for a few years. Placing a layer of 45-pound or heavier roll roofing or a 6-mil sheet of polyethylene over the soil to keep the vapor from getting into the crawl space would prevent such decay. This precaution can be recommended for all sites where, during the cold months, the soil is wet enough to be compressed in the hand.

If the floor is uninsulated, some fuel savings can be made by closing the foundation vents during the coldest months. However, unless the crawl space is used as a heat plenum chamber, insulation is usually located between floor joists, and the vents can remain open.

Figure 183–*Metal shield used to protect wood at porch slab.*



When soil covers are used, crawl space vents can be very small, needing only 10 percent of the area required without covers. (See section on crawl space foundations in chapter 2.)

Water vapor from household activities. Water vapor is also given off during cooking, washing, and other household activities. This vapor can pass through walls and ceilings during very cold weather and condense on sheathing, studs, and rafters, causing condensation problems. A vapor retarder of an approved type is needed on the warm side of walls. (See section on vapor retarders in chapter 6.) It is also important that the attic space be well ventilated. (See section on ventilation in chapter 4.)

Water supplied by the fungus itself. Some substructure decay is caused, principally in the warmer coastal areas, by a fungus that provides its own needed moisture by conducting it through a vinelike structure from moist ground to the wood. The total damage caused by this water-conducting fungus is not large, but in individual instances it tends to be unusually severe. Preventive and remedial measures depend on getting the soil dry and avoiding bridges of untreated wood such as posts connecting the ground to sill or beams.

Safeguards against termites

The best time to provide protection against termites is during the planning and construction of the building. The first requirement is to remove all wood debris like stumps and discarded form boards from the soil at the building site before and after construction. Steps should also be taken to keep the soil under the house as dry as possible.

Next, the foundation should be made impervious to subterranean termites to prevent them from crawling up through hidden cracks to the wood in the building above. Properly reinforced concrete makes the best foundation, but unit-construction walls or piers capped with at least 4 inches of reinforced concrete are also satisfactory. No wood member of the structural part of the house should be in contact with the soil.

The best protection against subterranean termites is by treating the soil near the foundation or under an entire slab foundation with an approved termiticide. Any wood used in secondary appendages, such as wall extensions, decorative fences, and gates, should be treated under pressure with a good preservative.

In regions where dry-wood termites occur, the following measures should be taken to prevent damage:

1. All lumber, particularly secondhand material, should be carefully inspected before use, and any infected piece discarded.
2. All doors, windows (especially attic windows), and other ventilation openings should be screened with metal wire with not less than 20 meshes to the inch.
3. Preservative-treated lumber can be used to prevent attack in construction timber and lumber.
4. Several coats of house paint can provide considerable protection to exterior woodwork in building. All cracks, crevices, and joints between exterior wood members should be filled with a mastic caulking or plastic wood before painting.
5. The heartwood of foundation-grade redwood, particularly when painted, is more resistant to attack than most other native commercial species.

Pressure-treated wood

Wood treated under pressure with chemicals to resist decay and insect attack is called pressure-treated wood. This type of wood is classified as a permanent building material by such authorities as the Federal Housing Administration (FHA) and the Forest Products Laboratory. Properly treated wood members can be expected to last almost indefinitely in most applications.

Pressure-treated wood products can be cut or drilled. Because the treating chemicals may not penetrate completely through thick materials, the cut ends or holes must receive brush treatment with a suitable preservative.

Types of preservatives. There are three general classifications of pressure treatments based on the type of preservative: creosote solutions, pentachlorophenol (penta), and waterborne preservatives.

Creosote and solutions of the heavier, less volatile petroleum oils help protect wood from weathering outdoors, but they have an odor, lack cleanliness, and are not readily paintable. Volatile oils or solvents with oil-borne preservatives, if removed after treatment, leave the wood cleaner than the heavier oils do. Pentachlorophenol may be carried in any of four mixtures–with heavy oil, mineral spirits, methylene chloride, or liquefied petroleum gas. Wood treated with pentachlorophenol dissolved in methylene chloride or liquefied gas has a dry, paintable, and gluable surface.

Creosote and penta treatments are used widely in farm, ranch, and marina applications. Penta in liquid petroleum gas (LPG) or in light petroleum solvent is also used for fencing and other exterior applications.

Waterborne preservatives provide a clean and paintable wood surface, free from objectionable odor. Because water is added during treatment, the wood must be dried after treatment to the moisture content required for use. The waterborne preservatives are used widely to pressure-treat lumber and plywood for use in decks, fences, marinas, and all-weather wood foundations. The water-borne salts are more commonly used for pressure-treating materials to be used for outdoor residential purposes; they are ammoniacal copper arsenate (ACA), chromated copper arsenate (CCA), acid copper chromate (ACC), chromated zinc chloride (CZC), and fluor chrome arsenate phenol (FCAP).

Treatment codes. The color of the wood does not show the quality of treatment. Wood treated with an oil-based preservative such as pentachlorophenol is usually light-to-dark brown. Most of the waterborne-salt treatments leave a greenish color because they contain copper or chromium salts. Sometimes lumber receives a brightly colored coating that prevents fungus stain during shipment. These coatings are not pressure treatments. They are only surface treatments and give no long-term protection against decay or termites. *When buying preservative-treated wood, pay close attention to the stamps, labels, or certifications on them.*

Each piece of pressure-treated wood or plywood should bear a quality mark. Such marks indicate that the technical requirements of a treating standard have been met or exceeded. Examples of quality marks of the AWPB are shown (fig. 184). Codes designating AWPB quality standards that are commonly used in residential construction are given in table 20. The placing of these code designations in the AWPB quality marks is shown in figure 184.

Products marked for ground contact are treated to a higher degree of chemical retention than those marked for above-ground applications. In some instances, the above-ground marking may indicate the use of a preservative not permitted for ground or fresh-water contact. In all cases, materials marked for ground contact are suitable for fresh-water installation. Materials marked for ground contact may be used safely above ground. Materials marked for above-ground use should not be used for ground or water contact.

Precautions in use of pressure-treated wood

The following precautions should be taken when handling wood pressure-treated with creosote, pentachlorophenol, or preservatives that contain inorganic arsenicals, and in determining where to use and dispose of the treated wood. When buying preservative-treated lumber, ask for EPA-approved consumer information sheets.

On site. Wood pressure-treated with waterborne arsenical preservative may be used inside residences as long as all sawdust and construction debris are cleaned up and disposed of after construction.

Logs treated with pentachlorophenol should not be used for log homes.

Wood treated with creosote or pentachlorophenol should not be used where it will be in frequent or prolonged contact with bare skin (for example, chairs and other outdoor furniture and decks), unless effective sealer has been applied.

Creosote-treated wood should not be used in residential interiors.

Pentachlorophenol-treated wood should not be used in residential, industrial, or commercial interiors except for laminated beams or other building components that have two coats of an appropriate sealer applied. Sealers may be applied at the installation site. Urethane, shellac, latex epoxy enamel, and varnish are acceptable sealers for pentachlorophenol-treated wood.

Do not use treated wood under circumstances where the preservative may become a component of food. Do not use treated wood for cutting boards or countertops.

Only treated wood that is visibly clean and free of surface residues should be used for patios, decks, and walkways.

Handling. Dispose of treated wood by ordinary trash collection or burial at a suitable waste disposal facility. Burial at a house construction site encourages termites. Treated wood should not be burned in open fires or in stoves, fireplaces, or residential boilers because toxic chemicals may be produced as part of the smoke and ashes. Treated wood from commercial or industrial use (e.g., construction sites) may be burned only in commercial or industrial incinerators or boilers in accordance with State and Federal regulations.

Avoid frequent or prolonged inhalations of sawdust from treated wood. When sawing and machining treated wood, wear a dust mask. Whenever possible these operations should be performed outdoors to avoid indoor accumulations of airborne sawdust from treated wood. When power-sawing and machining, wear goggles to protect eyes from flying particles.

Avoid frequent or prolonged skin contact with creosote-treated wood and with pentachlorophenol-treated wood; when handling the treated wood, wear long-sleeved shirts and long pants and use gloves impervious to the chemicals (for example, vinyl-coated gloves).

Wash exposed areas thoroughly after working with the wood, before eating, drinking, or use of tobacco products.

If oily preservatives or sawdust accumulate on clothes, launder before reuse. Wash work clothes separately from other household clothing.

Energy Conservation

Energy can be saved by reductions in heat gain or loss as well as through the use of efficient appliances and lighting. Reduction of heat transfer rate is accomplished by reducing conduction through the house shell, convection or air infiltration through cracks in the shell, and radiation of heat directly to or from the house. The installation of an efficient heating, ventilating, and air-conditioning (HVAC) system plays a major role in energy conservation. The type of lighting fixture used also has a major impact on energy conservation. Principles of passive solar energy can be applied in the design either to supplement heat or provide cooling, depending on the climate.

