

PRINCIPLES FOR PROTECTING WOOD BUILDINGS FROM DECAY

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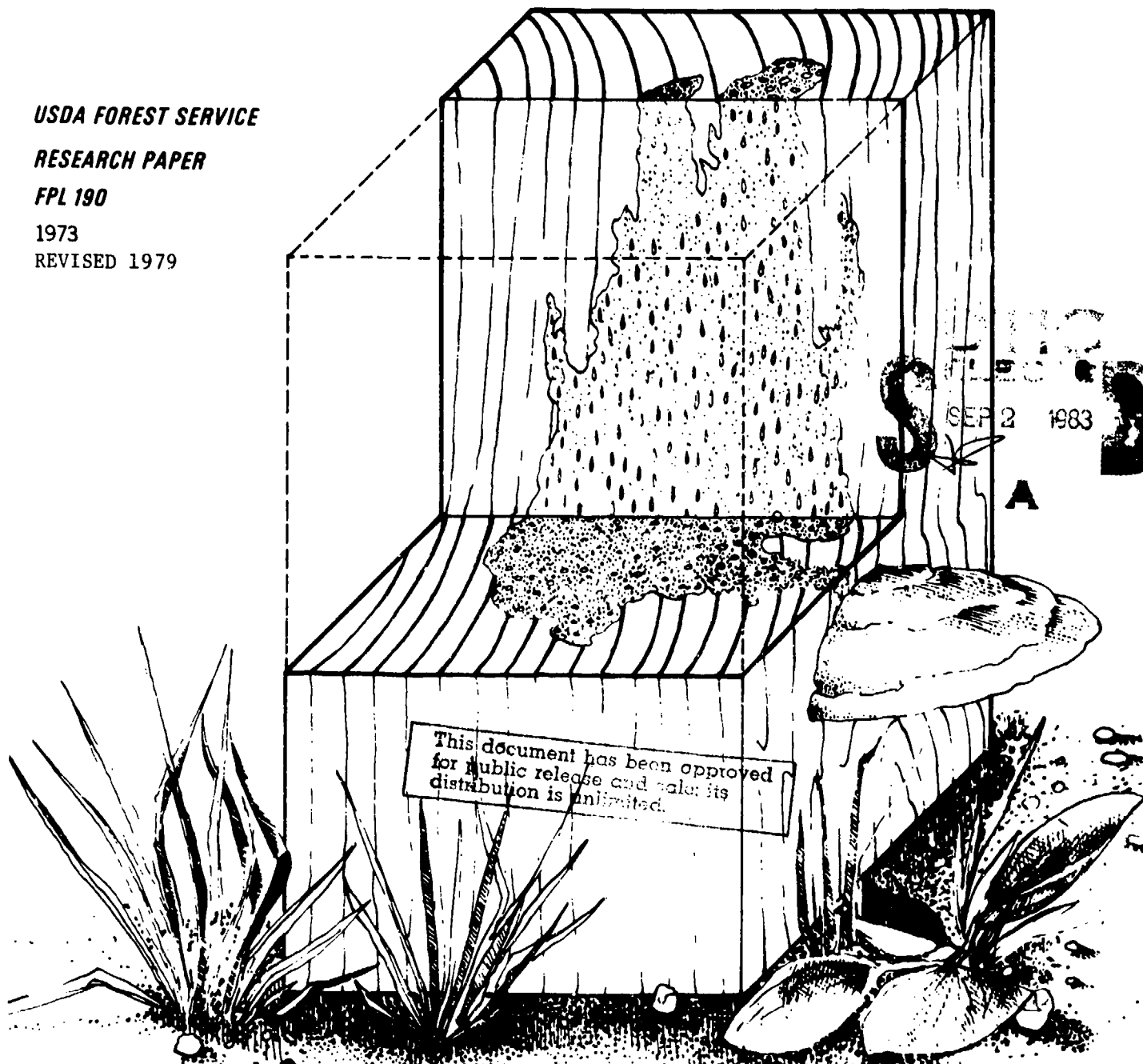
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SUMMARY

→ Problems caused by decay in buildings in the United States and the means to avoid or control them are dealt with in this work. The principal moisture situations and construction features most responsible for the occurrence of decay in various building parts are described, and directions are given for appropriately modifying or eliminating undesirable conditions. Emphasis throughout is on the two primary means of protecting against decay: (1) The use of dry wood and of construction methods to keep wood dry, and (2) methods to treat wood with a suitable preservative in areas where dry conditions cannot be maintained. ← The work is based on observations and research for more than 40 years by agencies of the Department of Agriculture in cooperation with the Department of Defense and the Federal Housing Administration, Department of Housing and Urban Development.

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PRINCIPLES FOR PROTECTING **WOOD BUILDINGS FROM DECAY**

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WOOD AS A CONSTRUCTION MATERIAL

Mankind is fortunate to have wood, an ever-renewable, abundant resource. Trees can be grown on a wide variety of sites and under many climatic conditions; this has made lumber and other wood products readily available for building construction and many other uses. Wood is easily shaped to dimension; therefore it is usable with relatively simple tools. The great variety of forms and the decorative features available are limited only by the skill, resourcefulness, and imagination of the user. When properly used, wood has consistently given many years of satisfactory service.

Much of the worldwide acceptance of wood as a construction material must be attributed to the capacity of wood to withstand weather and, in many species, to resist degradation by fungi and insects. The continuing serviceability of frame buildings--some are several hundred years old--attests to a high order of durability (fig. 1). Certain precautions in construction and maintenance are, of course, necessary to ensure this durability.

Many properties of a specific wood influence its suitability for a particular use.³ Two of these are of major importance in protecting buildings from decay: Moisture relationships and natural decay resistance.



Figure 1.--This house built in 1750 at Portsmouth, Conn., is an example of good performance of wood in house construction.

(M 25010)

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Moisture Relationships Significant in Decay Control

An understanding of wood-moisture relationships is essential to the application of decay preventive and control measures, because decay-producing fungi must have water.

Wood swells and shrinks with changes in moisture content caused by changes in humidity and by absorption and loss of water. Small dimensional changes of wood in use are unavoidable; excessive changes commonly are associated with poor design, careless workmanship, or inadequate maintenance. These conditions can lead to warping, checking, or nail pulling that opens joints or creates new avenues for the entry of rainwater and thus increases the chance of decay.

Wetting and drying of wood and the relative ease with which it can be treated with preservatives are influenced by absorptivity (the capacity of wood to pick up moisture) and permeability (the relative ease with which moisture can move inward under a pressure gradient). Oftentimes no distinction is made between these two properties.

Moisture Vapor

Wood will give off or take on moisture from the surrounding atmosphere until the amount it contains balances that in the atmosphere. The moisture content of the wood at the point of balance is called the equilibrium moisture content and is expressed as a percentage of the oven-dry weight of the wood. In the usual temperature range, the equilibrium moisture content depends chiefly on the relative humidity of the atmosphere.

Water vapor is adsorbed only in the walls of the wood cells. The moisture content when the cell walls are saturated but there is no water in the cell cavities is known as the fiber saturation point. At room temperature this point amounts to approximately 30 percent of the oven-dry weight of the wood. The amount of moisture at fiber saturation is the maximum that can be adsorbed from moisture vapor. The fiber saturation point is the approximate lower moisture limit for attack of wood by decay fungi.

As the cell walls take up or lose water, they swell or shrink accordingly. Correspondingly, the wood swells or shrinks; if the dimensional changes are uneven, warping, twisting, or cup-

ping occurs. For each 1 percent loss in moisture content below the fiber saturation point, wood shrinks about one-thirtieth of its possible shrinkage.

Liquids

Water, such as rain or droplets of condensate, may be drawn into the wood by capillary action. It moves inward most rapidly through the tubelike cell cavities. With a continuing source of supply, the water will continue inward at a significant rate until the capillary forces are offset by built-up air pressure and by the drag imposed by friction. While the water travels through the cell cavities, it will also enter the cell walls and saturate them.

Oils are similarly absorbed into wood but with a very important exception: Oils move into the cell cavities but do not enter the cell wall. Therefore, absorption of oil does not cause wood to swell.

Water generally moves into wood and wood structures much faster than it escapes through subsequent evaporation. Consequently, a relatively brief period of wetting may create a decay-promoting moisture level that will remain for a considerable time.

Penetrability of Wood

The movement of a liquid along the pathway of the cell cavities is influenced by the cellular structure. Most important are the pits in the cell walls, through which the bulk of the liquid must pass to get from one cell to another. Some pits are readily traversed; others are relatively impenetrable. Therefore, some woods are easily impregnated with preservatives, whereas others are practically impossible to impregnate.

In most species, heartwood is more difficult to penetrate than sapwood because in the process of heartwood formation certain changes occur in the pits that tend to plug them. In some hardwoods, the vessels become plugged with obstructions known as tyloses, which reduce permeability. Tyloses, for example, are responsible for the marked impermeability of white oak wood, which has made this a wood favored for barrel construction. Back pressure is also significant in liquid absorption. Air in wood becomes compressed

while a liquid is being absorbed until finally back pressure may become the dominant factor determining the rate of absorption.

A liquid can move into wood more easily along the grain than across it. Wood cells are much longer than they are wide, thus the liquid must move through many more cells when going across than when going in the direction of the grain. Therefore, water in contact with the side of a board is absorbed in far smaller amount in the same length of time than is water in contact with the end of the same board. This great difference in absorptivity between side grain and end grain is an important factor in determining the decay susceptibility of different kinds of wood construction.

Irrespective of differences in penetrability, the total amount of a given liquid that wood can hold varies with specific gravity. The denser the wood, the larger is the amount of space taken up by the cell walls and the smaller is the volume of cell cavities available to receive the liquid. Douglas-fir with an average specific gravity of about 0.45 can absorb about 160 percent water; that is, 160 pounds per 100 pounds of oven-dry wood. A denser wood such as oak with a specific gravity of about 0.60 can absorb only about 100 percent, but a very light wood such as balsa with a specific gravity of about 0.25 can absorb as much as 300 percent.

Effects of Fungus Infection on Absorptivity

Fungus infection tends to increase absorptivity of wood. The increased absorptivity may be pronounced even if the wood is not noticeably infected. The earliest changes in wood structure brought about by infection occur in the wood elements that affect absorptivity most. As the fungi move into wood, they pass through the pits and, in doing so, remove portions of the pit membrane and occluding substances; thus they enlarge the pit openings. In addition, they commonly remove portions of the cells of the wood rays, through which liquids flow into wood radially (fig. 2). Although degradation of the pits and the wood rays by fungus infection does not appreciably reduce wood strength, the increased absorptivity can be disadvantageous to wood exposed to the weather because it promotes pickup of rainwater and thereby increases vulnerability to decay.

Natural Decay Resistance

The structural elements of wood consist of lignins, celluloses, hemicelluloses, and ash-forming minerals. These have no effect on decay resistance, but the celluloses and lignins, along with stored starches and sugars, are the main food source for wood-destroying fungi.

Wood also contains extractives which are not part of the wood structure but impart color, odor, and taste. Some woods contain extractives that are toxic to fungi and act as natural preservatives; the type and amount of these extractives determine the degree of susceptibility or resistance to decay.

The wood extractives effective against decay are chiefly phenolics. They vary in specific composition and in potency as preservatives. They are present in effective amounts only in heartwood. In the heartwood of many durable species, decay-retarding extractives tend to decrease in quantity from the outer heartwood to the center of the tree. At a given radial position in the tree, they usually decrease progressively from the base to the top of the trunk. These within-tree differences generally are greater as the tree increases in size and age; the greatest decay resistance in an individual tree is most likely to occur in the outer basal heartwood and the least resistance in the inner basal heartwood.

The radial decline in resistance from outer to inner heartwood results largely from chemical changes in the protective extractives over long periods. The potent preservatives deposited when the heartwood is formed gradually alter with age and become less effective. Extractives that are effective against fungi are not necessarily the same as those effective against insects or marine organisms.

If long life is desired from untreated wood under conditions suitable for decay organisms, only heartwood should be depended on regardless of species. Under conditions that are suitable for decay organisms, the sapwood usually will be rotted quickly. In a few species, such as the spruces and the true firs (not Douglas-fir) the color of the sapwood and the heartwood is so similar that frequently the two cannot be distinguished easily. Generally, both the heartwood and the sapwood of these species have low resistance to decay.

Relatively young, second-growth trees usually contain a higher proportion of sapwood than does



Figure 2.--Photomicrographs of tangential surface of pine showing wood rays opened by mold infection (arrow at left) and normal rays with cells intact (arrow at right); wood-invading bacteria affect ray cells similarly.

(M 128 680)

virgin timber. Because most lumber coming from areas east of the Rocky Mountains is from second-growth timber, it contains large percentages of sapwood. For example, there are but few remaining all-heartwood supplies of baldcypress lumber.

Heartwood of virgin redwood and western redcedar is the chief source of domestic softwood lumber with high natural decay resistance. Douglas-fir heartwood is only moderately decay resistant in contact with the ground but in most exterior service above ground it will considerably outperform other structural woods such as the spruces, the true firs, and the hemlocks. White oak heartwood has been extensively used in shipbuilding because of its combination of strength and decay resistance, but it is not available in sufficient amount for general use in land structures.

Black locust, with its unusually durable heartwood, is suitable primarily for posts.

Comparisons of wood species for decay resistance by ascribing to each a single class of resistance lack precision because wood of the same species may vary considerably in resistance. This simple basis of comparison can be useful, however, if it is recognized that in specific cases the resistance may vary considerably from the average.

In table 1, common species native to the United States are grouped according to the average decay resistance of the heartwood. Quantitative significance may be assigned to the groupings by noting that fence posts of substantially resistant or very resistant heartwood should last 10 to 20 or more years and those with non-resistant heartwood about

Table 1.--Heartwood decay resistance of domestic woods

Resistant or very resistant	Moderately resistant	Slightly or nonresistant
Baldcypress (old growth) ¹	Baldcypress (young growth) ¹	Alder
Catalpa	Douglas-fir	Ashes
Cedars	Honeylocust ²	Aspens
Cherry, black	Larch, western	Basswood
Chestnut	Oak, swamp chestnut	Beech
		Birches
Cypress, Arizona	Pine, eastern white ¹	Buckeye ²
Junipers	Pine, longleaf ¹	Butternut
Locust, black ³	Pine, slash ¹	Cottonwood
Mesquite	Tamarack	Elms
Mulberry, red ³		Hackberry
Oak, bur		Hemlocks
Oak, chestnut		Hickories
Oak, Gambel		Magnolia
Oak, Oregon white		Maples
Oak, post		Oak (red and black species) ²
Oak, white		Pines (most other species) ²
Osage-orange ³		
Redwood		
Sassafras		Poplar
Walnut, black		Spruces
Yew, Pacific ³		Sweetgum ²
		Sycamore
		Willows
		Yellow-poplar

¹Southern and eastern pines and baldcypress are now largely second growth with a large proportion of sapwood. Consequently, it is no longer practicable to obtain substantial quantities of heartwood lumber in these species for general building purposes.

²These species or certain species within the groups have higher decay resistance than most woods in this grouping.

³Exceptionally high decay resistance.

5 years or less. A wood that lasts longer than another in the ground can also be expected to last longer when used above ground. The actual years of service--and correspondingly, the differences in service--will, of course, normally be greater above ground.

A number of foreign hardwoods have very high decay resistance. The best known is teak. Among the mahoganies, those from Central and South America (species of *Swietenia*) are generally classified as decay resistant. African mahogany (*Khaya* species) seems to have moderate decay resistance. The Philippine mahoganies (species of *Shorea*, *Parashorea*, and *Dipterocarpus*) have

exhibited no more than moderate or slight resistance. An exception is *Shorea guiso*, which has showed high resistance. The woods classed as red lauans usually are somewhat more resistant than the white lauans.

The season of the year when wood is cut is not known to have any effect on decay resistance. Wood cut or peeled in late fall or winter is usually safer from immediate damage than that cut in warm weather. In cold weather, freshly cut timber is exposed at a time when fungi are not active; thus, it may be moved to a safe place or it may become dry enough to avoid attack by fungi before warm weather begins.

Drying wood to be used untreated in contact with the ground does not increase natural resistance to decay. Drying may, however, have a very important influence on the life-expectancy of wood used in certain confined parts of buildings or in other unexposed places. Wood that is not dried before being built into spaces in which it cannot dry rapidly may retain moisture so long that decay organisms may harm it before it becomes dry.

It should be observed that no wood species classed as very decay resistant is uniformly resistant to all decay fungi. The water-conducting fungi (see "Protecting Buildings After Construction") are notorious for their ability to decay all-heart cypress, redwood, and other decay resistant woods. Therefore, when decay-resistant woods are used to repair a structure with decay, one should make certain that a water-conducting fungus is not present.

BIOLOGICAL DETERIORATION OF WOOD

Most measures to protect wood are directed against three types of destruction: Biological (destructive utilization of wood by various organisms), fire, and physical damage by breakage or by deformation. By observing simple and inexpensive precautions, the effects of these destructive forces can be held to a low level.

This report is concerned primarily with biological deterioration caused by decay fungi. Mold and stain fungi and bacteria are considered briefly, particularly as they influence decay. Such physical damage as warping and paint peeling are also mentioned as affecting decay or as signs of a possible decay hazard.⁴

Kinds of Damage

Four primary types of damage by wood-attacking fungi are commonly recognized: Sap stain (chiefly the dark type, commonly known as blue stain), mold, decay, and soft rot. The distinctions among types are generally useful although not always sharp. Also, bacteria degrade wood under special conditions.

Fungi destroy more wood than do any other organisms. Those causing decay, or rot, are by far the most destructive. Fungi in their simple growing stage are threadlike, and the individual strands, called hyphae, are invisible to the naked eye except in mass. These hyphae penetrate and ramify within wood.

Botanically, the fungi are a low form of plant life. They have no chlorophyll; therefore, they cannot manufacture their own food but must depend on food, such as wood, already elaborated by green plants. Fungi convert wood they are invading into simple digestible products, and in the process the wood loses weight and strength.

Sap Stain

Sap stain is a discoloration that occurs mainly in logs and pulpwood during storage and in lumber during air drying. As its name implies, it is a discoloration of the sapwood. The "blue-stain" type, which dominates and is the only one of the sap stains of much importance commercially, is caused by the dark color of the invading fungus. Sap stain can go deep into the wood causing a permanent blemish that cannot be surfaced off. The color of sap stain usually ranges from a brownish or a steel gray to almost black, depending on the fungus and the wood species.

Sap stain alone ordinarily does not seriously affect the strength of wood, but heavily stained wood is objectionable where strength is of prime importance. Its presence signifies that moisture and temperature have been suitable for the development of decay fungi; hence, early decay often is present though masked by the stain. Stained wood is more permeable to rainwater; thus wood in exterior service is more subject to decay infection.

⁴In some areas, termites cause heavy damage. Also, marine borers severely damage untreated wood items in contact with salt or brackish water. See the material listed under "Additional Reading" at the end of this report for discussions of these problems.

Mold

Molds cause discoloration that is largely superficial and can be removed by brushing or shallow planing. In coniferous woods the discoloration imparted by mold fungi typically is caused by the color of surface spore masses (green, black, orange); in hardwoods the wood itself often is superficially discolored by dark spots of various sizes.

Mold hyphae, however, penetrate wood deeply and increase permeability, sometimes very markedly. Also, heavy molding often is accompanied by hidden incipient decay.

Decay

Under favorable conditions, decay can rapidly destroy wood substance and seriously reduce the strength of wood. This may happen before there is any pronounced change in external appearance of the wood; thus even early decay can dangerously weaken a wood structural component. Advanced decay, of course, can render it entirely useless.

Two major kinds of decay are recognized--brown rot and white rot. Different types of fungi are responsible for each. With brown rot, only the cellulose is extensively removed; the wood takes on a browner color and tends to crack across the grain, shrink, and collapse (fig. 3). With white rot, both lignin and cellulose usually are removed, the wood may lose color and appear whiter than normal, it does not crack across the grain, and until it has been severely degraded, it does not shrink or collapse (fig. 4).

Soft Rot

Soft rot, although not identified and classified until recent years, is another form of severe wood degradation. Soft rot often can be identified by these characteristics: It tends to be shallower than typical decay; the transition between the rotted wood and the sound wood beneath is often abrupt; and if the damaged wood is scraped off with a knife, the blade may suddenly strike wood that has almost normal hardness. Additional aids in identifying are a comparatively slow, inward

development of the rot, and wood surfaces exposed to the elements tend to be profusely cracked and fissured both in and across the grain direction like weatherbeaten driftwood and old unpainted buildings.

The fungi that cause soft rot are in a completely different group than the more familiar and destructive decay fungi; physiologically, they tolerate both wetter and drier conditions. The wettest parts of cooling towers, for example, are subject to soft rot. Some of the molds and the sap stain fungi can progress far enough to cause soft rot if the wood is wet for a long enough time--which usually is substantially greater than the time involved in producing air-dry lumber.

Because soft rot ordinarily is relatively shallow and progresses inward slowly, it ordinarily is not of great concern to the wood user. But where the wood member is comparatively thin, as in the fill members of a cooling tower, even rather shallow rot can weaken the wood members severely.

Bacterial Damage

Bacteria, as well as fungi, can invade wood. Bacteria generally have been troublesome in logs stored in ponds or under continuous water sprays. They remove certain sapwood constituents, which increases the permeability of the wood. The greater permeability adds, like that caused by fungi, to susceptibility to serious wetting by rain. Moreover, millwork of bacteria-invaded wood absorbs excessive amounts of preservative solution when dip-treated. Generally bacteria do not appreciably weaken wood. Serious bacterial weakening has been observed, however, in thin items like cooling-tower slats and in piling wetted by fresh water for several decades.

Rot in the Living Tree

All types of wood-inhabiting fungi and bacteria occur in living trees. The decay fungi cause heartrot. One familiar heartrot occurs in pecky cypress, used for decorative paneling; another is the so-called white pocket common in low-grade



Figure 3.--Typical brown rot: Top, Early stage, evidenced by discoloration in flat-grain board and, at left, in end grain. Bottom, Late stage, with cracked and collapsed wood. Brown rot, as the name suggests, ultimately imparts an abnormal brown color to the wood.

(M 124 928)

lumber from over-mature stands of Douglas-fir. Heartrot fungi typically do not invade healthy sapwood because the wood is too wet and, possibly, because many of the sapwood cells are still living. Heartrot can be damaging to wood cut from the tree depending on the stage of development of the rot.

Heartrot fungi generally do not attack wood products. Therefore, further damage by them after wood is placed in service is unlikely. Conversely, most fungi that attack wood in service do not attack wood in the living tree to any significant extent.



Figure 4.--Intermediate stage of white rot: Top, Decay on end grain. White rot is indicated by abnormally light discoloration--often with mottling of the wood--and often by dark-colored "zone lines" bordering the discoloration (see arrows). It does not cause the wood to crack as does the brown rot. Bottom, Decay on side grain.

(M 124 927)

Initiation and Spread of Decay

Decay fungi penetrate and proliferate inside wood from one wood cell to another through the natural openings, the pits, or through the small openings they make called bore holes. They destroy the cell walls they contact.

The fungi may spread from one piece of wood to another by two methods:

1. Direct contact of sound wood with decayed wood.
2. Spores or unspecialized fungus fragments.

The tiny spores, which are analogous to seeds, are transported in large numbers--often for great distances--by wind and insects; those that light on susceptible wood may grow and create new infections.

The cycle of decay infection is illustrated in figure 5. The highly specialized, sexual spores of decay fungi are produced in so-called fruit bodies; the familiar field mushrooms are an example. Others are the shelf- or bracket-like bodies that appear on tree trunks, logs, dead branches, and rotting structures. Millions of spores can be produced by a single fruit body.

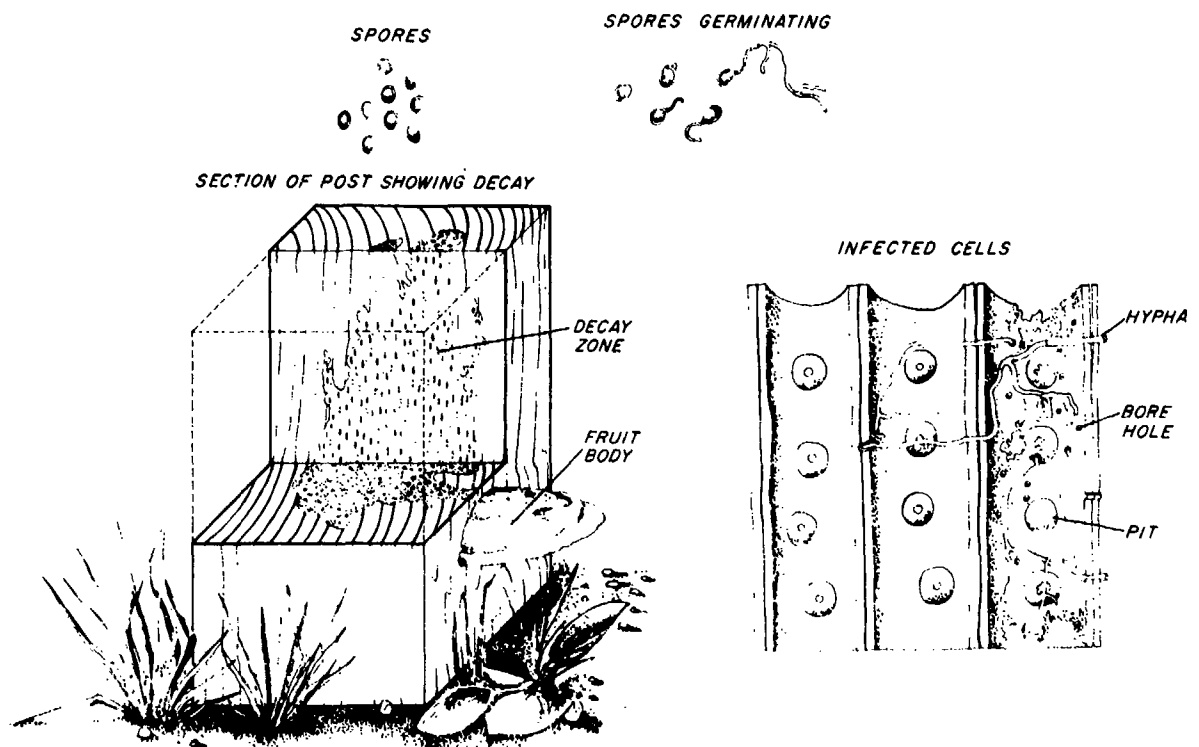


Figure 5.--Cycle of decay: Thousands of spores (top left) developed in fruit body (bottom left) of the decay fungus are distributed by wind or insects. On contacting susceptible wood they germinate and the fungus penetrates the wood infecting it cell by cell (right). After causing a certain amount of decay, a fruit body is developed and the cycle is repeated.

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Basic Conditions for Decay

Decay fungi have the same four primary needs as all of the higher forms of life, namely: Food, air (oxygen), favorable temperature, and water. By excluding or limiting any one of these, decay can be prevented or restricted.

Fungus-Susceptible Wood

Decay fungi depend on the wood cellulose or on both the cellulose and the lignin for their nourishment. Wood can be made unavailable as food by keeping it dry or by poisoning it with a preservative chemical. The heartwood of some timber species contains naturally occurring preservative chemicals that variously resist fungus infection.

Stain and mold fungi do not depend on the major wood constituents for food; rather, much of their development is supported by the nonstructural elements--mainly sugars and starch. Heartwood generally is not suitable for stain and mold fungi because it does not contain these nutritional elements in sufficient amounts.

Air in the Wood

All wood-attacking fungi require air as a source of oxygen. However, they need comparatively little oxygen and can maintain essentially a normal rate of development at levels considerably below the amount of oxygen in ordinary air. If wood is held under water, it cannot receive sufficient oxygen to support heavy fungus attack. This explains why many foundation piles have served for decades without preservative treatment when driven to a depth completely below the water table. Conversely, portions exposed to air by a lowering of the water table will rot. Foundation piles should be treated to ensure protection.

One of the earliest and simplest means of protecting stored logs is to submerge them in freshwater ponds. Similarly effective restriction of air can be obtained by keeping logs wet with a water spray. Certain specialized fungi and bacteria can invade wood under water, but their effect generally is one of increased permeability rather than of typical decay.

Moderate Temperatures

Decay fungi require moderate temperatures for rapid development. They can do little harm to wood at near freezing or above 100° F. Usually, the rate of decay is slow at temperatures below 50° F. and falls off markedly with temperatures above 90° F. In the main, decay fungi attack most rapidly in the range of 75° to 90° F.

Naturally occurring subzero temperatures merely inactivate fungi, but high temperatures kill them. The lethal effect of a high temperature depends on the specific temperature and the length of time it is applied. A temperature below about 150° F. probably would be impractical as an eradication measure because it would have to be applied for an excessive length of time. Temperatures generally reached in commercial kiln drying and pressure treatment sterilize wood.

Adequate Wood Moisture

Serious decay will occur only when the moisture content of wood is above the fiber saturation point (approximately 30 percent, oven-dry basis). This amount of moisture cannot be acquired from humid air but requires wetting of the wood by water. Initially dry wood kept dry under shelter and protected against condensation will not rot.

An excellent rule for drying lumber is to reduce the moisture content as soon as practicable to 20 percent or less. This is substantially below the approximate 30 percent minimum needed to support decay organisms, but the lower figure is advisable because it provides a margin of safety. Although an average moisture content of 20 percent can be easily attained in a load of lumber by air-drying, a number of boards may have a moisture content considerably higher than the average. At construction time, lumber should have a moisture content substantially below 20 percent to minimize dimensional changes as well as to prevent decay.

The moisture content at which wood is most susceptible to decay lies in a broad range from not far above fiber saturation to somewhere between 60 and 100 percent. The upper level for rapid decay is determined by the specific gravity and cross-sectional size of the wood. Both of these factors determine the rate of air exchange be-

tween the inside and the outside of the piece.