Reducing conduction

Conduction is the movement of heat directly through materials. Every material has a resistance to heat flow, referred to as its R-value. A vacuum stops conduction entirely; materials containing air layers, pockets, or bub-

Table 20–*AWPB quality standards codes*

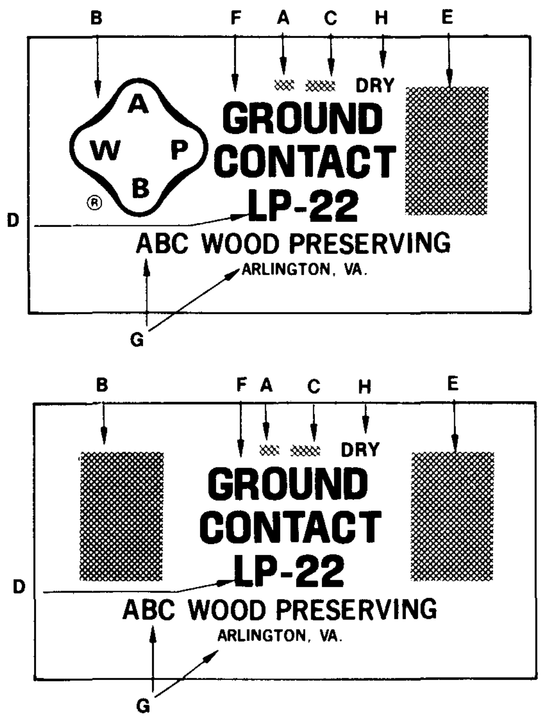
Preservative	Above-ground standard	Ground contact standard
General-purpose applications		
Waterborne preservatives	LP-2	LP-22
Light-hydrocarbon solvent/penta	LP-3	LP-33
Volatile-hydrocarbon-solvent (LPG)/penta	LP-4	LP-44
Creosote or creosote/coal-tar solutions	LP-5	LP-55
Heavy-hydrocarbon-solvent/penta	LP-7	LP-77
Special-purpose applications		
Waterborne preservatives for use in residential and light commercial foundations	—	FDN
Nonstructural landscape timbers from peeled cores	—	LST
All preservatives for use in marine (saltwater) exposure	—	MLP

bles have substantial resistance. Dense materials such as metal, glass, and concrete have little resistance and are poor insulators.

- Insulation in walls makes a large reduction in heat loss. Installing R-11 insulation, rather than none, in the wall cavities of a typical 1,600-ft^2, one-story, single-family, detached house in an area where the indoor–outdoor temperature difference is 70 °F, reduces total heat loss and gain by nearly 20 percent.
- Installing R-13 rather than R-11 insulation in the wall cavities of this house results in an extra 2-percent savings.
- An additional 5-percent savings is possible by installing 1-inch-thick polystyrene rigid foam sheathing instead of the usual ½-inch insulating board sheathing.
- If the walls of the house are constructed with 2- by 6-inch studs placed 24 inches on center, there is space in the wall cavity for R-19 insulation. Installation of R-19 instead of R-11 insulation increases the savings by another 6 percent.
- If the roof of the house is constructed with engineered roof trusses spaced 24 inches on center, installing R-19 instead of R-11 ceiling insulation reduces the heat loss through the ceiling by an additional 8 percent, and using R-30 rather than R-19 ceiling insulation saves an additional 4 percent.
- Good insulation installation practice reduces heat loss and heat gain. To do so, cover all insulated areas completely; extend ceiling insulation over the top of the top plate; insulate behind the band joist; insulate soffits of cantilevered floor construction; cut insulation batts to fit narrow stud spaces and leave enough surplus to staple the flanges; butt the ends of insulation batts tightly against one another; shove batts tightly against the top and bottom plates in the wall cavities; put insulation behind pipes, wires, and electrical outlet boxes in exterior walls; and stuff insulation into all cracks around door and window frames and into all other areas with odd shapes, and staple polyethylene over these areas to form a vapor retarder.
- Reducing the ratio of exterior wall area to floor area reduces energy demand. Theoretically, a two-story square house (approximately a cube) has the least heat loss. However, when R-11 and R-19 insulation is used in walls and ceilings, a one-story house relatively deep front to back has essentially the same heat loss as a two-story house, all other factors being equal.
- Assuming R-11 wall insulation, a one-story house, 32 feet deep by 50 feet long, would have 2 percent less heat loss than one 24 feet deep by 66½ feet long. The two houses have the same area. The difference in their heat loss is caused by the difference in the ratios of their exterior wall area to floor area.
- Avoiding L-, T-, and H-shaped floor plans conserves energy. A 24- by 50-foot house with a 20- by 20-foot "L" has the same area as a 32- by 50-foot rectangular house, but may have about 3 percent more heat loss.
- In the 1,600-ft^2 one-story house described above, reducing the wall height from 8 feet to 7 feet 6 inches could save another 1 percent of the total energy consumption, even with insulation filling the full thickness of the wall.
- Glass is a poor insulator. Reducing window area can substantially reduce conduction and related heating and cooling costs. The window area of the typical dwelling is probably equal to about 15 percent of the wall area. Under most codes this can be reduced to 10 percent. In the 1,600-ft^2 house, the reduction of glass could mean a reduction of between 9 and 18 percent in energy consumption if double glazing is used, or between 5 and 10 percent with triple glazing (or double glazing in either window or storm sashes). But this

Figure 184–*Examples of quality marks of the American Wood Preservers Bureau (AWPB).*

THE AWPB QUALITY MARKS



A Year of treatment
B American Wood Preservers Bureau trademark or trademark of the AWPB certified agency
C The preservative used for treatment
D The applicable American Wood Perservers Bureau quality standard
E Trademark of the AWPB certified agency
F Proper exposure conditions
G Treating company and plant location
H Dry or KDAT if applicable

strategy must be tempered depending on window orientation, shading, and climate.

- When reducing window area, it is preferable to raise the sill height rather than lower the top of the window opening. This has two advantages. First, it retains the height of the upper portion of the window, which provides better natural illumination. Second, it helps to reduce heat gain in the summer because the upper portion of the window is more easily shaded by the roof overhang.
- In a house with 200 ft^2 of window area equally distributed on all four sides of the dwelling, heat gain is 2,000 British thermal units per hour (Btu/h) less with double glazing or storm windows than with single glazing.
- Assuming that the 1,600-ft^2 house has two standard-size exterior doors, the addition of two wood storm doors may save 2 percent of the heating energy in winter, and two metal storm doors may save 1 percent.
- The use of 24-inch on-center wall framing and the adoption of the wall framing techniques set forth in *Manual of Lumber and Plywood Saving Techniques for Residential Light-Frame Construction* (NAHB Research Foundation 1971) allows about 2 percent less heat loss

than traditional framing techniques. This is because more heat is lost through the wood section than through the fully insulated cavity. This calculation assumes that ½-inch insulating board is used for sheathing and that the siding is 5/8-inch wood or plywood.

- Assuming that a 1,600-ft^2 house has a full basement and that the average basement wall exposure above grade is 2 feet, the heat loss through the typical 8-inch block wall and basement floor may be more than 20 percent of the total for the building. Adding furring strips and R-3 or masonry wall insulation covered with either gypsum board or 3/8-inch plywood reduces heat loss by about 10 percent. If 2- by 3-inch boards, 24 inches on center, are placed 1 inch inside the wall and R-11 insulation is used with 3/8-inch gypsum board or ¼-inch plywood, about another 6 percent can be saved.
- For a slab-on-grade house with 1-inch by 12-inch-wide R-4 slab edge insulation, the heating load is 14 percent less than with no edge insulation. The use of 2-inch by 24-inch-wide R-8 slab edge insulation can save an additional 8 percent.
- Grading so that the ground surface around the house slopes away from the house allows surface water to drain away from the dwelling. This helps to keep the earth next to the foundation wall drier (and thus warmer), which reduces heat loss through that wall.
- If the house is built on an unheated crawl space, vents that can be closed in winter and a vapor-retarding ground cover will reduce heat loss even when the floors are insulated.
- A heated crawl space plenum is a more economic design and preferable to the unheated crawl space. Use a vapor retarder on the ground and insulation on the perimeter walls rather than in the floor.

Although earth is a poor insulator, in great enough thicknesses it can save energy. Earth-bermed or "basement" houses with subgrade living space are inexpensive to heat and cool.

Reducing convection (air infiltration)

Convection is the movement of warm air. In a house, pressure differentials force warm air out from cracks in the ceiling and on one side of the house while drawing cold drafts into the house through cracks on the other side. In an old house the air can be completely replaced in half an hour, 48 times a day. In a reasonably tight new house, the air may change once every 2 hours. Convection heat losses and summer heat gains can be reduced by installing caulking, weatherstripping, and other physical barriers to seal up the cracks.