The commonly used term "dry rot" is an unfortunate misnomer because it implies that wood can decay without being wet, which it cannot. The notion of rot in dry wood may have originated from the appearance of dried wood after it has been decayed by a brown-rot fungus. Wood with brown rot often looks unusually dry, being brown and cracked as though it has been severely heated. It is better to avoid the term "dry rot" and simply use "rot" or "decay."

The term "dry rot" also is misapplied to decay caused by the water-conducting fungi. The necessary moisture in this case is imparted to initially dry wood by the attacking fungus itself. These specialized fungi conduct water through vinelike growths to considerable distances from an external source (such as the soil) to the wood they decay.

To prevent attack of a water-conducting fungus, measures against wetting must be aimed directly at the water-conducting fungus rather than at one of the usual sources of moisture (see Protecting Building After Construction). Fortunately, decay by the water-conducting fungi, although often rapid and severe, is a comparatively minor part of the overall problem. There are only two species of these specialized fungi; one occurs predominantly in the United States and the other mainly in Europe.

Effect of Climate on Decay

Temperature and amount of rainfall and their distribution throughout the year are climatic factors that affect the amount of decay in exterior structures exposed to the weather. Warm weather during many months of the year promotes decay more than hot weather for a few months and cold weather during the remainder of the year. Similarly, prolonged rains are more conducive to decay than the same amounts delivered in heavy but relatively brief showers.

To relate the climate of geographical areas to

its decay-contributing potential and to establish a measure to determine the kind and amount of protection needed for various building components influenced by climate, a "climate index" was developed. The climate index is derived from a formula based on mean monthly temperatures and frequencies of rainfall (as published by the U.S. Weather Bureau in Local Climatological Data), relation of decay rate to temperature, and measured actual rates of decay in different areas. It is designed to keep the indexes in the United States largely within the range of 0 to 100. The formula is:

$$\text{Climate Index} = \frac{\sum_{\text{Jan.}}^{\text{Dec.}} (T - 35) (D - 3)}{30}$$

where T is the mean monthly temperature ($^{\circ}\text{F}$), D is the mean number of days in the month with 0.01

inches or more of precipitation, and $\sum_{\text{Jan.}}^{\text{Dec.}}$ indicates the summation of the products for each of the 12 months, January through December. The climate index for Madison, Wis., for example, is derived as follows: Monthly products $(T - 35) \times (D - 3)$: Jan. 0:0:0:72: 168 : 248 : 252 :210:156:75: 0:0^{Dec.}. The products are then added, giving 1,181, which when divided by 30 gives an index of 39.

The map in figure 6 is derived from the formula. It is useful for estimating the climate index of localities where differences in elevation are insufficient to cause abrupt differences in climate over comparatively short distances. Three climate-index levels are shown on the map: (1) Index less than 35, where the least preservative protection is needed; (2) an index of 35 to 65, where moderate protection is needed; and (3) an index greater than 65, where the most protection is needed. In regions where mountains cause marked variations in climate, the formula can be used more reliably than the map for indexing a particular locality.

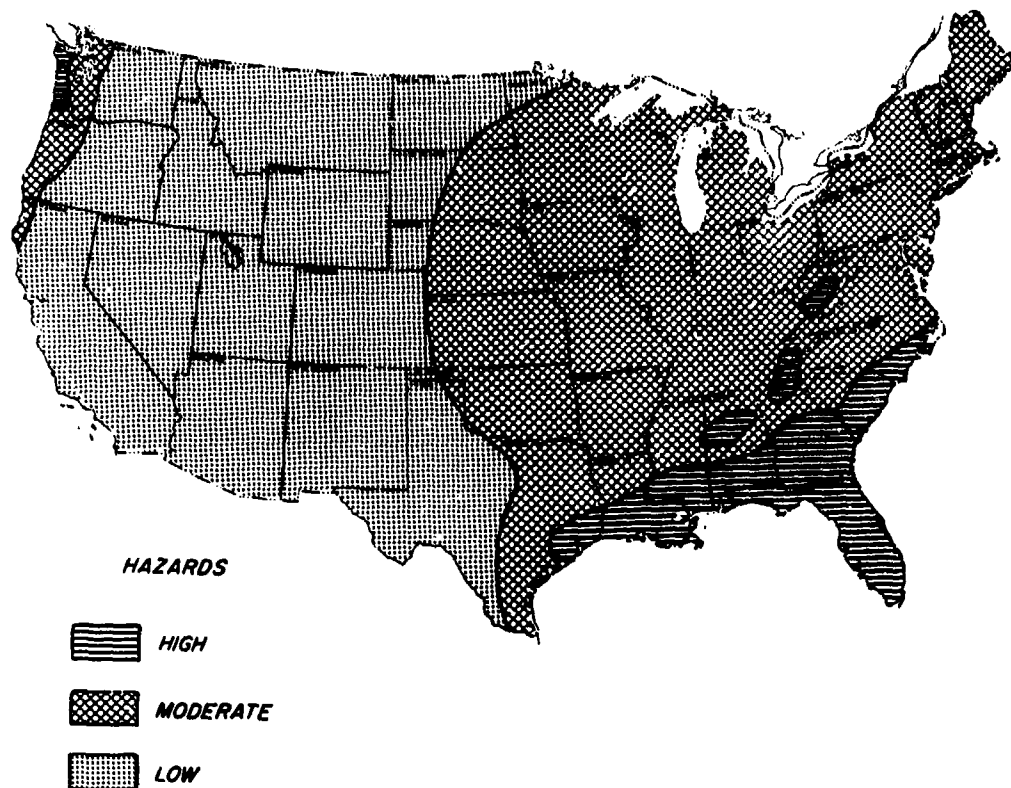


Figure 6.--Levels of decay potential for wood exposed to the weather in aboveground service based on a climate index derived from standard temperature and rainfall data: Darkest areas, wettest climates, most suitable for decay; Index greater than 70. Lightest areas, driest climates, least suitable for decay; index less than 35. Gray areas, moderately wet climates, moderately suitable for decay organisms; Index 35 to 70.

(M 145 493)

HOW WOOD IN BUILDINGS BECOMES WET

To protect wood in buildings from decay, the first concern is for practicable measures to ensure use of dry wood and to keep it dry after it is in the structure. Therefore, it is important to understand how wood in buildings becomes sufficiently wet to decay.

Water to support decay can arise from five main sources: Original moisture in unseasoned wood, ground moisture, rainwater, condensate, and piped water. In addition, water is created as a byproduct of the fungal breakdown of wood, but this happens only where decay already has started and so is not of primary concern.

Original Moisture and Wet Lumber

Freshly sawed green lumber has a moisture content that will support attack by decay fungi. As observed earlier, one should aim to dry lumber down to a moisture content of at least 20 percent, never leaving more than 30 percent, if it is to be safe from decay. When wet lumber is placed in a building it usually dries before there is much decay. Preferably, however, drying should be accomplished before installation in a building, in order to minimize later dimensional changes from

shrinkage. Also before wet lumber dries, potentially harmful stain, mold, and incipient decay may develop if the wood is not fungus resistant. If lumber that is both infected and wet is enclosed within a relatively vapor-tight wall or in a damp crawl space, it may become damaged by further progress of the decay (fig. 7).

Installation of wet or incompletely dried lumber can cause trouble in another way. In drying, there is danger of splitting and warping with accompanying loosening of joints that, in exposed places, promote rain seepage and decay infection.

Fully air-dried or kiln-dried lumber can, of course, be rewetted sufficiently to decay if not properly protected from rain wetting at the lumber yard, during transportation, or at the building site. This is discussed later under "General Protective Measures."

Wetting From Ground Moisture

Damp soil can cause serious wetting in a frame building. Also, damp soil usually harbors a variety of decay fungi that can directly infect wood in contact with it. Ground moisture can get to wood parts of buildings in four ways:

(1) By direct movement into wood in contact with the soil. The more common direct contacts are substructure members next to dirt-filled porches and terraces, forms left on concrete foundations, and basal exterior woodwork where grade levels have been raised.

(2) By condensation of vapor in crawl spaces as described in the section on condensation.

(3) By being transported through the conducting strands of the rare water-conducting fungi



Figure 7.--White surface growth of a decay fungus in an exterior wall. The decay resulted from using infected and incompletely dried studs and closing them in shortly after they were installed.

(M 110 726)

(see "Protecting Buildings After Construction").

(4) By indirect transfer from soil to wood through concrete or masonry. Some wetting of plates and other wood resting on groundline slabs can occur by capillary transfer through the concrete, but most serious wetting occurs in basements on wet sites where hydrostatic pressure adds to the capillary movement.

Wetting from Rain

Siding and other exterior woodwork may get wet from rain driven directly against it, from roof runoff, or from water splashed from the ground. Rainwater enters largely by capillary movement and is trapped in the interfacial space between joint members. In the exposed part of a building, the joints are especially vulnerable to wetting and decay. Some rainwater may be carried into wall joints by wind pressure and gravity flow. Winds less than 40 miles per hour, however, have surprisingly little effect on the total rain seepage into siding. The chief effect of strong wind is to reduce the protective influence of roof overhang and gutters by driving rain onto the siding, windows, and doors.

Joints of end grain where siding abuts trim or where a porch rail meets a post are the most absorptive. Though a joint may be painted, the paint seal rarely remains tight; moreover, water can enter even through hairline checks in the paint. Longitudinal splits in siding lumber occasionally may result in troublesome amounts of water entering a wall.

The amount of rainwater accumulating in exterior woodwork depends on the extent of the wetting and the rapidity of drying. The extent of the wetting is a function of the amount and the frequency of rainfall, the prevalence and velocity of wind with the rains, the water-shedding protection afforded by the building design (such as roof overhang), and the degree to which water-trapping joints and crevices are avoided by the type of construction.

The rate of drying is governed mainly by the lengths of periods of dry weather between rains and by construction details determining the amount of air exchange in the wetted zone and the corresponding rate of loss of water vapor. In exterior walls, for example, evaporation of any water that gets into the wall is governed largely by the permeability of the sheathing paper used.

Damaging amounts of rain seepage may occur in any wood exposed on the surface of the building. The greatest danger is to roof edges (fig. 8), appendages (porches and exterior stairs), and exposed structural members. Except in dry climates (fig. 6), significant amounts of decay may also occur in siding, trim, sash, and decorative structures such as shutters. Siding of the comparatively durable cedar and redwood heartwood is rarely subject to decay. Sapwood siding, generally of pine species, is subject to molds and stains. These molds and stains generally can be more troublesome than decay.

Wall decay can be caused by runoff from the roof splashing from the ground, a lower roof, or a canopy (fig. 8). This trouble is most likely in regions where rainfall is frequent. Ground splash is greatest when the runoff strikes a flat, hard surface, such as a concrete walk. The amount of wetting also varies with foundation height and the height and width of eave. Splash on masonry walls with permeable joints occasionally leads to decay of wood joists or beams embedded in the walls.

Even where wetting does not afford conditions for decay, it can cause paint failure. Paint failure in siding may develop some distance from the leakage, because after the water enters a joint at the end of a siding board it can flow along the top edge of the board to a different location. Local accumulations of water near joints may raise the humidity of the air between siding and sheathing, then cooling at night results in condensation at various points on the back of the siding. A thin film of water on the back of wood siding can put heavy stresses on the paint coating.

Wetting from Condensation

Condensation results from cooling of air on contact with a cold surface. The amount of water that air will hold varies chiefly with temperature. The warmer the air, the more water vapor it will hold. When air is cooled, it eventually reaches the saturation point, and further cooling causes some of the vapor to condense. The temperature at which condensation begins is the dewpoint temperature. Any surface at or below the dewpoint temperature of an atmosphere will become wet with condensate.

Under a given set of vapor and temperature conditions, the amount of condensate collecting on a given wood surface will be governed by two factors: (1) How rapidly the water vapor can permeate



Figure 8.--Wall and roof edge discoloration from decay promoted by water runoff from roof: Top left, Decay in lower sheathing and plate induced by splash from sidewalk. Top right, Wall decay caused by leak in gravel stop. Bottom left, Runoff from porch roof caused dangerous wetting and decay behind siding adjacent to the window. Bottom right, Sheathing decayed at roof edge because it lacked metal flashing.

(M 128 125)

materials between the condensing surface and the atmosphere or materials beyond and (2) how rapidly the condensate can escape from the surface during any periods when the temperature is above the dewpoint.

Water vapor moves through a structure from an area of high vapor pressure toward one of lower vapor pressure. In buildings, vapor pressure gradients are created by temperature differences. During the heating season, the gradient is outward from the warm interior; when air conditioning is employed, the gradient is reversed. Most materials used in constructing buildings, such as wood, plywood, asbestos-cement, cork, plaster, and concrete, are permeable to water vapor to varying degrees. Where a dewpoint temperature exists and unless entry of vapor into walls, ceiling, and

floors is restricted, damaging condensation will occur within these structures.

When conditions promoting condensation occur within a structure, the use of thermal insulation without a vapor barrier will not prevent condensation but merely change the location of the point where the dewpoint temperature occurs.

Critical wetting by condensation may occur in four areas: (1) Near the perimeter of crawl spaces in cold weather; (2) in floors, walls, and ceilings of cold-storage rooms; (3) in areas where sizable amounts of steam are released or unintentionally escape, such as from leaking steam pipes or radiators; and (4) in the floor below air-conditioned rooms over a damp crawl space. Also, certain climatic and occupancy conditions would favor condensation on slab foundations.

Condensation in Crawl Spaces

Wetting of the perimeter substructure wood by condensate can be serious in crawl spaces under a heated building during cold weather. Two conditions are responsible for this type of condensation: (1) Warm, damp air in the crawl space associated with moist or wet ground; and (2) prevailing outside temperatures of about 50° F. or below. Under these conditions, the relatively cold air outside cools the sills, plates, and joists on or near the foundation creating a dewpoint temperature on the exposed, inside surfaces of these members (fig. 9). The wettest places ordinarily are the corners where air movement in the crawl space is slowest and the wood correspondingly gets coldest. Enough condensate can ultimately be absorbed by the wood to support decay.



Figure 9.--Cold-weather condensation in corner of crawl space; the lumber had recently been installed to replace decayed lumber. The condensation, which continued and threatened further decay, was easily eliminated by laying an inexpensive vapor-resistant cover on the damp ground

(M III 247)

There is substantial evidence that crawl-space condensation is most likely to promote decay if the wetted wood is already infected when installed. The lumber may have dried out after reaching the building site, but the dormant decay infection can again become active when the wood is rewetted.

Condensation sufficient to support decay in floors immediately above the crawl space can be caused by overcooling with summer air conditioning. Because the entire floor is cooled, the central as well as perimeter floor area may be affected.

Similarly, although rarely, hazardous condensation may occur during cold weather in floors

above a wet crawl space in an unheated building; the wetting again is not restricted to perimeter locations. Where this occurs, the air in the crawl space is slightly warmed by the residual heat in the ground. This condition, coupled with a lower temperature of the unheated floor--cooled by the ambient air--brings about a dewpoint temperature on the underside of the floor.

Condensation in Walls

Except in cold-storage rooms, condensation in walls seldom leads to decay, but--like rain seepage--it can cause paint problems. Troublesome condensation sometimes occurs in exterior walls during the winter, mainly in the North, although it occasionally occurs as far south as the Gulf Coast.

During cold weather the air in living quarters moves outward at a rate determined by the vapor-pressure differential and the permeability of the wall components; then, if the heated air on reaching the sheathing or siding is cooled to the dewpoint temperature, condensation will take place on the cold wood.

Where average temperatures for January are 35° F. or lower (fig. 10) vapor barriers should be installed in exterior walls of all new wood-frame buildings at the time of construction.

Wetting is most likely to occur if vapor-resistant rather than vapor-permeable paper is used under the siding or if the siding itself is vapor impervious. In walls containing no material with high resistance to passage of vapor from the wall space to the outside, condensate accumulation is rare. In northerly climates the possibility of wall condensation is increased by incorporating thermal insulation within the wall. The presence of the insulation is not likely to be troublesome, however, if a vapor barrier is installed on the warm side of the wall and if winter humidifying is properly regulated.

Condensation in an exterior wall or in an attic is sometimes aggravated by damp air from the crawl space entering the wall void. Warming the air in the wall space, sometimes in part by the sun, tends to create a stack effect causing the air to rise in the wall and new damp air to move in.

Condensation sometimes occurs on cold water pipes in walls, but seldom to a bothersome degree. Occasionally, a restricted amount of decay is found where pipes penetrate a sill plate. Similarly, steam exhaust pipes, if of insufficient length, may

lead to steam condensing on a wall. With central air conditioning, condensation occurs on imperfectly insulated ducts and pipes. Most trouble is water drip resulting in mold, but important decay has been found in wood supporting the heating-cooling unit and in wall plates where refrigerant pipes enter the building.

Winter condensation often occurs on the room side of exterior walls and results in unsightly molding of the surface. This is chiefly a problem of small, tightly constructed homes in which moisture released in the living quarters has limited opportunity to escape.

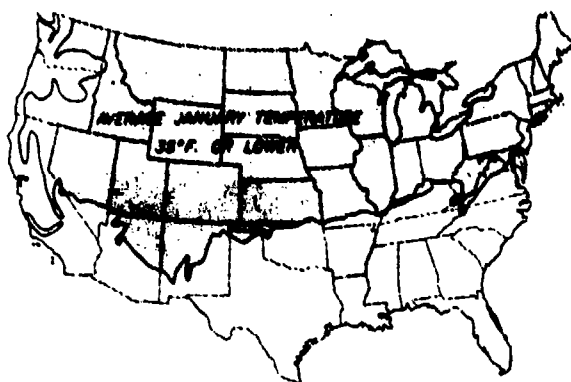


Figure 10.--Moisture problems from winter condensation in exterior walls occur most often in the North where the average temperature for January is lower than 35° F.

(M 682 21F)

Condensation Associated With Heat Radiation

Exposed surfaces cool at night by heat radiation. On a clear, still night the surface temperature of a building may drop 10° F. or more below that of the surrounding air. In the Southern States and the tropics, this leads to condensation on exterior surfaces. The condensate is absorbed by unpainted wood but collects as a fine film on painted surfaces; this commonly leads to surface molding and nonadhesion of oil paints on repainted surfaces.

Although not completely verified, condensation induced by heat radiation probably explains mold on the underside of thin roofs, as in carports, stoops, or exposed unboxed eaves. In some localities, condensation is heavy on screens, streaking

the wire and wood below or soaking into the frames as it runs down.

Condensation on Ground- line Slab Foundations

In humid climates, condensation often occurs on slab foundations. Cooled by the supporting ground, the slab acquires a dewpoint temperature. The same condition can occur in a building artificially humidified. Because condensation may be conspicuous at times, it has been suspected of dangerously wetting wood resting on the slab. Evidence does not support this.

In northern climates the periphery of the slab may cool below the dewpoint temperature during the winter. This presumably can induce condensation wetting of basal plates of the outer walls, but here, also, evidence is lacking.

Wetting By Piped Water

To a minor extent certain components of a building get wet enough to decay because plumbing leaks are neglected or tapwater is used carelessly. Fortunately, most plumbing leaks are found and corrected before serious damage results. An exception is the economically constructed shower stall that receives heavy usage--particularly the type in many military barracks. Observations of decay in wood framing and sheathing near the showers--particularly in the wood under the stalls--suggest unfamiliarity with the construction needed to maintain a watertight lining. Related to this type of hazard has been minor decay commonly occurring around tubs, kitchen sinks, toilets, and washtubs from water seepage into adjoining wood. Occasionally, a small water pipe leak will not be found until appreciable decay has occurred.

In lawn sprinkling, frequent, heavy wetting of siding can lead to a moisture problem. This is a possibility mainly in arid and semiarid areas where sprinkling is the main source of lawn moisture. Wetting sufficient to support decay of sheathing and framing can occur through a stucco facing.

Frequent and excessive washing of wood floors by hosing or mopping can lead to sufficient moisture accumulation to support decay; this has been observed in kitchens, school gymnasiums, and military drill halls.

Miscellaneous Wetting

Overflow from cooling towers for air conditioning sometimes results in excessive wetting of a wall. On a sloping roof, water may flow continuously over the eave, or the mist from the condenser may be blown against the wall.

An additional factor promoting decay is the metabolic water produced by the fungus itself as it breaks down the wood. This metabolic water weighs about half as much as the destroyed wood; therefore, it may be sufficient to support decay in poorly ventilated space despite slow losses by evaporation. In some crawl spaces, cold-weather condensation further retards drying of the wood.

PROTECTING FOUNDATION AND SUBSTRUCTURE WOOD

The foundation can do much to protect a wood building from decay organisms because it separates the wood from the ground. If properly constructed, the foundation bars moisture movement from the ground into the wood substructure. The kind of foundation--crawl space, slab, or basement--determines the type of protection needed.

Foundations With Crawl Space

A building set over a crawl space usually rests on a perimeter foundation wall; in addition, interior supports or piers may be used or, for large buildings, supplementary walls.

Foundation Materials

The perimeter foundation usually is of concrete or of brick or stone masonry. The poured concrete wall is less likely than the more loosely constructed masonry wall to have internal openings for the water-conducting decay fungus to pass through unnoticed. Masonry foundations and piers of hollow block or brick can be greatly improved by capping them with a minimum of 4 inches of reinforced poured concrete. A waterproof membrane such as polyethylene on top of a masonry foundation resting on damp ground has been reported to prevent capillary movement of water into wood resting on the wall.

Post supports are constructed of concrete, masonry, or wood. If of untreated wood, they should stand on well-elevated concrete footings. For this purpose precast footings are widely available. Pressure-treated wood pile supports below grade are, of course, used under large buildings in many areas.

There is a trend to use wood as the major foundation component, with the wood resting

directly on the ground. Basic types of wood foundation are pole, post-and-beam, joists-and-header, and plywood-frame (box beam). Wood foundations--particularly if expensive to replace--should be protected by the best preservative treatment that can practicably be used. The expense and effort that is justified to provide superior treatment will depend on the cost of the structure and the service life expected of the foundation.

Wood or wood-product forms should not be left on concrete foundation walls or posts. Forms make a bridge between the ground and the wood above it (fig. 11), creating easy access to the wood by water-conducting fungi.



Figure 11.--Wood forms left on a concrete pillar create a bridge between ground and substructure wood, making the wood vulnerable to attack by a water-conducting fungus.

(M 110 724)

Height of Foundation

The top of the foundation should be at least 8 inches above the finished grade and have at least 6 inches of foundation exposed below the siding in areas subject to some decay (fig. 12). A foundation height above grade of 12 to 18 inches is advocated for areas where frequent hard rains can cause significant splash wetting of wood siding, sheathing ends, or sills. In the crawl space at least 18 inches between joists and ground and 12 inches between ground and girders should be allowed. The greater interior spacing between ground and wood, as compared with the exterior spacing, allows for crawl-space inspection. The need for ample crawl space cannot be too strongly emphasized--a substructure that is difficult to reach may not receive adequate inspection.

Dry, Uninfected Lumber

The importance of using dry, uninfected lumber in the crawl space has been emphasized. Partially dry lumber in the substructure may not only be wet enough to support fungus growth, but may already be infected by a decay fungus. If moist, infected lumber is used and enclosed so it cannot dry readily, it is likely to decay rapidly--assuming, of course, temperatures also are favorable. Decay incurred in this manner is not prevalent, but when it does occur it can be costly because the affected wood usually is not readily accessible.

Precautions Against Condensation in the Crawl Space

Sufficient condensation to promote decay of sills, headers, joists, and subflooring may result from winter condensation or that associated with air conditioning by refrigeration. Winter condensation and most of that associated with air conditioning can be prevented by keeping the crawl space dry, with soil drainage, with ventilation, or with a soil cover. The method needed varies with the type of condensation. Where drying is impractical, the use of treated wood is necessary.

Soil drainage.--If the surface soil in the crawl space can be kept dusty dry by good drainage, the danger of condensation is small even if ventilation is substandard.

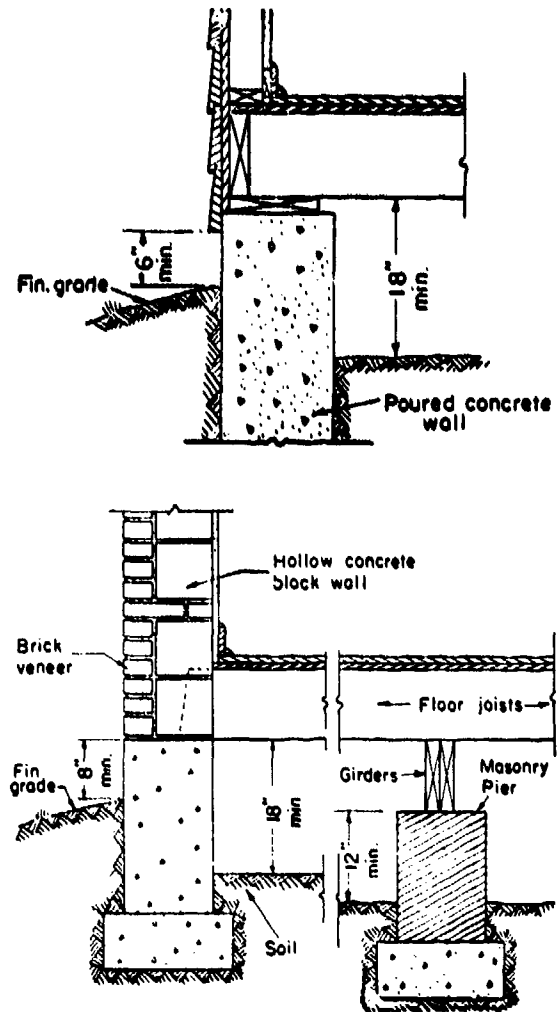


Figure 12.--Generally the distances shown are adequate spacing between ground and wood in substructure and siding; greater outside clearance is recommended for high-rainfall areas. Similar spacing is recommended if the foundation is a concrete slab.

(M 128 678)

Ventilation.--Good ventilation of the crawl space is a safeguard against damage by decay fungi. Vent openings in the perimeter foundation should provide cross movement of air if they are placed uniformly around the perimeter and as near corners as possible without reducing the strength of the wall. Near-corner positioning is desirable because dead air is most common there. The total effective opening of the vents should be propor-

tional to the size of the space; openings totaling 1/160 of the ground area are adequate. Accordingly, a crawl space of 900 square feet would require a total vent area of about 5.6 square feet.

Screening reduces passage of air through vents by 25 percent or more. To compensate for this the screened vent area should be about a third larger than the 1/160. Also, if vents are below grade level, a somewhat larger size opening is needed. Shrubby placed in front of a vent can materially reduce its effectiveness.

Vent areas meeting the above standards are effective against winter condensation but not necessarily against condensation under air-conditioned buildings in high-humidity coastal areas (see "Protecting Special Rooms"). Also, since vents often are closed in cold weather, ventilation alone seldom can be relied on as a sole means of condensation control in cold climates. For this reason ground covers were developed.

Ground covers.--A good ground cover will effectively limit condensation if vents are closed during winter. A cover should be considered particularly where winter temperatures commonly are 50° F or below and ground surfaces are prevalently damp, or where there is air conditioning over a damp crawl space.

A good ground cover (fig. 13) will generally keep the substructure wood dry despite damp ground. If a cover is used, the vent opening area can be substantially less than has been recommended. A cover should not only have adequate vapor resistance but also sufficient strength to permit some traffic on it, because it may be necessary to crawl on the cover while making inspections or repairing plumbing, heating ducts, and electrical wiring. The crawl space also may be used to store certain materials, which place an additional burden on the cover.

Materials that have both vapor resistance and strength, yet are not costly, are 45-pound or heavier roll roofing and 6-mil polyethylene sheeting. A 4-mil polyethylene film often is used with a layer of sand or gravel on top to reduce the chance of physical damage.

The strips of ground cover should be overlapped slightly and the outer edges carried to the foundation wall. Special measures to limit escape of water vapor at the seams or edges are not necessary. The ground does not have to be perfectly flat, for in time the cover will conform to moderate surface irregularities.

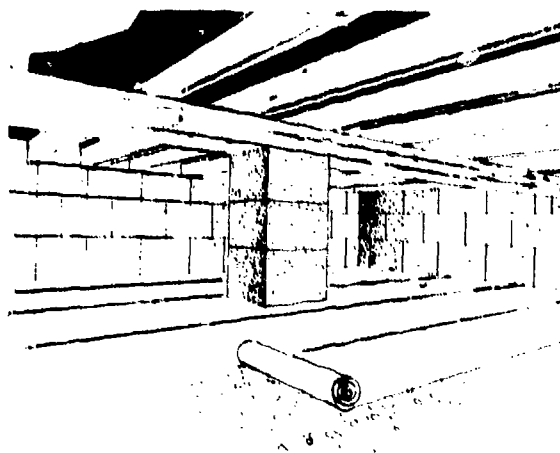


Figure 13.--Polyethylene sheeting, preferably 6 mil thick, or roll roofing, 45 pound or heavier, and certain duplex vapor-barrier materials provide excellent ground cover on damp soil in crawl spaces. A cover reduces the hazard of winter condensation (fig. 9) and of summer condensation in flooring of air-conditioned rooms above.

(H 124 710)

Concrete Slab Foundations

Slab Construction

In some areas the concrete slab-on-ground foundation has wide acceptance. Because it cannot be inspected beneath, the slab should be made as crackproof as practicable, and necessary openings through it should ultimately be tightly closed. Cracking can be minimized by good reinforcement of the slab. Joints can be avoided by making the slab a monolithic type in which the floor and footing are poured in a single operation. Joints and openings made for plumbing and conduits should be filled with high-quality coal-tar pitch or coal-tar plastic cement.

Elevation of Slab

The top of the slab foundation should be at least 8 inches above the finish grade, and wood or wood-product siding should come no closer to the grade

than 6 inches, as recommended for the perimeter wall of the crawl-space foundation. Where considerable rain splashing is likely, as in the Gulf States, a greater clearance is desirable; clearances of 18 inches are not uncommon.