- Use sill sealer between the top of the foundation wall and the band joist or sill plate in frame construction, to reduce air infiltration. Use sill sealer or flexible caulking between the bottom exterior wall plate and the floor sheathing in western or platform framing.
- Use a 1- by 4-inch board for the bottom wall plate (rather than a 2 by 4), because a 1 by 4 is flexible enough in most cases to conform to irregularities in the floor surface. This reduces air infiltration and also cuts heat loss through the framing material.
- Caulk outside cracks at doors, windows, around other openings or penetrations of the wall, and at comers.
- Pay special attention to avoiding, eliminating, or sealing cracks that can allow air to enter the house or structure including cracks around pipe or wire penetrations of the exterior walls.
- Nail sheathing tightly to the framing to minimize air infiltration into the stud space. Even if the stud space is filled with insulation, air leakage increases losses by convection and conduction that reduce the thermal efficiency of the wall.
- For the same reasons, replace wall sheathing damaged during construction.
- The quality of windows greatly influences the amount of air infiltration. A window fitting poorly without weatherstripping allows about 5½ times more air infiltration than an average window with weatherstripping.
- Storm windows not only reduce heat loss, they also reduce air infiltration. For best results, they need to be tightly fitted.
- Exterior doors are a major source of air infiltration. Even when fitted well, a door allows as much air infiltration as a double-hung window that is poorly fitted. This estimate should be doubled for wood doors because they tend to warp. Storm doors reduce this air infiltration by half.
- Weatherstrip attic access doors and apply one or more pieces of rigid insulation, cut to size, to the attic side of the door. This insulation can improve the thermal characteristics of panel or hollowcore doors.
- Weatherstrip the attic access hole and insulate the back of the scuttle closure panel.
- Stuff mineral wool insulation around pipes, flues, or chimneys penetrating into the attic space, especially in cold climates.
- Even if the ceiling insulation has a vapor retarder, good practice calls for 1 ft^2 of attic ventilation area for each 300 ft^2 of ceiling area. Increased ventilation of the attic space can reduce air temperatures during the

summer and thereby decrease air-conditioning loads. Insufficient data are available to pinpoint the effect of ventilation on the heating load. Further, the actual reduction is affected to a great extent by the amount of attic insulation used. At the R-19 level of insulation use, the reduction of attic temperature resulting from increased ventilation reduces heat gain only to a minor extent. Climate also is an important determination of heat gain. Except in the hottest climates, mechanical attic ventilation (fans) may well use more energy than it saves. This occurs because of the flow of conditioned air from the house into the attic space, which is induced by the slightly lower air pressure in the attic when the exhaust fan is running.

- If a range hood is installed, use the recirculating type in cold climates and the exhaust-to-outside-air type in warm climates where the air-conditioning load is more important than the heating load. To use the recirculating type of hood, local regulations may require a window in the kitchen.
- In cold climates, minimize the use of exhaust fans. Research has shown that fans can be the source of very large amounts of infiltrating air. When they are necessary, a model with a positive damper closure is recommended.
- If a fireplace is installed, it should be equipped with a damper to cut heat loss when the fireplace is not in use. A removable sheet metal closure or glass doors for the opening will cut heat loss even more when the fireplace is not in use.
- Garages and carports can help reduce the heating load. In cold climates, attached garages or carports should be placed on the north, northeast, or northwest sides of the house to block the wind and to permit full access to the low winter sun.

Reducing radiation

Radiation is the movement of heat through space and air. It can be stopped by reflectance or by shading with solid objects. Short-wavelength ultraviolet light rays from the sun, which can penetrate glass, change to long-wavelength infrared heat waves when they strike a dark color. The infrared rays are trapped inside the structure because they do not readily pass through glass. In passive solar heating, ultraviolet rays from the sun pass through windows, are absorbed by dark surfaces, and are reemitted as infrared heat rays which are trapped inside the house. This is the “greenhouse effect.”

- Shading glass having southern exposure with a roof overhang reduces heat gain in the summer without impairing heat gain in the winter. At the 35° latitude (North Carolina, Oklahoma, Las Vegas), a 28-inch overhang provides complete shading in the summer for floor to ceiling glass having a southern exposure. This shading reduces summer heat gain through the glass by 50 percent.
- The area, location, and shading of windows and the use of double glazing or storm sash have important effects in reducing cooling loads for air-conditioning.
- Occasionally, it is possible to locate the dwelling or windows to take advantage of the shadow cast by existing trees to reduce solar heat gain in the summer. During landscaping appropriate trees can be selected and planted to shade the house during summer.
- In hot climates, garages or carports attached to the east side or west side of the dwelling shade glazing on east or west walls, thereby reducing solar heat gain.
- Even with a well-insulated ceiling, the color of the roof makes a difference in heat gain. A light-colored roof surface lowers the design load requirement for cooling.

EFficiency of HVAC and appliances

Use of efficient heating, ventilating, and air-conditioning (HVAC) equipment, and appliances, as well as efficient installation techniques, can save energy.

- Avoid oversized heating and cooling equipment. One of the most important energy conservation measures is to determine carefully the heat loss and heat gain requirements of the dwelling and to install equipment no larger than is required. Oversized equipment results in short periods of operation, higher first cost, higher operating costs, poor comfort conditions, and lower seasonal efficiency. Specify air conditioners having high Seasonal Energy Efficiency Ratios (SEER). In areas of high humidity consider SEERs ranging from 8.0 to 10.0.
- If electricity is to be the source of energy for heating and the dwelling is to be air-conditioned, consider using a heat pump. Heat pumps use about one-third to one-half the energy of electric resistance heating. In extreme climates, hot or cold, check with the local power supplier for applicability of heat pumps.
- Heat pumps should be sized by a professional engineer, based on analysis of both the heating load and the cooling load. Somewhat more weight should be given to the dominant load, but with careful attention to the heating load output of the heat pump at average outdoor temperatures for the local climate.
- The HVAC subcontractor should install warm-air furnaces with filters that can be changed easily by the homeowner. Clogged filters reduce fuel efficiency both for heating and cooling.

- Consider installing a clock thermostat so that the thermostat can be set back at night and the furnace started automatically in the morning. Reducing the temperature by 5° for 8 hours at night in Chicago saves 7 percent of the annual heating bill; setting the thermostat back 7½ ° saves 9 percent; and setting it back 10° saves 11 percent. In warm climates like that of Los Angeles, the percentage savings are more (12, 14 and 16 percent, respectively) but the total dollar savings are less than in colder climates. These figures may not be applicable when heat pumps are used.
- Where possible, avoid putting heating and cooling ducts in nonconditioned space such as attics; otherwise, insulate the ducts. Wrap metal duct joints in nonconditioned spaces with duct tape to minimize heat leakage, even when they are to be wrapped with insulation. Heat loss through poorly fit unwrapped duct joints located in nonconditioned spaces can be as high as 25 percent of the total demand.
- Locating air-conditioning condensers where they receive afternoon shade from the house, trees, garage, or carport increases condenser efficiency and slightly reduces energy.
- Locate the water heater as close as possible to the area of greatest demand for hot water. This is usually the kitchen and laundry area. Avoid placing hot water pipes in unheated areas such as attics or crawl spaces if possible; otherwise, use pipe insulation.
- Set the water heater temperature to 120 or 125 °F. If the temperature settings are not marked on the thermostat, 120 °F may be estimated by assuming the middle setting is equal to a temperature of about 140 to 150 °F. For bathing, washing, clothes washing, and dishwashing 120 °F is hot enough. (The 150 °F setting is not high enough to sanitize dishes or clothes; to sanitize, 180 °F is required for at least 2 min.) A setting of 120 °F instead of 150 °F can save as much as half the energy required for water heating—a very important saving because heating water frequently uses more energy than anything in the house except heating (or cooling) air.
- Install a shower head with low water consumption. Studies show that bathing accounts for about 40 percent of the hot water used in the typical household.
- Some appliances and mechanical electrical equipment are more energy efficient than others. Consider comparative energy usage when selecting these items.
- A side-by-side refrigerator-freezer may use up to 45 percent more energy than the over-under refrigerator-freezer.
- Some frostless refrigerators use up to 50 percent more energy than the regular defrost type. This means an average use of perhaps 350 Btu more energy every hour all year long.
- Microwave ovens use less energy than conventional gas or electric ovens. Self-cleaning ovens reportedly require less energy for cooking but have a high energy consumption for cleaning.

Reducing lighting

- In the typical dwelling, lighting is the fourth largest energy user, requiring about 3.4 percent of the total energy bill. During the winter, heat loss from lighting is gained by the structure, so it is not lost. In summer, however, it is estimated that lighting adds about 600 to 700 Btu/h to the average cooling requirement in a dwelling of medium size. Not much can be done about this in terms of installed capacity, but the total energy use for lighting can be cut back somewhat by using less general purpose lighting and more task lighting.
- Use fluorescent lights when possible because they produce nearly four times more light per watt than the typical incandescent light bulbs.
- Fixtures that use one large bulb are substantially more efficient than those that use several smaller bulbs.
- Pale finishes for walls, ceilings, and floor enhance the level of natural light. Paints that have a high light-reflectance value are available, even in colors.
- Do not use recessed or "bullet" lamps that penetrate into nonconditioned space such as an attic. All heat from such lamps is lost. Also, the fixture can be a major channel for air and acoustical infiltration for outdoors.

Passive solar energy

In addition to the energy-efficient features already discussed, the use of passive solar heating and natural cooling can reduce energy costs. In a completely passive solar home that is carefully designed and thermally protected, heating costs may be one-half to two-thirds less than those for a house without solar heating, depending on the climate, location, and other factors. Such saving is accomplished by proper design and appropriate use of south glazing and of heat storage materials.