Vapor Barrier Under the Slab

A membranous vapor barrier should be placed under the slab if conventional construction practice is followed. A membrane with suitably high vapor resistance will ensure that ground moisture does not migrate through the slab and warp wood floors resting on the slab, degrade the flooring finish, or damage the adhesive where floors are bonded to the slab. There is still some doubt whether, in the absence of a vapor barrier, ground moisture will penetrate a conventional slab at a sufficient rate to support decay.

Membranes may be heavy asphalts or polyethylene films. Effective barriers can also be installed above the slab, but this limits the finish flooring to a type that can be installed on flush sleepers.

Slab Insulation

In the colder climates, it is desirable to install thermal insulation around the perimeter of the slab and beneath it. This not only keeps the floors warm, but also limits condensation on the slab and wetting of wood in contact with the slab. The exact location of the insulation will depend on how the slab is constructed. The insulation for floor slabs should be nonabsorbent; have high resistance to heat transmission; have resistance to breakdown by moisture, micro-organisms, or insects; and have mechanical strength to withstand superimposed loads or expansion forces. Cellular glass, bonded glass fibers, and insulating concrete are available for the purpose. A thick gravel fill under the slab helps to reduce heat loss.

Because condensation may be conspicuous at times, it has been suspected of dangerously wetting wood resting on slabs. Evidence does not support this; nevertheless, because of the load-bearing importance and inaccessibility of substructure components resting on the slab, it is considered a wise precaution to pressure treat them. As just noted, the tendency for condensation can be substantially reduced by insulating the

perimeter and the ground side of the slab.

One should not attempt to prevent condensation on a slab by placing a vapor barrier on top of the wood. No ordinary barrier will entirely prevent condensation on the slab and what does occur will be prevented from evaporating by the overlying barrier. In addition, a moisture barrier so placed can be doubly dangerous if any significant amount of moisture comes through the slab from below.

Basement Foundations

Wood in the substructure is easiest to protect from decay organisms if the building is set on a basement foundation. The basement permits frequent inspection beneath the building. Also, the ordinary basement has a concrete floor and walls; thus there is no damp soil to cause condensation on substructure wood as in crawl spaces. However, damaging amounts of water can enter through cracks or joints by hydrostatic pressure. Therefore, adequate waterproofing of basement walls is essential, particularly on wet sites.

Any wood bearing posts in the basement should be elevated above the floor on footings to keep the lower end dry (fig. 14). The basement wall should extend above the exterior grade level at least 8 inches with at least 6 inches of the exterior surface exposed, and precautions of construction should be as noted for crawl-space walls.

Porch Foundations

The same precautions should be observed for a porch foundation as for the main foundation. If the porch has a wood floor, provision should be made for ventilation and inspection beneath it, and the height of the foundation above grade should be at least 8 inches. The bottom of platform joists should be high enough above the ground to permit inspection from beneath. Whether the porch floor is of wood or concrete, it should slope away from the building to allow rainwater to drain.

Porches constructed by pouring a slab platform on a dirt fill can create a special kind of decay hazard. The proximity of the dirt fill to the building substructure violates the guiding principle of keeping wood and soil well separated. Unless an appropriate barrier is placed between the porch

and the building, fungi, especially the water-conducting type, can move into the building substructure along the line of juncture.

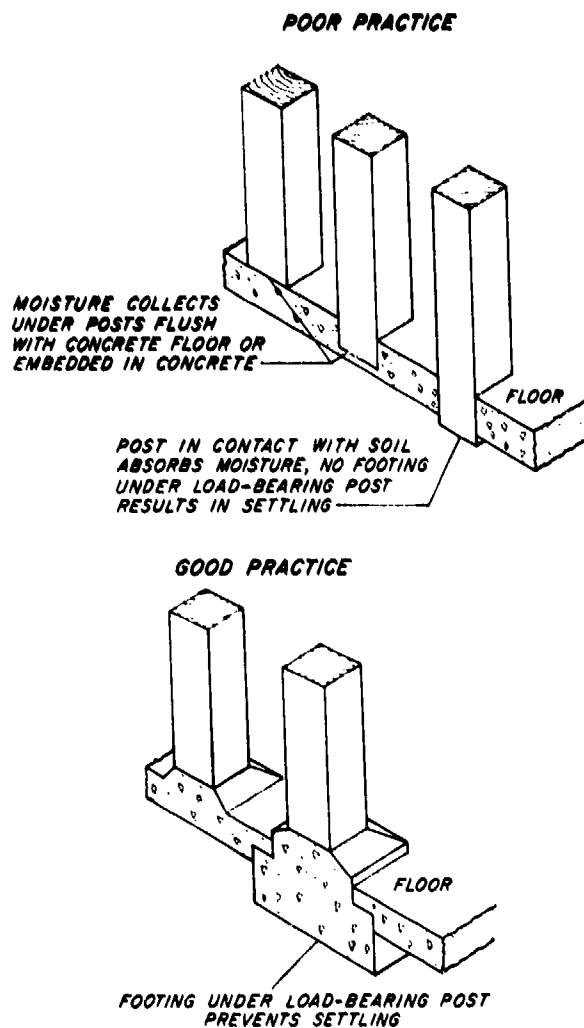


Figure 14.--Poor (top) and good (bottom) methods for installing wood posts on a concrete floor at ground level.

(M 136 613)

The dirt-filled porch can be made reasonably safe by building it independent of the house at all points and providing a 2- or 3-inch airspace that can be covered at the top. This necessitates adding

⁵Federal Supply Service, General Services Administration. Federal Specification TT-W-571, Wood Preservation, Treating Practices.

⁶American Wood Preservers Bureau. FDN-78. AWPB Standard. Quality Control Program for Softwood Lumber Timber and Plywood Pressure Treated with Water-Borne Preservatives for Ground Contact Use in Residential and Light Commercial Foundations. AWPB, P.O. Box 6085, 2772 South Randolph Street, Arlington, Va.

a porch foundation at the end toward the house; it is well worth the extra cost. An alternative is to pour the porch slab and building foundation as a monolithic concrete structure without joints. Also, a metal shield can be used to protect the sill area but care is needed to ensure adequate termite protection (see Additional Reading at the end of this report). With a slab-on-ground building no danger exists if the porch slab is at a lower level than the building slab.

The above precautions also apply to terraces, steps, and other horizontal surfaces adjacent to the building foundation.

For the safest type of porch, step, or terrace, the dirt fill is avoided and a self-supporting slab is used for the platform. Provision must be made for removal of any wood forms under the slab.

Preservative Treatment of Wood in Foundation and Substructure

Foundation wood, or substructure wood that is in direct contact with the ground or laid on a moisture-resistant ground cover, should be given the best practicable preservative treatment, especially if it is intended to serve for the life of a permanent building. The preservative type and amount should meet the highest standards prescribed for land service by Federal Specification TT-W-571⁵, or by Standard AWPB-FDN⁶. Major building codes and the U.S. Department of Housing and Urban Development (FHA) Minimum Property Standards require that each piece of lumber and plywood in wood foundations be identified with the American Wood Preservers' Bureau (AWPB) "FDN" grademark to indicate conformance with standards that were developed for wood foundations.

Generally, wood items in or on a slab foundation or on other concrete laid on the ground should be pressure treated unless experience indicates that less complete protection will adequately serve. Items in contact with an elevated foundation wall ordinarily do not require preservative treatment, but if they are closer than 8 inches to the ground, and in a warm damp climate, pressure treatment is suggested.

If part of the crawl space is used as a plenum to conduct air for heating or cooling, wood used in the substructure should be treated with one of the

waterborne chemicals and not with an oil. Oil fumes could contaminate the air within the building.

PROTECTING EXTERIOR WALLS, BUILDING APPENDAGES, AND ASSOCIATED WOODWORK

Although in individual cases the most damaging and costly decay can occur in load-bearing components of the substructure, in total the most prevalent and costly decay occurs in exterior items such as windows, doors, porches, steps, railings, walls, and associated woodwork. The greater prevalence of decay in these exterior parts is chiefly caused by exposure to wetting from rain. Less common, but significant, sources of wetting are condensation, use of wet lumber, careless sprinkling, ground contact, and ground splash.

General Protective Measures

Use Dry, Uninfected Lumber

Proper moisture content and freedom from infection can be obtained most reliably by using lumber that has been kiln-dried and kept under cover.

For best performance, siding and trim should have a moisture content when installed of 7 to 12 percent in the dry Southwest and of 9 to 14 percent in the remainder of the United States (table 2).

Table 2.--Moisture contents recommended for wood at time
of installation

Use	Moisture content (based on oven-dry weight)					
	West ¹		Coastal areas ²		Other areas	
	Average		Range		Average	
	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
Interior finish	6	4-9	11	8-13	8	5-10
Softwood flooring	6	4-9	11	8-13	8	5-10
Hardwood flooring	6	5-8	10	9-12	7	6-9
Siding, exterior trim, sheathing, framing	9	7-12	12	9-14	12	9-14

¹Most of eastern California, Nevada, Utah, and western Arizona and contiguous parts of Oregon and Idaho.

²Mainly the warmer coastal regions: California south of the Bay area, and the South Atlantic south of Chesapeake Bay and across the Gulf States to Texas.

³Range is generally more important than average. If pieces fall within the range, condition will be satisfactory regardless of average.

Protect Stored Lumber

The importance of proper lumber storage cannot be overemphasized. Much of the rapid deterioration of wood in use can be traced to incipient fungus infections originating during air-drying or storage. Lumber and other wood items should be protected against wetting from the ground and from rain; this is necessary to prevent incipient fungus infections and to ensure that the lumber is maintained at the moisture content suitable for a particular use (table 2). Even for temporary storage, as at a building site, lumber should be stored off the ground.

At permanent storage areas, lumber is usually placed under a roof for protection; in transit or at a building site, it may be kept under tarpaulins or plastic covers. Finish items should not be delivered to a building site until the structure has a tight roof and walls that provide indoor storage.

Commonly available on the market is lumber, mainly framing and sheathing, that has been dip-treated with emulsions of water-repellents dyed red, yellow, purple, etc. The water repellents used do not meet Federal Specification TT-W-572⁷ and contain no fungicide. These treatments are intended solely to reduce rain wetting during transit, storage at the building site, and the early stages of construction. However, they do not eliminate the need for protecting lumber from rain wetting and soil contact during storage. Where moderate protection of the completed structure is required, they should not be used in lieu of water-repellent treatments meeting Federal Specification TT-W-572.

Lumber at permanent storage sites should be placed on foundations of concrete or treated wood or in a dry shed with a dry concrete floor where it may safely be kept on untreated skids or pallets. If the soil has not been treated with an approved insecticide in areas with appreciable termite hazard, the foundations should be high enough to permit inspection below the piles.

Lumber with no more than 20 percent moisture can be bulk-piled under cover with safety. Wet lumber should be put in a ventilated space on dry stickers as in a regular air-drying pile.

When receiving lumber, do not assume that lumber supplied as "dry" is as dry as it should be. It is highly desirable to make sure with an electrical

moisture meter; with its needlelike penetrating electrodes the instrument rapidly indicates the interior moisture content (fig. 15). Moisture meters that do not require penetrating electrodes also are available for use with finish items and plaster.

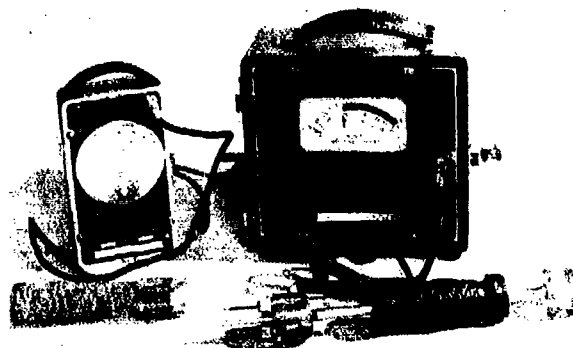


Figure 15.--Resistance-type moisture meters showing needlelike electrodes that are driven into wood to measure moisture content. Electrodes are commonly 3/8 inch long (left) but longer (right) are available for deeper penetration to determine moisture contents when searching for hazardous amounts of moisture in building members.

(M 117 486)

Provide Roof Overhang

The extent of roof overhang is the single most important design feature determining the amount of wetting of walls, windows, and doors in any climate. The addition of gutters reduces wetting from splash and wind-driven roof runoff. The protective value of roof overhang varies with the width of projections, amount of rainfall, duration of rains, and the amount of wind accompanying the rain. An overhang of at least 2 feet on a one-story building is recommended in areas of substantial rainfall.

Avoid Wetting By Splash

Splash damage occurs where roof runoff strikes

⁷Federal Supply Service, General Services Administration. Federal Specification TT-W-572, Wood Preservative; Water Repellent.

the ground or a lower roof and wets the wall (fig. 8).

The logical control of splash wetting is a wide roof overhang or an efficient eave gutter. Where splash is limited to a small area, such as a stoop, a roof-edge baffle can be used, although this is less satisfactory than a gutter. Also, splash can be reduced by making the foundation high enough to provide good separation between the ground and the wood.

Minimize Construction That Traps Water

The serious rain wetting of wood in buildings occurs primarily at joints. Therefore, in exterior construction, joints and other forms of contacting surfaces should be avoided where possible. Exterior bracing, for example, can be a water-trapping hazard, whereas interior bracing is safe (fig. 16). Similarly, an exterior step newel constructed of two 2 by 4's is more hazardous than one 4 by 4, or the use of subflooring for stoops is more hazardous than a single floor (fig. 16). Of course, when double construction is accomplished by laminating with a waterproof glue, a piece is essentially solid and without joints so long as the glue line is intact.

Tight joinery, paint, and calking are aids rather than primary means to prevent rain seepage. On structures exposed to heavy rainwash, they should not be exclusively relied on to prevent excessive seepage.

Where there is heavy rainwash or some other form of intermittent, heavy wetting of the surface, a good water repellent properly applied can aid considerably to keep joints from getting wet. Although it will not prevent gravity flow of water into loose joints or prevent penetration of rainwater when driven by unusual wind pressures, the water repellent nevertheless effectively interferes with capillary movement of water into reasonably tight joints. (See "Degree of Preservative Protection Needed.")

Design to Shed Water

Insofar as possible, building components should be designed to: (1) Divert rainwater from joints and other water-trapping places exposed to the weather, and (2) allow whatever water reaches critical surfaces to drain rather than stand long enough to soak into the wood.

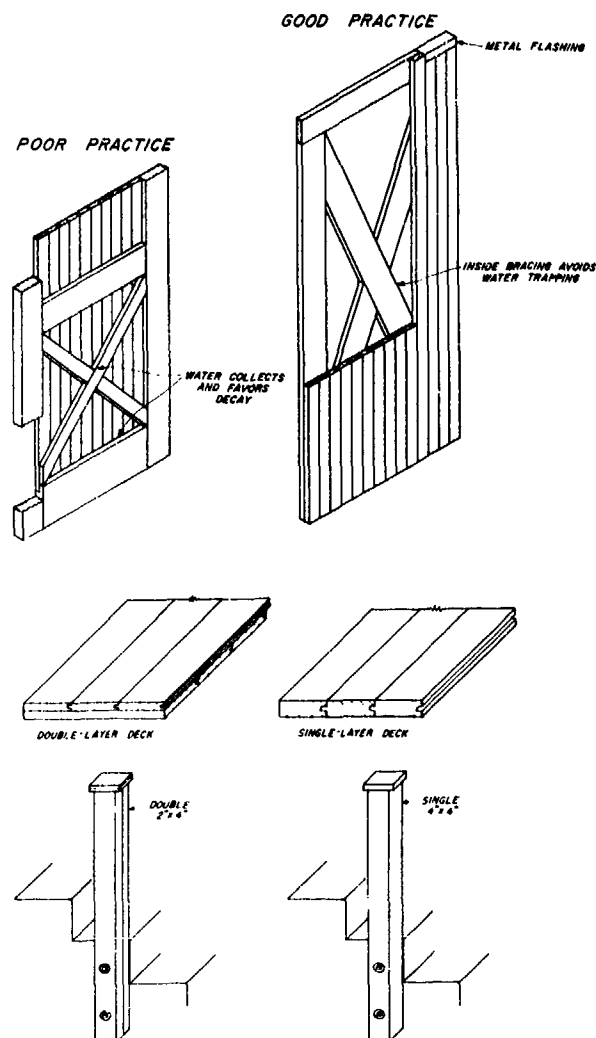


Figure 16.--Poor (left) and good (right) practices in construction to avoid trapping rainwater. Double thicknesses of lumber and exposed contacting surfaces--especially those required by architectural frills--should be avoided as much as possible

(M 124 862)

Good examples of how the absence or presence of water-shedding construction can favor or deter accumulation of rainwater are found in the building of exterior boxed beams. When a roof beam is boxed, the soffit is sometimes extended beyond the exposed fascia and rainwater collects on the ledge thus formed and seeps into the boxing. If the fascia is extended down beyond the soffit, this is prevented (fig. 17).

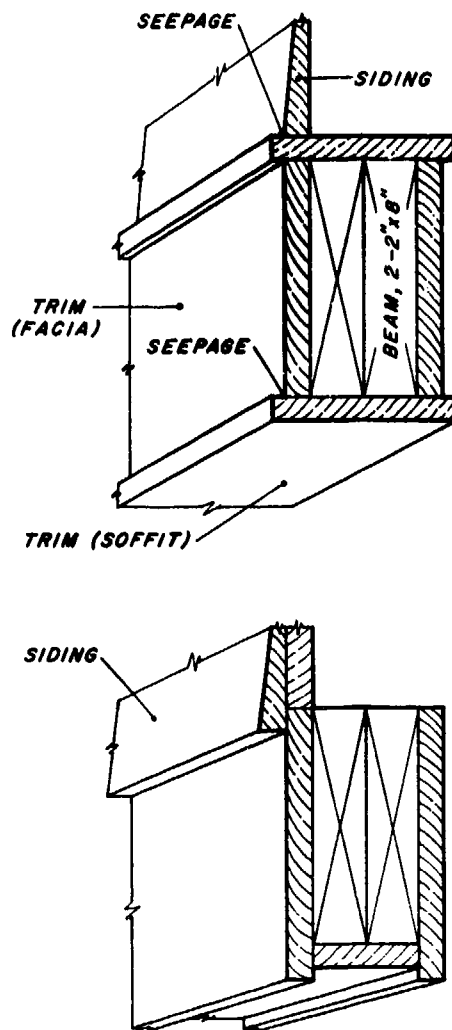


Figure 17.--Boxed beam (top) has horizontal ledge that traps rainwater. Boxed beam (bottom) illustrates good construction; boxed similarly to the standard eave, it is less subject to rain seepage because it does not have the rain-trapping ledge.

(M 124 971)

For minimum maintenance, roofs should be sloped sufficiently to allow rainwater to run off rapidly. The number, location, and size of drains and the needed roof and valley pitch vary with climatic areas and particularly with the amount of rainfall. Long, low-pitched valleys on large buildings are particularly hazardous. Interior drains, strategically located, often are desirable. Roof design should prevent runoff from striking an exterior wall or another roof below. This is accom-

plished by providing for adequate overhang, gutters, or baffles--according to circumstances.

Flat roofs must be especially well protected against leakage to offset their poor drainage features; hence they need regular, careful inspections coupled with timely maintenance.

Components, such as step treads, porch or stoop flooring, and window sills, all with relatively broad, flat surfaces exposed to weather, will wet easily and be susceptible to decay if the upper surface is not sloped to facilitate drainage. Flat-sawn lumber tends to shrink and swell more than quartersawn (edge grained) and this disadvantage is particularly pronounced in wide boards. Consequently, flatsawn step treads and flooring are more apt to cup and hold water; flatsawn siding and trim are more apt to split, warp, or twist after attachment and break paint films or crack caulking. Most of this trouble is in proportion to the severity of exposure. Much lumber is flatsawn, but quartersawn material is available if specified.

Unnecessary horizontal projections from the building wall, such as water tables and lookouts, frequently become decayed and should be avoided in the wetter climates unless treated with preservative or made of a naturally decay-resistant wood.

Install Flashing Where Special Safeguarding is Needed

Noncorrosive metal or durable waterproof felts are used as flashing to prevent rainwater from entering critical junctures of exterior components of buildings. These include joints where siding joins the roof (dormers, porches, and canopies), the top of window and door trim where unprotected by sufficient roof overhang, the juncture of siding and a concrete porch slab, horizontal joints between panel siding, roof valleys, and at the roof edge--between roof cover (shingles) and sheathing. Generally, flashing should be used wherever a horizontal projection from the wall occurs in an exposed location (fig. 18).

In applying flashing, nails should not be exposed, except in unusual cases where the nailing is through a surface that will not be wetted by rain. Nailing through the exposed vertical part of roof-edge flashing can lead to serious leakage. Roof-edge flashing should be attached below the underlay paper. This is particularly necessary in a tile

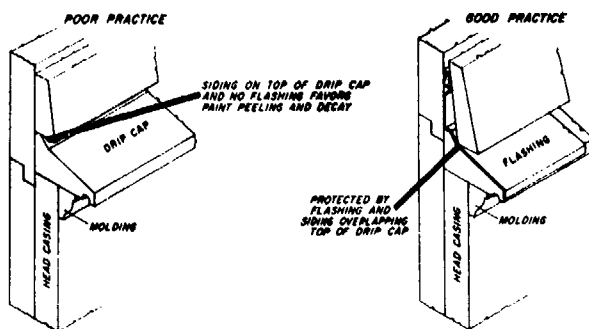


Figure 18.--Joining of siding to a drip cap; note how the "poor practice" (left) allows for entry of rainwater into several decay-vulnerable joints, whereas "good practice" (right) provides protection by flashing and by siding overlapping top of drip cap. (M 136 614)

roof in a tropical area because during heavy rainfall water flows over the tile cup edge and drains over the underlay paper to the roof edge.

Flashing is sometimes used to protect exterior load-bearing items such as projecting roof beams and laminated wood arches. If this style of construction is wanted, it is much safer to use adequately treated wood rather than to depend on the more temporary protection offered by flashing.

Treat With Water-Repellent Preservative

Exterior woodwork is often made additionally resistant to rain wetting and decay by dip treating the finished or knocked-down item in an oil solution of a water-repellent preservative. Some items commonly protected by this treatment are screens, sash, shutters, doors, siding, and trim. High-hazard items, such as porch rails and outdoor steps, may need pressure treatment in areas most conducive to decay (fig. 6). Limited protection to siding, trim, and other items under moderate-to-light wetting exposures can be attained in all areas by flooding with brush or spray after the wood is on the building, with particular attention given to joints.

Water-repellent treatments are discussed in "Preservative Treatments for Building Lumber."

Install Vapor Barrier for Walls in Cold Climate

In areas with long, cold winters (fig. 10), con-

densation that results chiefly in paint failure may occur in walls. This happens particularly where artificial humidification is used without appropriate precautions and in small homes in which humidity is high because of crowded occupancy.

This type of condensation can be prevented by using a vapor barrier (table 3) near the inner surface (warm side) of the wall; by avoiding excessive artificial humidification of the living quarters; and by improving--when needed--ventilation of small living quarters.

Only two situations warrant placing the moisture barrier elsewhere than on the inside of the wall. In warm humid climates when severe air conditioning by artificial cooling is used for long periods or in cold-storage rooms with refrigerant cooling, the vapor gradient is reversed, and the barrier should be near the outer face of the wall.

Protecting Siding

Wetting of siding tends to be troublesome mainly by causing paint problems, but a large amount may nevertheless promote decay of the more susceptible woods. Similarly, wetting can induce mold discoloration of paint and of unpainted surfaces. Protection of siding is not difficult.

Good Construction for Siding

Lumber siding.--If lumber siding is vertically alined (boards and battens or boards with interlapping joints), no special construction details are necessary to protect it.

If lumber siding is horizontally alined, as is most common, certain helpful precautions can be taken. Added protection can be given to drop siding, where appearance permits, by applying trim over the ends of the siding. Standard drop siding is less subject to rain seepage than such patterns as tongue-and-groove with a beveled lower edge. With bevel siding, the conventional metal cover applied over the corners of each siding course gives good protection against rain seepage. Bevel siding with smooth back surfaces wets much less from rain seepage than does rough-backed siding. This is particularly true of redwood and cedar siding. These additional protective measures are of particular value in high-rainfall areas.

If narrow plywood or hardboard is used to simulate horizontal lumber siding, the protective needs are essentially those of the lumber siding. The material must be strictly of exterior grade.

Where siding abuts a roof, as on a dormer, it is advisable to leave a 2-inch clearance between siding and shingles in high-rainfall areas and 1 inch elsewhere, thus exposing 1 to 2 inches of flashing. This prevents roof runoff from contacting the end grain of the siding. Also, it is a good practice to leave a minimum of 6 to 12 inches of clearance between siding and gradeline (depending on climate) and 1 inch between siding and slabs of porches. These suggestions also apply to shingle and panel siding.

Except for cold storage rooms and occasionally air-conditioned quarters, only the breathing type of sheathing paper (table 3) should be used under wood siding.

Shingle siding.--Most shingles are of naturally decay-resistant wood. Consequently, decay problems are few if good building practices are followed. With a single coursing, the overlap must be sufficient to ensure a continuous double layer to prevent water from seeping behind the shingles. Any nailing strips should be of decay-resistant or preservative-treated wood.

In applying asbestos-cement shingles, special attention should be given to proper application of felt backer strips at all vertical joints, to proper flashing at corners and trim, and to caulking at juncture of siding and trim.

Panel siding.--For siding of plywood or of hardboard panels, only exterior-grade material is acceptable. The glue bond between veneers or between wood particles in interior-grade material will not withstand wetting. The following procedures are recommended for installing wood panel siding:

1. After the panels are in place, flood the joints with double-strength preservative (10 percent pentachlorophenol plus water repellents). A squirt-type oil can or small pressure-type sprayer can be used to advantage.

2. Prime the joints with a good quality paint primer of white lead in linseed oil, with no zinc pigment (Federal Specification TT-P-25⁸).

3. Protect the horizontal joints with flashing commercially available for the purpose. Do not use horizontal batten strips.

4. Protect the vertical joints by filling with the best grade of weather-resisting mastic or caulking compound (allowing space in the joint) or by covering the joints with batten strips of decay-

Table 3.--Principal uses of building papers and specifications

Vapor barrier	Use	Federal specification	FHA Conformance (according to "FHA Minimum Property Standards one and two living units," May 1963)	Commercial products not covered in specifications
Heavy duty ¹	Refrigerators, ground covers, vapor barriers under concrete slabs, swimming pools, shower rooms, garbage rooms	UU-B-790a ² , Type I, Grade A; 45-lb. or heavier smooth surface roll roofing (polyethylene membrane ³)	Passes FHA "Test Procedure for Vapor Barrier Materials under Concrete Slabs and for Ground Cover in Crawl Spaces," (Sept. 20, 1957)	Various existing and new products being developed to meet FHA requirements
Ordinary service	Side walls and under attics or roofs	UU-B-790a ² , Type I, Grade A	Transmission rate not exceeding 1 perm	Foils mounted on paper or on back of sheet rock; Mylar 2-mil polyethylene
Sheathing paper	Under wood, shingle, asbestos stucco siding ⁴	HH-R-595 ⁵ , Type I or II	Saturated felt. Complies with ASTM D-226 or F.S. HH-R-595 ⁵	Tarred or asphalt felt, 15 lb. per square
Floor liner	Wood floors frequently scrubbed	UU-B-790a ² , Type I, Grade D		
	Wood floors infrequently scrubbed	UU-B-790a ² , any class, any type; HH-R-595 ⁵ , any type	No. 15 asphalt-saturated felt	Building paper, deadening effect
Roll roofing	Roofing to temporary buildings			Roll roofing available in weights of 45, 55, 65 lb. or more per square (108 per sq. ft.)
Roof underlayment	Waterproof membranes used under slats, tile, or asphalt shingles	UU-B-790a ² , Type I, Grade C; HH-R-595 ⁵ , Type I or II	Saturated felt. Complies with ASTM D-226 or F.S. HH-R-595 ⁵	

¹Represents material having a perm value of 0.25 or less and sufficiently rugged to withstand some abuse in service.

²Building paper, vegetable fiber (Kraft, waterproofed, water repellent, and fire resistant).

³Also Commercial Standard CS 238--6 mil polyethylene membrane (construction, industrial, and agricultural applications).

⁴30-lb. felt is sometimes used under some kinds of siding. Because this material is much more resistant to movement of water vapor than 15-lb. felt, vapor barriers used in combination with sheathing paper consisting of 30-lb. felt should have a perm value of 0.25 or less.

⁵Roofing felt (coal-tar and asphalt-saturated felt rolls; for use in roofing and waterproofing).

⁸Federal Supply Service, General Services Administration. Federal Specification TT-P-25, Primer, Paint, Exterior (Undercoat for Wood, Ready-Mixed, White and Tints). 1965.

resistant wood. Both caulking and battens may be needed in the wettest climates.

5. Carry the bottom edge of the lowest panel down over the supporting framing to form a drip edge.

Treating Siding With Water-Repellent Preservative

Treatment of board siding with a water-repellent preservative can be beneficial in the wetter climates. The treatment minimizes entry of rainwater behind the siding, thereby limiting damage from decay and sap stain and reducing the tendency toward paint blistering (fig. 19). This is especially pertinent for two-story houses and one-story houses with a roof overhang of less than 2 feet, particularly if there are no gutters.

Treating ordinarily cannot be justified solely for protection against decay and stain if the siding is of naturally resistant woods, such as the heartwood of western redcedar or redwood. However, a good water-repellent preservative protects siding of all species against paint blistering. Because blistering is a major problem of paint maintenance, the use of a water-repellent preservative is advisable wherever the rainfall and type of roof construction subject the siding to considerable wetting.

Treating relatively unsheltered siding will provide worthwhile protection in all tropical regions and in areas within the United States with long warm, wet periods. The value of this protection will be greater where the rainfall is usually in prolonged periods rather than in short, heavy showers, and where winds often are sufficient to blow the rain against the siding.

In treating new pine siding before it is installed, a 3-minute dip or an equivalent vacuum treatment in a water-repellent preservative is recommended. The ends of the boards out on the job should be retreated by dipping or by liberal brushing with the preservative solution. The siding may also be spray treated before it is installed or after it is in place, but spraying is less effective than dipping before installation, especially for protection against decay. Treating in place involves applying the preservative solution generously around board ends at windows, doors, and corners, and to the lap joints between the boards.