Passive solar heating of houses requires careful attention to design. One important design factor is the orientation of the house. If there is a choice, solar gain can be maximized by aligning the ridge of the house on an approximately east-west axis. Perpendiculars to the house ridge may have an azimuth angle 25° east or 25° west of south without greatly reducing the potential solar gain.

Another factor is the amount and location of glass. It is easy to provide an excessive amount of glass with improper orientation, which may result in wintertime overheating and increased Summertime air-conditioning loads. Likewise, improper designs can add to cost without yielding appropriate benefits. It is recommended that professional assistance be obtained when considering passive solar designs. The three most common passive solar systems are called direct gain, sunspace, and Trombe wall.

There are two kinds of direct gain systems, one sometimes called sun tempering and the other called direct gain. In sun tempering, additional south-facing glazing is added along with a proper overhang or shading system to prevent excessive heat gain in the summertime. In this system, the amount of additional south-facing glazing is limited to the amount that will not cause overheating without the addition of concrete, brick, block, slate tile or other heat-absorbent or heat-storage material. In the direct gain system, south-facing glazing, properly shaded against heat gain in the summer, is added along with additional thermal storage, mass, water, or phase-change materials to store the extra heat and slowly release it when the sun is not shining.

In the sunspace or sunroom design, substantial amounts of glazing and heat-storage material are provided along with a system for transferring excessive heat from the sunroom to the adjacent room or rooms. In most instances, it has been found that overhead glazing or sloped glazing admits too much unwanted heat.

The Trombe wall system typically consists of a masonry wall inside the dwelling, sometimes vented and sometimes not, close to a large span of exterior glazing. The wall, warmed by the sun in the daytime, gradually loses the excess heat to the dwelling during the night. Shading is essential to prevent heat from being absorbed by the wall and then diffused into the house during the summer.

All these systems have advantages and disadvantages, but the sun tempering, direct gain, and sunroom designs are more popular than the Trombe wall.

Natural cooling is another method using architectural and mechanical techniques to conserve energy in the summertime. Summer energy consumption is reduced by use of shading, dehumidification, natural and mechanical ventilation, and increased air motion (i.e., with overhead fans).

Noise Control

Little attention has been given to noise control in most single-family houses, but increasing noise pollution indicates a need for considering some control measures. Control measures may include planning to keep out outdoor noise, planning interior separation of noisy from quiet areas, placing sound absorbers in living spaces, and construction that reduces sound transmission. Many of the construction features that enhance energy conservation are also beneficial for noise control.

Exterior planning

Noise absorption is affected by the shape and orientation of a house. If the narrow dimension faces the exterior noise source, there is much less sound transmission to the inside than if the long dimension faces the source. Courtyards facing the noise source not only provide more area for sound transmission, but also provide surfaces for sound to be reflected and amplified. Landscaping can be used effectively to deflect and absorb sound, but requires more than a hedge or scattered shrubs and trees. A dense forest at least 25 to 50 feet deep or a solid fence can noticeably reduce noise. A more extreme measure, but quite effective, is a berm between the noise source and the house. Special attention should be given to providing tightly sealed doors and windows on the side facing the noise source. Double walls, triple glazing, and good weatherstripping are all effective in reducing sound transmission.

Interior planning

Interior noise control basically involves separating quiet spaces from those containing noisy equipment. Spaces with mechanical equipment are best located on an outside wall. Kitchens, bathrooms, and utility rooms can be located on the noisy side of the house or near mechanical equipment. Closets can be effectively used as buffers between bedrooms and noise-producing areas. They can also be used between two bedrooms to provide sound insulation. Back-to-back closets are even better. Doors must be kept closed for closets to be effective. A bookcase or storage wall also helps isolate two adjoining rooms. Doors opening to hallways should be staggered rather than located opposite each other. Special attention should be given to vertical separation. Do not locate mechanical equipment in the basement directly under bedrooms.

Sound absorbers

Some materials absorb sound and change it to heat rather than reflect it. Sound absorption is often desirable except in the case of music, which often needs reflection to avoid the feeling of a “dead” space. Common absorptive materials in residential spaces are carpet, furniture, drapes, and acoustical ceiling tile. Kitchens, whose hard surfaces result in a lot of sound reflection, cannot be as conducive to quiet conversation as living rooms that have many sound absorbers. Surface-mounted acoustical panels on the walls and ceiling can reduce some of the noise in such areas as kitchens. Absorptive material placed in the heating ducts can reduce sound transmission between connected spaces or the transmission of noises from the heating system.

Construction to reduce sound transmission

The effectiveness of various wall, floor, and ceiling construction in reducing sound transmission is rated by Sound Transmission Class (STC). The lower the STC, the less effective the construction is in stopping sound transmission to neighboring rooms. The approximate effectiveness of walls with varying STC numbers is shown in the following tabulation:

STC number	Effectiveness
25	Normal speech can be understood quite easily
35	Loud speech audible but not intelligible
45	Must strain to hear loud speech
48	Some loud speech barely audible
50	Loud speech not audible

Some alternatives in construction that improve STC include the use of resilient channels, staggered studs, and combinations of sound-deadening board. The addition of insulation to wall cavities may also add to their resistance to sound transmission. Some examples of wall constructions and their range of STC ratings are shown in figures 185 through 188. Floor-to-ceiling constructions that provide sound insulation are shown in figures 189 and 190.

Even though the constructions shown resist sound transmission, sound may take a route around these barriers. Sound can travel through cracks at the top or bottom of a wall. It may also travel through electrical outlets or

Figure 185–*A plain stud wall with gypsum board on both sides has an STC rating of 32 to 36. Adding a second layer of gypsum board to each side increases the STC rating of 38 to 41.*

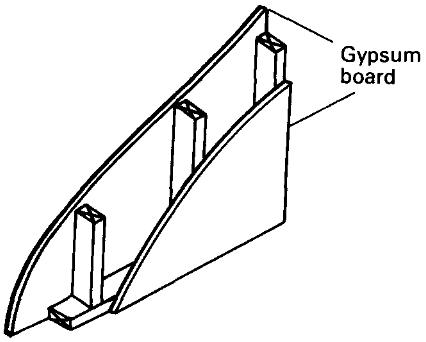


Figure 186—*A single-stud wall with gypsum board on both sides has an STC rating of 32 to 36. Adding a second layer of gypsum board to each side increases STC rating of 44 to 47.*

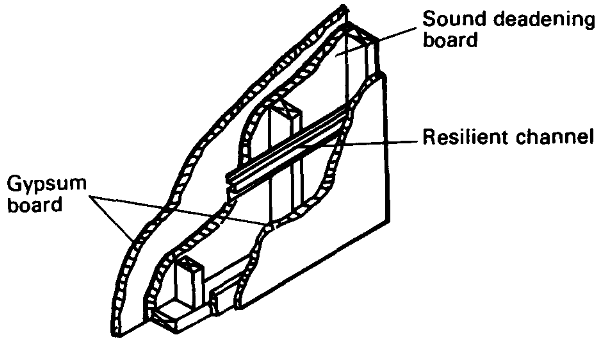
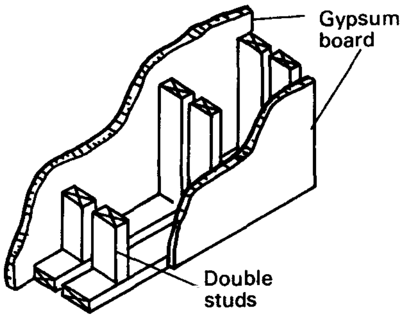


Figure 187–*A double-stud wall on separate plates has an STC rating of 42 to 44. If insulation is added to the stud cavities on one side, the STC rating is increased to 50 to 53.*



recessed cabinets in opposite faces of the wall placed in the same stud space. Sound may travel around a wall by passing through a floor into a basement or crawl space and back through the floor into an adjoining room. Doors, even tightly sealed, provide a better path for sound than the wall systems designed for sound isolation, and a very small crack under or around a door increases the sound transmission significantly.

Heating and cooling equipment can be a major noise source. If the furnace is located in a closet in the living area, the walls should be masonry, or gypsum drywall should be mounted on resilient channels over wood studs. A solid-core wood or insulated metal door should be used, and it should be tightly weatherstripped. Combustion air should be taken from the attic or crawl space, not through wall or door louvers from-the living area. The return air duct and plenum should be lined with acoustic material to absorb the fan noise. Duct openings to different rooms should not be directly opposite each other. Ducts should be sized to avoid air velocities of more than 1,000 feet per minute, which create noise in the ducts and at the outlet grilles.