⁹U.S. Department of Commerce. Water Repellent Non-Pressure Treatment for Millwork. Commercial Standard 262-62.

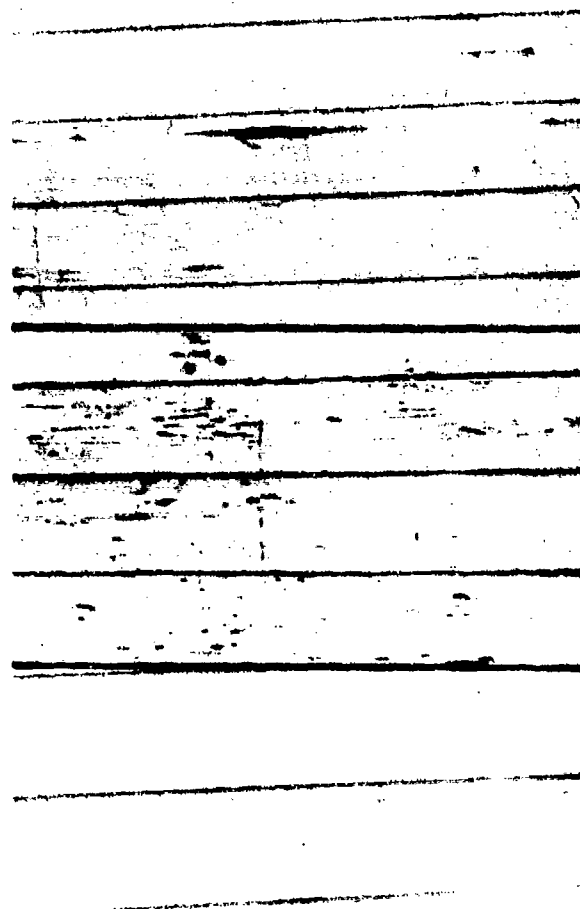


Figure 19.--Condition of siding after various treatments, 5 years after repainting: Top, Unsatisfactory. Spray treated with a water-repellent preservative over the old paint. Center, Unsatisfactory. Old paint removed but not followed by spray treatment. Bottom, Satisfactory. Spray treated after first removing old paint.

(M 128 128)

Cedar and redwood siding seem to be adequately treated by applying the preservative solution to the outer face or even just to the edges of the siding. Treating of siding of these woods is largely by brush application on the construction site.

Plywood panel siding ideally should be treated in accordance with Commercial Standard 262.⁹ This treatment presumably would be given by the manufacturer. If plywood siding is destined for the tropics, it should be pressure treated.

Protecting Roof Edges

The roof edge is especially subject to decay because it is in the open and exposed both to the direct wetting from rain and to wetting from roof runoff (fig. 8). Because it has one of the highest potentials for decay of any building part, it requires careful attention both in designing and during maintenance.

Roof runoff, particularly with asphalt shingles, tends to travel around the shingle butts and wet the various components of the roof edge. Corroded, undersized, occluded, or sagging eave gutters can lead to overflow at the back edge of the gutters and to wood wetting. Heavy rains sometimes cause water to overflow the joint channel in roof tiles and flow over the underlayment. When this occurs, the roof edge is subject to more wetting than it is from surface flow over the protruding tile edge.

Serious decay frequently occurs in (1) fascia, especially at joints between two fascia boards; (2) molding at the roof edge; and (3) rafter ends and sheathing edge, particularly when no fascia is used. In inexpensive or essentially temporary buildings, roll roofing is brought down over the roof edge and nailed to fascia, either with or without a nailing strip. The nailing strip is subject to direct wetting by water running off the roof; eventually water penetrates the roofing at nail punctures, leading to decay of the underlying wood.

Unless specially protected, exposed rafter and beam ends are vulnerable to decay in wet climates. If decay of fascia or sheathing edges progresses unchecked, it eventually will involve rafter ends, and greatly increase the cost of repairs.

Construction to Protect Roof Edges

The following five construction features are recommended to protect roof edges against rain wetting:

1. Extend shingles, tile, slate, or metal roof coverings at least 1 inch beyond any wood at the eave and rake edges.

The gable end, or rake, can be additionally protected by laying under the shingles a cant strip of bevel siding 1/2 by 6 or 8 inches, thin edge inward, along the gable edge, to guide the water away from the edge.

2. Use corrosion-resistant metal flashing on the eave and rake edges. With roofs covered with gravel or other aggregate, a gravel stop serves as the flashing. With other types of roofs, an L-shaped flashing is used (fig. 20). Also at the eave, place the underlay over the top of the flashing. Do not nail through the exposed vertical part of the flashing. Let the flashing extend away from the building sufficiently to provide a free drip edge. Bending the bottom of the flashing out from the fascia is not sufficient for this purpose; insertion of a 1-inch strip between the flashing and the fascia provides better protection (fig. 20). Occasionally the flashing is brought down to cover the fascia completely.

3. In northerly areas where ice dams cause trouble, install flashing to protect against water backed up by the dams. Lay smooth-surface 55-pound roll roofing on the roof sheathing from the eave upward 6 inches beyond the inside face of the stud line (fig. 21).

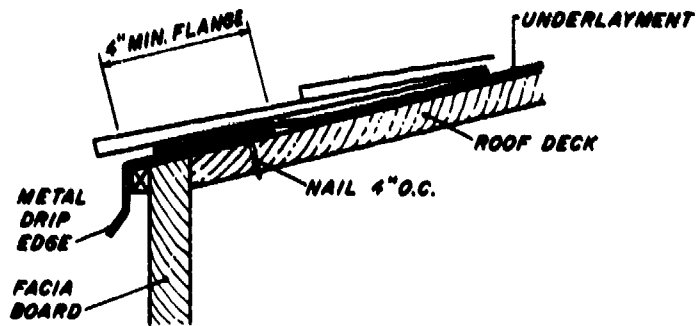
4. Particularly if the roof is flat, have the soffit area appropriately ventilated (fig. 22).

5. Avoid nailing roll roofing to the fascia (either with or without an exposed nailing strip) unless the fascia and nailing strip are of naturally decay-resistant or preservative-impregnated wood. The exposed edges of roll roofing should be secured, if possible, with a suitable adhesive rather than with nails.

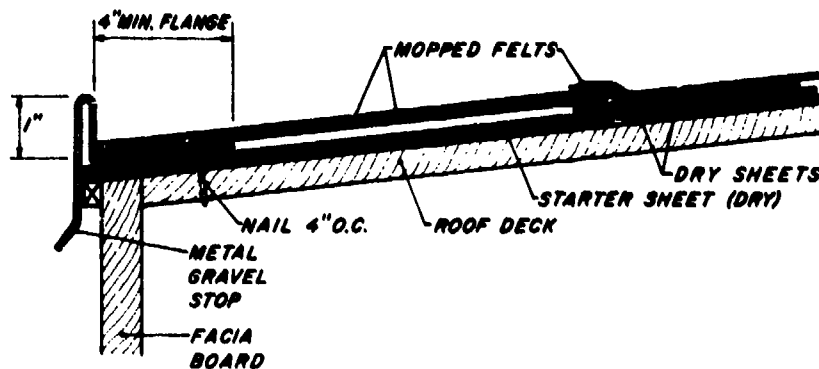
Preservative Treatment for Roof Edges

Fascia, nailing strips on roll roofing, and exposed molding can be given maximum protection by deep preservative treatment. Two treatments that will leave the wood paintable are: (1) Impregnation with pentachlorophenol (penta) in a volatile petroleum solvent and (2) impregnation with a waterborne salt. In areas of moderate rainfall, naturally decay-resistant wood or a 3-minute dip in a water-repellent preservative usually protects these items.

For exposed rafter ends in the wet climates, a minimum treatment would consist of dipping the ends or liberally brushing or spraying them with a water-repellent preservative (if pentachlorophenol, a penta concentration of 10 percent, or a double application of the conventional 5 percent solution, is desirable).



METAL DRIP EDGE-EAVES SECTION



GRAVEL STOP AT EAVES

Figure 20.--Appropriately designed metal flashing (top) and similar gravel stop (bottom) provide good protection to edges of built-up roofs. The turned-out lip of the flashing diverts much of the rainwater from the fascia and wall.

(M 124 972)

Protecting Building Appendages

Of all exterior components of buildings, appendages are most subject to maximum wetting from rain and to decay. Most decay in outside steps and stairs, porches, platforms, and similar appendages results from rain wetting. Soil contact also can lead to even more hazardous wetting of carriages and supports of steps and outside stairs, and except in the driest climates should be strictly avoided unless treated with preservative.

Construction for Protection of Appendages

In the wetter climates (fig. 6) design alone can

do little to prevent decay in appendages of wood buildings. In other climates, however, proper design can materially lengthen service life. Basic features consist of providing cover by a very wide eave, sloping the porch or similar deck to drain off rainwater, and keeping the construction simple to minimize joints and contacting surfaces in and between which water can be trapped (fig. 16). Depending on the wetness of the climate, these precautions can be supplemented by using treated or naturally decay-resistant woods.

Several procedures can minimize trouble from rain wetting of porches, stoops, platforms, and other flat decks exposed to the weather. Perhaps most important is to avoid double flooring (fig. 16). Others are to: Calk the joints in the flooring with white lead in oil if naturally resistant or treated wood is not used; promote drainage away from

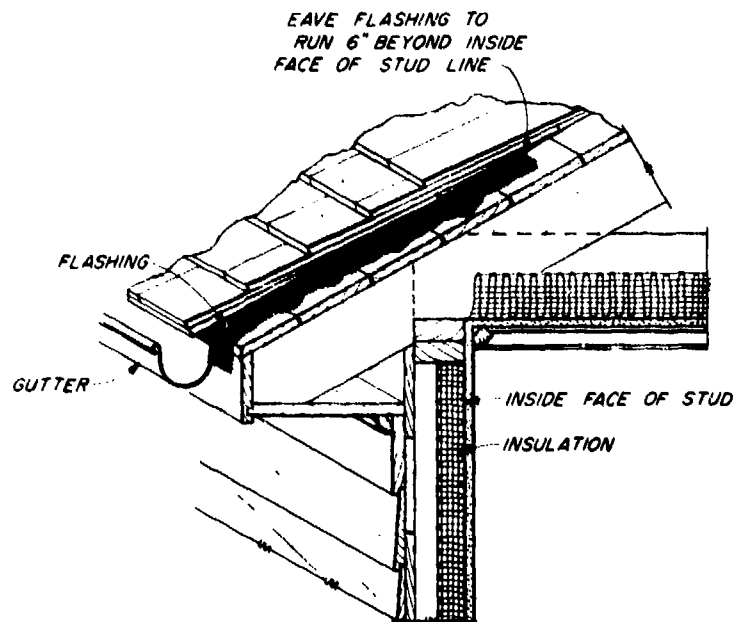
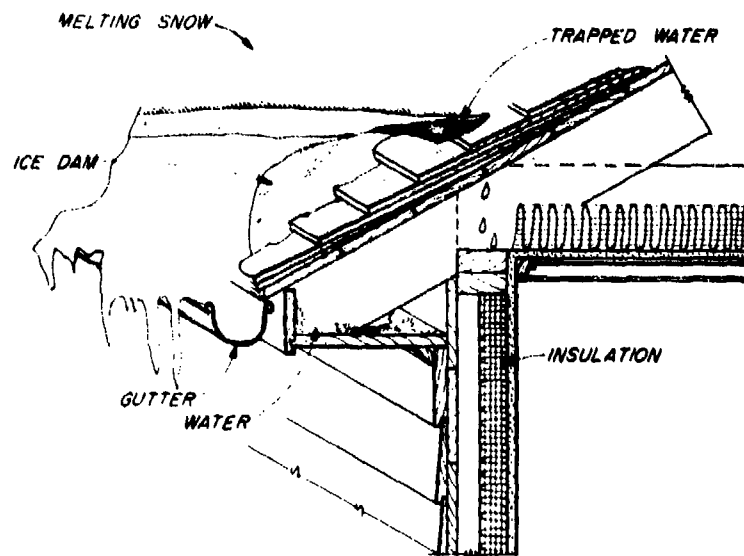


Figure 21.--Top, How exterior walls can be wetted by melted snow trapped behind an ice dam. Bottom, How flashing prevents wetting of exterior walls from snow water.

(M 955 77)

the building; and provide drain channels in the bottom rail of screens to keep the rail and window ledge dry.

As little molding or other trim as possible should be used. Railings should have a simple design with few joints into which water can seep, and components should be so joined that they can

be easily replaced if decay does occur. In boxing the roof beam across the front of a porch, the fascia board should extend below the soffit (fig. 17); thus there will be no horizontal ledge to hold water. Step rails should be placed over the top of the newel--not abutted to its side. An eave gutter should be provided to prevent roof runoff from

striking porches or other decks.

For porches a self-supporting concrete slab is much preferable to one on a dirt fill. If a dirt fill is used, the porch should be separated from the building or it should be constructed as described in "Protecting Foundation and Substructure Wood." All forms used in pouring concrete should be removed.

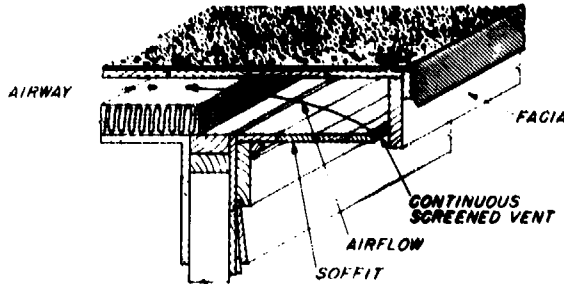


Figure 22.--Good roof-edge construction for a flat roof with a soffit at the eave. The soffit is continuously vented, and airflow is increased by an airway beneath the roof.

(M 134 935)

Preservative Treatment of Appendages

Because wood steps, stairs, porches, and other appendages cannot be adequately protected in a wet climate by design alone, they will have a longer service life if they are of naturally decay-resistant wood or are treated with a preservative. Framing or other items to be left unpainted can be pressure treated with any preservative covered by Federal Specification TT-W-571² that will be suitably free of discoloration or odor; for items that must be essentially free of oil for painting, only the waterborne salts or pentachlorophenol in volatile petroleum solvent should be used. These preservatives also are safest where there is possibility of discoloring flooring or other wood by oil creep along nails.

Water-repellent as well as fungicidal protection is often desirable. Suitable water repellents cannot be incorporated in a water solution to be applied by pressure, and if paintability is desired they should not be in an oil solution to be applied by pressure. But they can be added later by dipping or by spraying.

A short-soak (dip) treatment of 3 to 15 minutes in a mixture of pentachlorophenol and water re-

pellent in light oil, such as mineral spirits (Commercial Standard CS 262³), can add a great deal to the service life of many appendages (fig. 23). Woods with moderate natural decay resistance, like Douglas-fir, will give especially good service after dip treatment in a water-repellent preservative.