Figure 188–*A staggered-stud wall on a single plate with sound-deadening board under gypsum board on one side has an STC rating of 44 to 46. Adding insulation to the stud cavities increases the STC rating to 46 to 50.*

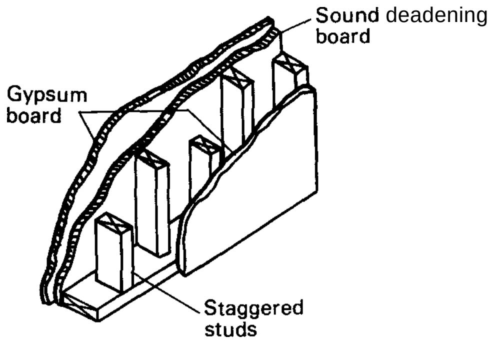


Figure 189–*A floor-ceiling structure having carpet, pad, plywood subfloor, and ceiling gypsum board supported on resilient channels has an STC rating of 46 to 48.*

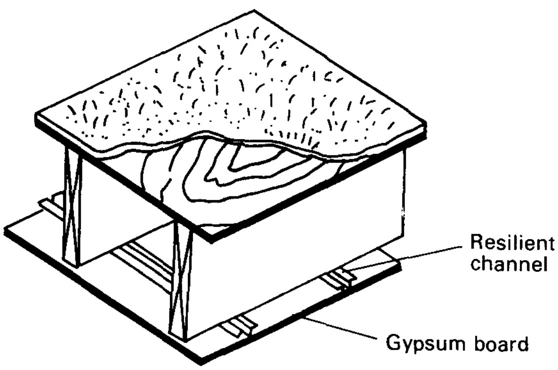
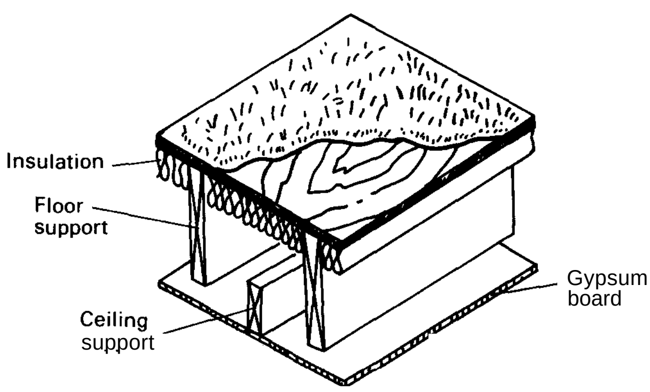


Figure 190–*A floor-ceiling structure having carpet, pad, plywood subfloor, and ceiling gypsum board supported on separate ceiling joists has an STC rating of 51 when 2 to 3 inches of insulation are installed beneath the plywood subfloor.*



Piping for hydronic-heating systems should be wrapped with insulating material to reduce vibration. Pipes should be sized to limit the speed of flow, and provision must be made for venting any air that gets into the system.

Wind, Snow, and Seismic Loads

Some geographic locations have loading requirements beyond those expected in the usual conventional construction. These loads are considered in the local building codes and appropriate structural design is required. Wind loads are critical in coastal areas of the Southeast because of the frequent hurricanes. Some areas of the country have heavy snow loads. This is particularly true in high mountain areas. Seismic loads are critical on the West Coast, where earthquakes are a constant threat. This section is not intended to provide engineering design for these extreme loads, but presents some general considerations for good performance.

Wood construction generally performs well when subjected to natural disasters. Two reasons for good performance are that wood members can resist short-term loads considerably above working stresses and that the large number of mechanically fastened joints make the structure ductile.

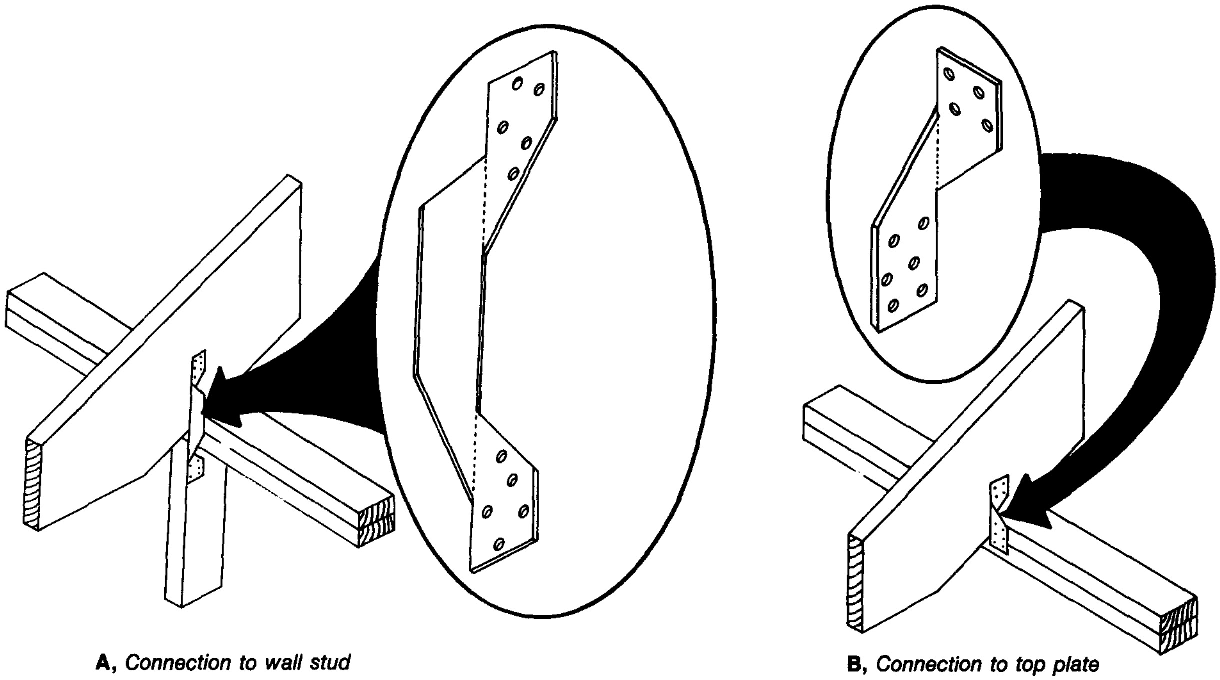
Wind load

The primary consideration for good performance under extreme wind load is that all members of the structure be tied together. The roof is most vulnerable and should be well secured to the walls. The walls must also be secured to the floor and foundation system. A good connection to the foundation is necessary; do not depend on the weight of the house to hold it in place. Wide roof overhangs, carports, and porches need to be well anchored because of the large area for uplift. Connectors should load nails laterally rather than in withdrawal. In order to accomplish this, sheet metal connectors or straps are often required.

Instead of depending on toenailing to the top plate, use commercially available connectors for connecting roof trusses or rafters to the wall (fig. 191). Where a rafter and joist system is used, collar beams or gussets are important to hold the roof together at the ridge (fig. 192). Metal straps or plates can be used to tie the wall to the floor and sill plate (fig. 193). This tie can also be accomplished with structural wall sheathing that extends down over the floor framing and is well nailed (fig. 194). Finally the sill plate has to be anchored to the foundation (fig. 195). These connections are further discussed in chapter 3.

The principle of tying all components of the structure together is often best accomplished with engineered components such as roof trusses. Connectors are specifically

Figure 191–*Connectors used to attach trusses or rafters to the wall:*



engineered to hold all the parts together. The truss concept is carried a step further in a structure called the truss-frame. It combines roof truss, floor truss, and studs into a unified structural component. The studs extend into both the roof and floor trusses resulting in rigid joints completely tied together with metal plate connectors (fig. 196). The truss-frame is designed as an engineered component and fabricated in a truss plant. If the frame is tied to the foundation, it will have great resistance to wind loads. Rigidity perpendicular to the frames is provided by the diaphragm action of roof and wall sheathing and the subfloor. The truss-frames are hauled to the building site and placed by a crane in the same manner as roof trusses. The building can be very quickly enclosed using this system because, once the frames are set, enclosure with sheathing is all that is required. The truss-frame has been accepted by major model building codes and has been successfully used in all parts of the country.

Observation of wind damage has shown that building shape has some influence on overall damage. Hip roofs sustain less shingle damage than gable roofs because turbulence around the gable end starts the removal of shingles at the edge.

Snow load

The major preparation for snow load is simply the use of larger structural members. The size of structural members is usually specified by the local building code. Rafters and beams in particular are designed for maximal snow load conditions. Observations have shown little evidence of failures in light-frame houses. Failures reported are generally in commercial buildings with long spans over large open spaces.

Figure 192–*Collar beam or gusset required at ridge in a rafter framed roof system.*

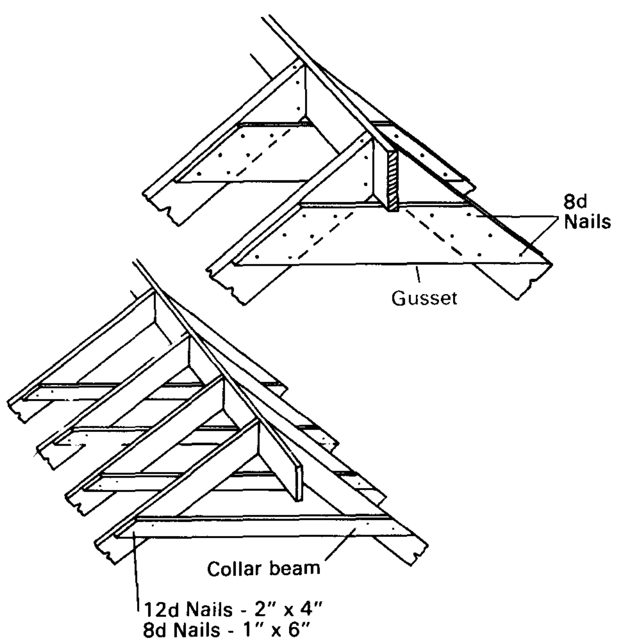


Figure 193–*Steel strap for connecting the wall to the sill plate.*

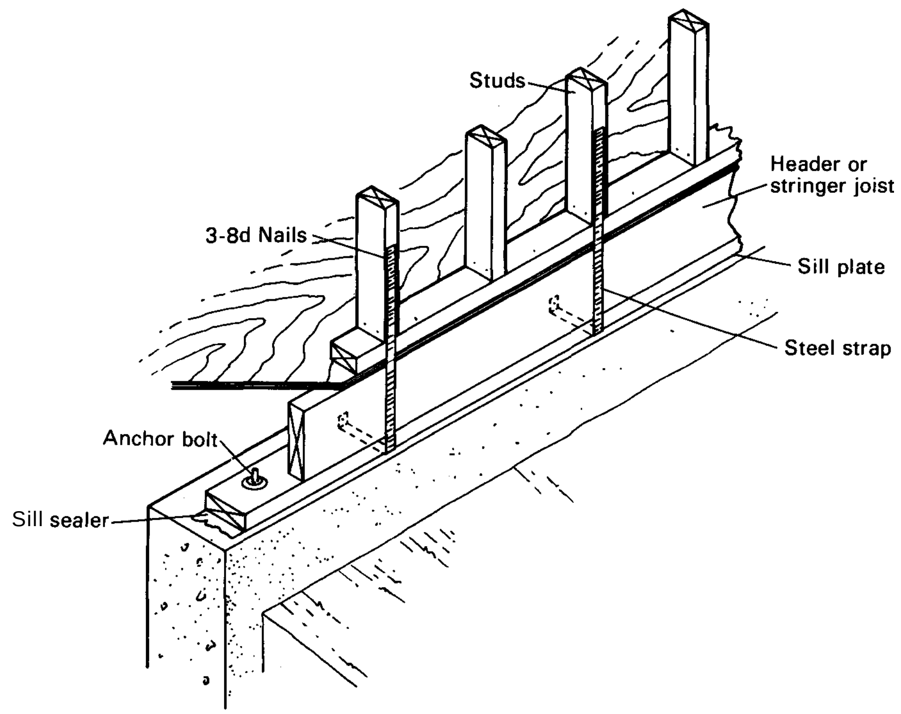
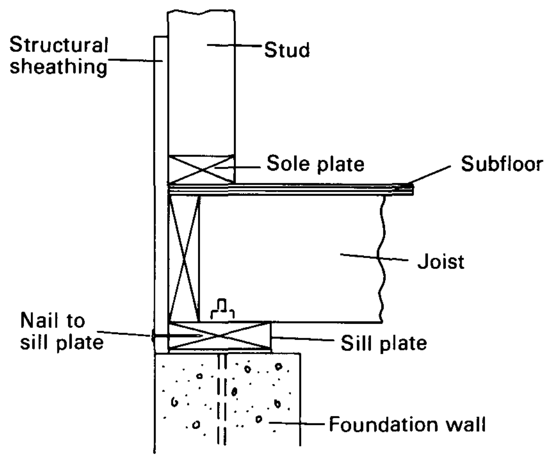


Figure 194–*Structural sheathing nailed to sill plate for tying the wall to the foundation wall.*



There are some general considerations of shape that may influence snow load. Snow usually slides off steep sloping roofs. It often blows from flat roofs where the roof is all at one elevation. The problem of snow buildup develops on sloped roofs when the wind is perpendicular to the ridge. Turbulence at the ridge causes drifting on the downwind side, resulting in an unbalanced loading on the roof structure. Another drift problem develops where two building sections of different heights join. Snow blows off the higher section onto the lower section, resulting in a deep drift. This is particularly critical when the lower section is a flat roof.

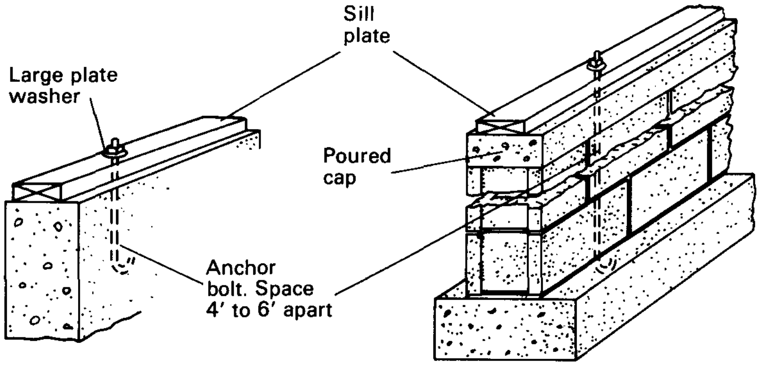
In a joist-and-rafter roof, it is particularly important that the joists be well nailed to the rafters to prevent rafters from spreading as a result of outward thrust from the snow load. Bracing the center of the rafters to a center bearing partition may also prevent sag in the rafter caused by a heavy snow load (fig. 197). The best resistance to snow loads is often accomplished with engineered components such as roof trusses.

Seismic load

The major items needed to provide earthquake resistance are adequate lateral bracing, shear resistance in walls, and good connections between all major components. Buildings that have performed best have had simple rectangular configurations, continuous floors, and small window and door openings. They may be described as having a symmetric box-like lateral resistive system. In addition to the building acting as a unit, anchorage to the foundation is particularly important to avoid having the foundation move out from under the house.

The primary cause of failure observed following earthquakes been inadequate lateral bracing in walls. The best

Figure 195—*Anchorage of the sill plate to the foundation wall.*



Concrete Concrete block

Figure 196—*The truss-framed system combines floor, walls, and roof into a unitized frame for structural continuity from the foundation to the ridge.*

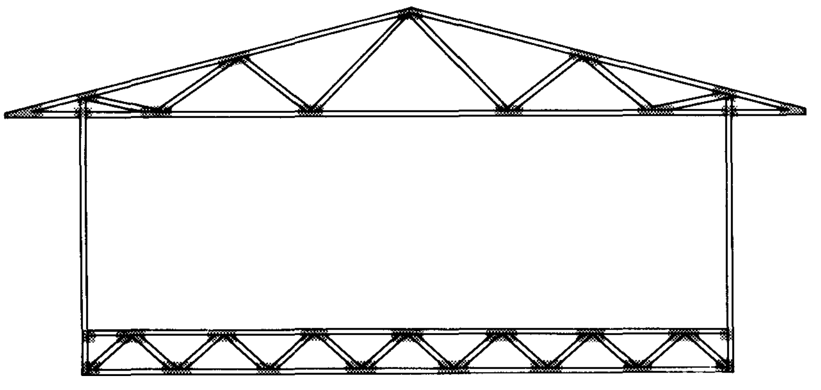
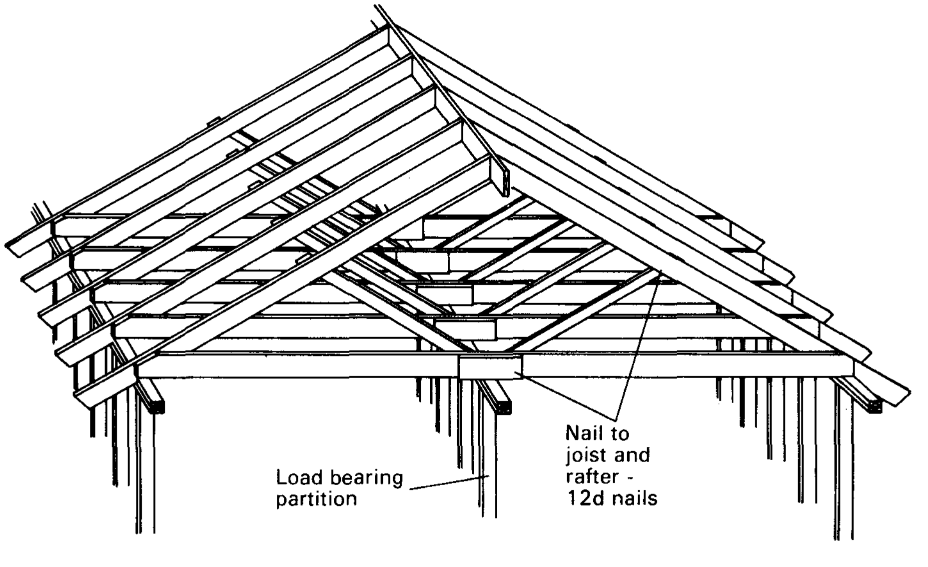


Figure 197—*Bracing of rafters to a center load-bearing partition to prevent sag from a heavy snow load.*



bracing is provided by well-nailed structural wall sheathing. Good diagonal bracing is also acceptable. Where wood diagonals are used, they must be high-quality material. Major failures have occurred where wood bracing had large knots. Another problem is racking walls that are not arranged symmetrically. This may result in rotation of the building, which can cause collapse.

Large openings in walls have been a major cause of failure observed in earthquakes. The openings appear to be more critical when they are near a comer. Particular danger of failure exists where large openings have a second story over them, as do some garage doors, because of the weight of the second story added to the lack of racking resistance.

The joining of two elements of a building of different height (e.g., in a split-level house) can also cause problems. The two sections have different frequencies of vibration, and so may not move together.

Summary

Natural forces such as high wind, excessive snow load, and earthquake can exert forces on the wood-frame house beyond normal design loads. However, wood can generally resist short-term loads beyond its working stresses, and the resilience of the structure and redundancy of the large number of connectors adds to the ability of the house to support excessive loads. Structural adequacy is improved by good connections between all components and good lateral bracing. A simple, unified shape is an added plus. Engineered components such as roof trusses or the truss-frame perform particularly well when subjected to severe structural loads.

All-Weather Construction

It is not always possible to avoid construction when at times weather conditions are too cold, too wet, or too hot and dry. There are steps that can be taken to overcome these obstacles. The objective of the discussion presented in the following paragraphs is to highlight the major concerns when building under adverse weather conditions. The details of the methods and materials are the subject of other publications such as the *All-Weather Home Building Manual* (NAHB Research Foundation 1975), which are cited in the section on additional readings.

Cold weather

Builders in cold weather areas plan for winter construction by preparing access roads by late fall. They excavate for and pour foundations before heavy frost sets in. The completed foundation is protected by decking the first floor and by covering the bottom of the foundation with straw.

Builders that do excavate in winter use a big backhoe with heavy ripper teeth or a big bulldozer with a ripper attachment to break up frozen earth. Scheduling is important when excavating in winter. Builders look for a 2- or 3-day break in severe weather before they schedule a foundation excavation. Excavation is often done and foundation walls poured or laid in 3 days. The hole for the foundation is ripped and dug the first day, except for the last 12 inches. On the second day, the last 12 inches are excavated and footings are formed and poured. On the third day, the foundation walls are formed and poured or the masonry block is laid.

Concrete for footings and foundation walls comes heated from the supplier after November 15. Canadian and some U.S. builders pour concrete in temperatures below zero, but most prefer to pour foundation walls in temperatures not much lower than 10 °F. Builders order from 1 to 2 percent calcium chloride in the mix to help the concrete set quickly, and they protect the pour by placing insulation around and on top of the wall forms. Heated mortar with 1 or 2 percent calcium chloride is used by masons to lay concrete block walls in winter.

Some form of insulation is used around the concrete footings and on the bottom of the foundation to keep frost from getting under the footings and causing them to heave. Builders use straw, hay, or blankets of fiberglass backed with polyethylene. Straw or hay is spread from 12 to 24 inches thick over the footings and the bottom of the foundation. The plastic insulating blankets are designed to cover the footing or the entire foundation hole.

Temporary or permanent heat is hooked up as soon as the house is enclosed, and is left on until the house is complete. If the hookup is permanent, the furnace is often hung by metal straps from the first floor joists until the basement floor is poured. Temporary heat is usually provided by propane or oil-fired portable heating units called salamanders.

Protective enclosures are used in both the United States and Canada. The windbreaks or lean-tos not only protect brick masons from windchill and low temperatures but also keep the mortar from freezing before it sets. Often, masons place one or two portable heaters inside a plastic-enclosed scaffolding to insure that the masonry wall will set and cure properly.

The treated wood foundation system discussed in the section on foundations offers an alternative to concrete or masonry that is less susceptible to damage from cold weather conditions, eliminates the problem of scheduling concrete delivery and the masonry subcontractor, and allows work to proceed on the upper floor and wall framing immediately after the foundation is in place.

Wet weather

Builders in wet weather areas maintain their production volume despite the rain and the mud. Their primary problems include site drainage, site preparation, material delivery, material storage, excavating, and getting the roof on as quickly as possible to keep the rain out.

The builder's first move in wet weather is to drain the building site and keep it drained of surface water. Careful grading of the lot is the first step in disposing of surface water. This is accomplished by rough-grading the site so that water flows away from the foundation area. Hand-dug, small surface drains also remove excess surface water from the foundation area. Slot trenches and drainage pipes work well to drain surface and subsurface water on rolling terrain where the water can be channeled down the hill, but they are less effective in flat swampy areas where the natural grade is slight. In flat swampy areas, builders frequently rely on well points to drain subsurface water.

The next step is preparing the driveway for wet weather construction. After the driveway has been fully or partially paved, material deliveries are easier, hand labor is saved, and concrete trucks can get to the foundation area without getting stuck. Framing and other heavy materials can be delivered or moved from storage to the working area without bringing in special equipment. Builders in the Northeastern and North Central States use crushed stone or pea gravel on the driveway, along with heavy planks and timbers, to ease material delivery and to keep concrete trucks from getting stuck. Some builders pour the driveways before foundation work begins. This provides a solid area for delivery of materials and for working, and a dry area for temporary storage of heavy materials.

Wet weather excavating problems are most difficult in areas on silts and clay soils. Not only does it take longer to excavate muddy clay, but gumbo clays and marine clays clog the trenchers. Rubber-tired equipment is all but impossible to use in mud. Excavators in all parts of the country use sand and gravel on muddy sites to overcome loss of traction and soil load-bearing problems. Builders in some parts of the South where gumbo clay is prevalent spread sand over the entire construction site to provide better soil workability and for landscaping after construction is completed.

Builders in wet weather areas such as the Gulf Coast States and Middle Southern States design their schedules around two important factors: site access and "blacking-in" or closing-in under roofing. Framing is often not begun until driveways and sidewalks are poured. Once the slab is poured or the foundation is installed, the important thing is to black-in the roof as quickly as possible to keep out the rain. To accomplish this, scheduling the roofing subcontractor to come in and lay the asphalt felt is critical. Many builders in the Gulf Coast States have the framing carpenters do the blacking-in so they do not have to rely on the roofing subcontractor to do that job.

Hot and dry weather

Building conditions in the Southwestern United States are unlike any other in the country. The climate in parts of southern California, west Texas, New Mexico, Arizona, and Nevada is hot and dry. Much of the area is desert. Temperatures in the summer soar to more than 120 °F in some places, while humidity is less than 5 percent. The high temperatures and low humidity, along with wind and dust storms, combine to make building conditions difficult.

Because of the extreme heat, builders start work early in the morning and quit early in the afternoon. Roofers, framers, and masons are often on site before 5 a.m., and they don't work much after 1 or 2 p.m. Concrete subcontractors usually don't work after 12 noon.

Concrete pouring begins around 5 a.m. and is completed by 9:30 or 10 a.m. Very little concrete is poured after 10 a.m. because the mix gets too hot. The subcontractors use a wet finish and saturate the soil and gravel under the slab with water before they pour. They also spray the finished concrete with a petroleum-base solution or cover the slab with plastic to prevent moisture from evaporating. Special additives are rarely used when pouring concrete in desert areas.

Maintenance and Repair

A well-constructed house requires relatively little maintenance if adequate attention is given at the planning stage to details and to choice of materials, as presented in this handbook. Many small expenses initially added to cost more than pay for themselves in later maintenance savings. For example, the extra expense of corrosion-resistant nails for siding and trim saves many times that much annually because of the less frequent need for painting. Also the use of edge-grained rather than flat-grained siding provides a longer paint life and thus justifies the higher cost.

The following sections outline some factors relating to maintenance of the house and how to reduce or eliminate conditions that may be harmful as well as costly. These suggestions can apply to both new and old houses.

Basement

The basement of a poured concrete or block wall may be damp for some time after a new house has been completed. However, after the heating season begins, most of this dampness from walls and floors gradually disappears if construction has been correct. If dampness or wet walls and floors persist, the owner should check various areas to eliminate any possibilities for water entry. Possible sources of trouble include:

1. Drainage at the downspouts. The final grade around the house should have a slope away from the building and provide a splash block or other means to drain water away from the foundation wall.
2. Soil settling at the foundation wall and resultant pockets in which water may collect. These areas should be filled and tamped so that surface water can drain away.
3. Leaking in a poured concrete wall at the form tie rods. The leaks usually seal themselves, but larger holes should be filled with a cement mortar or other sealer. Clean and slightly dampen the area first for good adhesion of mortar.
4. Concrete-block or other masonry walls exposed above grade often show dampness on the interior after a prolonged rainy spell. A number of waterproofing materials on the market provide good resistance to moisture penetration when applied to the inner face of the basement wall. If the outside of below-grade basement walls is treated correctly during construction, waterproofing the interior walls is not normally required.
5. There should be at least a 6-inch clearance between the bottom of the siding and the grass. This means that at least 8 inches should be allowed above the finish grade before sod is laid or foundation plantings made. This clearance minimizes the chance of moisture absorption by siding, sill plates, or other adjacent wood parts. Shrubs and foundation plantings should be kept away from the wall to improve air circulation and drying. In lawn sprinkling, it is poor practice to allow water to spray against the walls of the house.
6. Check areas between the foundation wall and the sill plate. Any openings should be filled with a cement mixture or a caulking compound. This filling decreases heat loss and prevents entry of insects into the basement, as well as reducing air infiltration.
7. Dampness in the basement in the early summer months is often augmented when windows are opened for ventilation during the day allowing warm, moisture-laden outside air to enter. The low temperature of the basement cools the incoming air and frequently causes condensation to collect and drip from cold-water pipes and collect on colder parts of the masonry walls and floors. To air out the basement, open the windows during the night and close them during the day.

Perhaps the most convenient method of reducing humidity in basement areas is with dehumidifiers. A mechanical dehumidifier is moderate in price and does a satisfactory job of removing moisture from the air during periods of high humidity. Basements containing living quarters and without air conditioners may require more than one dehumidifier unit. When dehumidifiers are in operation, all basement windows should be closed.

Crawl-space area

Crawl-space areas should be checked as follows:

1. Inspect the crawl-space area annually for signs of termite activity such as termite tubes on the walls or piers. In termite areas, soil in the crawl space or under the concrete slab is normally treated with some type of chemical to prevent termite infestation. Examine the foundation walls for any cracks, as such cracks form good channels for termite entry.
2. While in the crawl space, check exposed wood joists and beams for indications of excessive moisture. In older houses where soil covers have not been used in the past, signs of staining or decay may be present. Use a penknife to test questionable areas. Decayed wood will be soft and will provide little resistance to prodding.
3. Soil covers should be used to protect wood members from ground moisture. These may consist of plastic films, roll roofing or other suitable materials. A small amount of ventilation (discussed in chapter 2) is desirable to provide some air movement. If the crawl space does not presently have a soil cover, install one for greater protection.

Roof and attic

The roof and the attic area of both new and older houses may be inspected with attention to the following:

1. A dirty streak down the gable end of a house with a close rake section can often be attributed to rain entering and running under the edge of the shingles. This results from insufficient shingle overhang or the lack of a metal roof edge. The addition of a flashing strip to form a drip edge can usually minimize this problem.
2. In winters with heavy snows, ice dams may form at the eaves, often resulting in water entering the cornice and walls of the house. The immediate remedy is to remove the snow on the roof for a short distance above the gutters and, if necessary, in the valleys. Additional insulation between heated rooms and attic space and increased ventilation in the overhanging eaves to lower the general attic temperature will help to decrease the melting of snow on the roof and thus

minimize ice formation. Also, deep snow in the valleys sometimes forms ice dams that cause water to back up under shingles and valley flashing.

3. Roof leaks are often caused by improper flashing at the valley or ridge, or around the chimney. Observe these areas during a rainy spell to discover the source of a leak. Water may travel many feet from the point of entry before it drips off the roof members.
4. Attic ventilators are valuable year round; in summer, to lower the attic temperature and improve comfort conditions in the rooms below; in winter, to remove water vapor that may work through the ceiling and condense in the attic space and to minimize ice dam problems. The ventilators should be open in both winter and summer.

To check for sufficient ventilation during cold weather, examine the attic after a prolonged cold period. If nails protruding from the roof into the attic space are heavily coated with frost, ventilation is usually insufficient. Frost may also collect on the roof sheathing, first appearing near the eaves on the north side of the roof. Increasing the size of the ventilators or placing additional ventilation in the soffit area of the cornice will improve air movement and circulation.

Exterior walls

One of the maintenance problems that sometimes occurs with a wood-sided house involves the exterior paint finish. Several reasons are known for peeling and poor adherence of paint. One of the major reasons perhaps can be traced to moisture in its various forms, including paint quality and method of application. Another factor involves the species of wood and the direction of grain. Some species retain paint better than others, and edge grain provides a better surface for paint than flat grain. Chapter 7 covers correct methods of application, types of paint, and other recommendations for a good finish. Other phases of exterior wall maintenance that homeowners may encounter are as follows:

1. If, instead of galvanized, aluminum, stainless steel, or other noncorrosive nails, bright steel nails have been used in applying the siding, rust spots may occur at the nailhead. The spots are quite common where nails are driven flush with the heads exposed. The spotting may be remedied somewhat, in the case of flush nailing, by setting the nailhead below the surface and puttying. The puttying should be preceded by a priming coat.
2. Brick and other types of masonry are not always waterproof, and continued rains may result in moisture penetration. Masonry veneer walls over a sheathed wood frame are normally backed with a waterproof sheathing paper to prevent moisture entry into the wall cavity. When walls do not have such protection and the moisture problem persists, a waterproof coating should be used over the exposed masonry surfaces. Transparent waterproof materials can be obtained for this purpose.
3. Caulking is usually required where a change of materials occurs along a vertical line (e.g., where wood siding abuts on brick chimneys or walls). The wood should normally have a prime coating of paint for proper adhesion of the caulking compound. Caulking guns with cartridges are the best means of waterproofing these joints. Many materials with a neoprene, elastomer, or other base are available for permanent caulking.
4. Rainwater may work behind wood siding through butt joint and sometimes up under the butt edge by capillary action when joints are not tight. Painting the siding board under the butt edges at the lap adds mechanical resistance to water ingress. However, moisture changes in the siding cause some swelling and shrinking that may break the paint film. Capillary action is effectively reduced by treating the siding with a water repellent before its application. For houses already built, the water repellent can be applied under the butt edges of bevel siding or along the joints of drop siding and at all vertical joints. Such water repellents, often combined with a preservative, can be purchased at local paint dealers as a water-repellent preservative. In-place application is often done with a plunger-type oilcan. Excess repellent on the face of painted surfaces should be wiped off.

Interior

Gypsum board. The maintenance of gypsum board interior surfaces is no problem in a properly constructed house. However, damage to the wall surface may require repairs at times:

1. Cracks may develop caused by shrinkage of framing or movement of structural members. Structural problems should be solved before proceeding with repairs. Cracks can be filled with joint cement and sanded smooth as in the original process of treating joints between sheets.
2. Accidental damage may result in gouges or holes in the gypsum board. Gouges or relatively small holes can be filled with joint cement and sanded smooth. Larger holes may require cutting a section from the gypsum board and replacing it with a new section of board the size of the opening. Cut the section to extend between two studs so that the edges of the new section can be supported by the studs. Nail the new section in place and fill the joints around the perimeter with joint cement. Finish the joint by feathering edges and sanding smooth as in the original process of treating joints between sheets.

Moisture on windows. Moisture on inside surfaces of windows may often occur during the colder periods of the heating season. The following precautions and corrections should be observed during this time:

1. During cold weather and in cold climates, condensation or frost may collect on the inner face of single-glazed windows. Water from the condensation or melting frost runs down the glass and soaks into the wood sash to cause stain, decay, and paint failure. The water may rust a steel sash. To prevent such condensation, the window should be provided with a storm sash or double glazing, which also minimizes condensation. If condensation still persists on double-glazed windows, it usually indicates that the humidity within is too high. A humidifier, if used, should be turned off for a while or the setting lowered. If possible, other moisture sources such as house plants, showers, and cooking should also be reduced enough to remedy the problem. Also, increasing the inside temperature reduces surface condensation. If the problem persists, some type of mechanical ventilation may be necessary.
2. Occasionally, in very cold weather, frost may form on the inner surfaces of the storm windows. This may be caused by (a) a loose-fitting window sash that allows moisture vapor from the house to enter the space between the window and storm sash, (b) high relative humidity in the living quarters, or (c) a combination of both. Generally, the condensation on storm sash does not create a maintenance problem, but it may be a nuisance. Weatherstripping the inner sash offers resistance to moisture flow and may prevent this condensation. Lower relative humidities in the house are also helpful.

Problems with exterior doors. Condensation in the form of water or frost may occur on the glass or even on the interior surface of exterior doors during periods of severe cold. Furthermore, warping may result. The addition of a tight-fitting storm or combination door usually remedies both problems. To prevent or minimize warping as well as reduce heat loss, either a solid-core flush door or a panel door with solid stiles and rails is preferable to a hollowcore door.

Openings in flooring. Strip flooring finish that has been laid at too high a moisture content or with varying moisture contents may be a source of trouble to the homeowner. As the flooring dries out and reaches moisture equilibrium, spaces form between the boards. These openings are often very difficult to correct. If the floor has a few large cracks, one expedient is to fit matching strips of wood between the flooring strips and glue them in place. In severe cases, it may be necessary to replace sections of the floor or to refloor the entire house.

Another method is to cover the existing floor with a thin flooring, $^5/_{16}$ or $^3/_8$ inch thick. This requires removal of the base shoe, fitting the thin flooring around door jambs, and perhaps sawing off the door bottoms. New flooring can best be laid at right angles to original flooring. (For proper methods of laying floors to prevent open joints in new houses see chapter 6.)

Unheated rooms. To lower fuel consumption and for personal reasons, some homeowners close off unused rooms and leave them unheated during the winter months. Low temperatures, unfortunately, are conducive to condensation because surfaces may be below the dewpoint temperature of the air. Certain corrective or protective measures can be taken to prevent damage and subsequent maintenance expense, as follows:

1. Do not operate humidifiers or otherwise intentionally increase humidity in heated parts of the house.
2. Open the windows for ventilation of unheated rooms for several hours during bright sunny days. Ventilation helps draw moisture out of the rooms.
3. Install storm sash on all windows, including those in unheated rooms. This materially reduces heat loss from both heated and unheated rooms and minimizes the condensation on the inner glass surfaces.