Protecting Exposed Load-Bearing Members

For architectural effects or for ease of construction, load-bearing members are sometimes exposed to wetting from rain (fig. 24). Laminated or solid arches in churches and gymnasiums are extended beyond the roof edge to a concrete abutment; purlins or roof beams are extended beyond walls; rafters are extended beyond roof decking; and sometimes the sides of heavy edge rafters or beams, particularly in flat beam-and-plank roofs, serve as fascia and are exposed to the weather and subject to a high seepage and decay hazard. Protruding parts of arches have been destroyed by decay within 4 years in warm, moist coastal areas.

Construction to Protect Load-Bearing Members

If load-bearing members, such as arches, rafters, and roof beams, must be exposed to appreciable wetting, they should be pressure treated. Metal caps or flashing will give considerable protection but should not be depended on to give long-time protection in high-rainfall areas. Metal sockets in which wood arches or columns rest should have a drain hole at the lowest point to prevent their serving as a reservoir for water.

Preservative Treatment of Exposed Load-Bearing Members

Only pressure-treated wood should be used for load-bearing members exposed to considerable wetting. Because of the relatively high cost and the load-supporting requirements, exposed arches should always be given a high-quality treatment. The preservative should be chosen for appearance, for paintability, and, in glued laminates, for its effect on gluing. For laminated wood, the fabricat-

ing company should be consulted for chemicals acceptable for treatment.

Exposed load-bearing items other than arches may be benefited in areas of low-to-moderate rainfall--and in wet areas if considerable protection is also afforded by roof overhang--by brush-

ing heavily or by soaking with a water-repellent preservative. This treatment would precede any installing of a metal cap. Penta-grease treatment (see "Preservative Treatments for Building Lumber") should be especially effective on the end grain of exposed members.



Figure 23.--Contrast between dip-treated steps (top) and untreated (bottom) after 5 years of exposure near Gulfport, Miss. On-site dip treatment consisted of immersing the precut lumber 3 minutes in a light oil solution of 5 percent pentachlorophenol and water repellent.

(M 128 614)



Figure 24.--Load-bearing wood members exposed to weather: Top, Laminated arches. Bottom, Exposed rafters. Exposed load-bearing wood in a permanent building should be pressure treated.

(M 134 934)

SPECIAL ROOMS PROTECTING

Shower, cold-storage, laundry, and air-conditioned rooms, kitchens, and enclosed swimming pool areas can have special moisture and decay problems. Decay in these areas, though small overall, is occasionally costly; the affected

wood ordinarily is not visible, hence damage may not be apparent until a wood member falls. Fortunately, there are usually indications of wetting before any significant decay occurs, and most difficulties can be easily avoided by good design.

Shower Rooms

Sources of moisture that promote decay in shower rooms are: (1) An occasional plumbing leak; (2) condensation in walls, ceiling, and floor; and (3) leaks through walls and floors. Even minor leaks can lead to costly decay. Wetting and decay are most acute in barracks and dormitories where shower rooms and stalls are heavily used. Condensation may be especially serious where rooms next to showers are air conditioned. Moisture may be reduced at its source by forced mechanical ventilation.

Decay-Resistant Construction for Shower Rooms

Shower rooms can be kept free of serious decay by the following conditions: (1) Watertight plumbing; (2) watertight lining of the walls and floor; (3) an effective vapor barrier as near as possible to the warm side of the walls, floors, and ceiling (also applicable to adjacent dressing rooms); and (4) decay-resistant wood framing and sheathing in the walls and floor, and resistant window sash and frames (if present).

Although the vapor barrier and the decay-resistant wood may not be needed for decay control in the average home; the vapor barrier nevertheless frequently helps to prevent early paint failures on adjacent siding. Regulated forced-draft ventilation is a good supplementary precaution to limit the buildup of vapor in a shower area.

For the home, individual shower stalls are often prefabricated of metal or fiberglass. Therefore they are usually watertight. In other construction the shower pan becomes a waterproof layer on the floor (fig. 25) except for slab-on-ground construction on the first floor.

Vapor-barrier material to be installed on the warm side of the walls, ceilings, and floors of the heavily used shower area will be of adequate quality if it meets Federal Specification UU-B-790¹⁰, Type I, Grade A. The shower pan itself serves as a vapor barrier under the area covered by it. If

the barrier membrane is attached to wood treated with an oil preservative, it should be polyethylene. Oils may damage asphaltic materials.

Walls should be waterproof, and the upturned pan edge overlapped at least 2 inches. A satisfactory wall material is waterproof plaster on galvanized wire lath, particularly when covered with tile or sheet metal with waterproof crimped or soldered joints. The effectiveness of panel liners will depend on how well holes made by the attaching nails are sealed. Special grades of smooth-surface asbestos-cement panels are satisfactory if the joints are properly sealed. Without precautions, leakage through joints between the panels can occur in the shower room. Joint seals can be made by using well-designed metal connectors or--if the appearance is acceptable--by gluing on batten strips of asbestos cement.

Holes for the entry of water pipes also are weak points in shower-room walls--particularly in walls with panel liners. These are not easily sealed. Locating entry holes as high as possible helps. In buildings where appearance is not a consideration, entry holes can, of course, be avoided by using surface piping. Shower and dressing rooms in particular can benefit from forced-draft ventilation, especially in air-conditioned buildings.

In cold weather, window ledges and frames in showers and adjacent rooms may rot from condensation running off the panes. This can be reduced by using double panes or storm windows. In general, windows should be avoided in shower rooms or over tubs fitted with shower heads.

Preservative Treatment for Shower Rooms

Wood window sash and frames in shower rooms and framing or sheathing in floors and walls should be pressure treated with a wood preservative. Trim above tubs with showers should also be pressure treated. A waterborne preservative is preferable (see Federal Specification TT-W-571¹¹). Vapor barriers should be polyethylene if attached to studs or joists that are treated with an oil preservative.

¹⁰Federal Supply Service, General Services Administration. Federal Specification UU-B-790, Building Paper, Vegetable Fiber (Kraft, Waterproofed with Water Repellent and Fire Resistant). 1968.

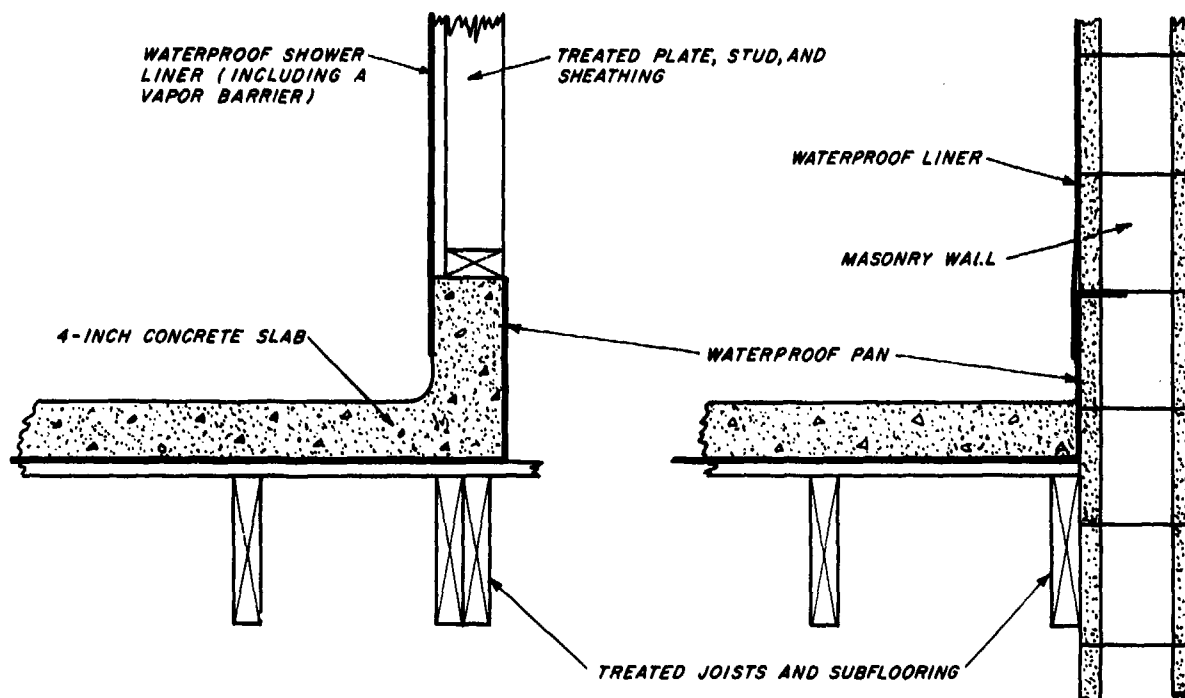


Figure 25.--Basic designs for heavily used shower rooms: Left, With wood-frame wall. A continuous waterproof pan encloses the slab and 8-inch wall curb. A waterproof liner overhangs the curb by several inches. Where an adjoining room also has slab floor, the slab can be broken to allow installations of the pan as shown. Right, With masonry wall. For masonry or concrete walls, the pan must be tied into the walls to prevent water that runs down the wall from getting back of the pan and seeping below the shower slab. The pan can be bent into one of the masonry joints or it can be secured to side of masonry wall and overlapped from above by a waterproof shower-wall liner. All adjacent wood is pressure treated.

(M 128 807)

Cold-Storage Rooms

Wood in walls, floor, or ceiling of a cold-storage room is subject to decay associated with condensation unless certain simple elements of design are incorporated. Also, fibrous or other hygroscopic thermal insulation may become waterlogged, and metal parts rust. Surface molding is common. The construction designs discussed here can be applied to any refrigerated space held at temperatures below 65° F.

In cold-storage rooms there are two distinct zones of condensation: (1) On inner wall surfaces and on stored products, and (2) within the walls, floor, and ceiling.

Vapor moves into a cold-storage room when a door is opened. Worn or inadequate gaskets on door jambs and on pipe openings through walls are also points of entry for water vapor. The walls and

stored products near the door, being colder than the incoming vapor, act as condensing surfaces and become wet. If doors are used frequently, some surfaces may be wet for long periods and become heavily molded. This is objectionable even though not a decay problem. Wet wall surfaces and room contents will gradually dry, however, if the door is left closed sufficiently long. The drying occurs because the temperature of the cooling coils is several degrees below that of the room and the coils act as condensers on which moisture in the room sooner or later collects.

Most materials used in constructing cold-storage rooms, such as wood, plywood, asbestos-cement, cork, plaster, and concrete, are, to varying degrees, permeable to water vapor; unless entry of vapor into the wall, ceiling, and floor is restricted, damaging condensation within these areas can be expected.

Construction to Minimize Condensation in Cold- Storage Rooms

A cold-storage room of typical frame construction, built next to an outside wall, is shown in figure 26; the vapor barrier and the thermal insulation are particularly essential.

Vapor barrier.--A vapor barrier must be installed in floors, ceilings, and all walls except those between rooms of the same temperature. All joints should be lapped at least 2 inches on walls, ceilings, floors, and at the junctions of walls with ceilings and floors.

The vapor barrier should be the heavy-duty type

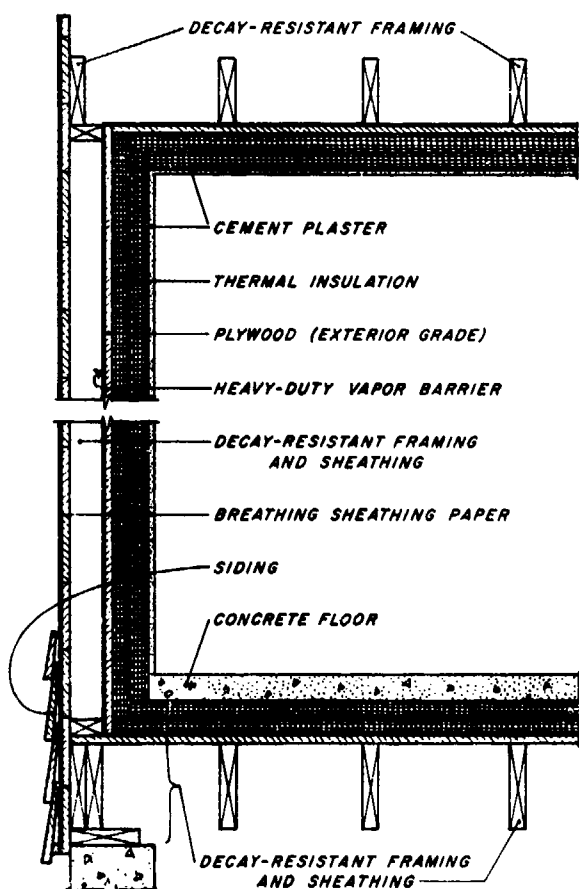


Figure 26.--Design for a cold-storage room to avoid moisture accumulation and decay in walls, ceiling, and floor. The vapor barrier is outside the insulation, conforming to the basic rule that a barrier used for controlling condensation must be placed on the warm side of a partition.

(M 124 970)

with a permeability not to exceed 0.25 perm and rugged enough to withstand considerable abuse (see table 3). Typical barriers of this kind are smooth-surface roll roofing weighing at least 45 pounds per square, duplex material, and 6-mil polyethylene film. If the barrier is to be placed against wood that has been creosoted or treated with a preservative containing a petroleum solvent, polyethylene film should be used.

The exact location of the vapor barrier will vary with the type of construction, but it must be on the warm side of thermal insulation. With frame construction, the vapor barrier can be installed on the inner faces of the studs and ceiling joists before the plywood sheathing is attached. In the floor, the barrier usually is laid over the supporting subfloor before the thermal insulation is installed.

A vapor barrier is also needed on the warm side of doors of wood or other vapor-permeable material. Steel bumper plates mounted flush on the inner sides of doors are not recommended because they act as vapor barriers on the wrong side of the door. It is safer to have an air-space between bumper and door. Flush steel bumpers might be safe if liberally perforated to permit vapor passage.

Insulation and room liner.--Thermal insulation is not needed in partitions between rooms of the same temperature but is needed in all other walls, floors, ceilings, and doors. It must be located on the cold side of the vapor barrier. To ensure that the dewpoint temperature will always be on the cold side of the vapor barrier, the amount of insulation needed should be calculated on the basis of the lowest temperatures expected.

If the vapor barrier is effective and the thermal insulation adequate, the type of the inner wall surface is immaterial. However, as an additional precaution it is well to have lining materials that are as vapor permeable as possible. If vapor leaks past the barrier, and can escape to the inside, it will then not build up within the wall. Unpainted cement plaster is a good liner.

An entrance area, or vestibule, to the refrigerated space will minimize the inflow of warm humid air because the first door can be closed before the second is opened. Vestibules such as these need tight-fitting entrance doors.

Preservative treatment for cold-storage rooms.--All framing and sheathing used in constructing a cold-storage room and the wood trim and doors should be pressure treated with an approved wood preservative. The safest preserva-

tive is a waterborne salt because it presents no problem of odor, oil creepage, or injury to barrier material.

Air-Conditioned Rooms

Air conditioning by refrigeration can create conditions in which condensation and even decay can result. Although these conditions are not widely prevalent, they are discussed here because of the rapidly expanding use of air conditioning and because little has been written about its potential for decay-favoring condensation.

The more moderate degree of cooling with air conditioning generates less condensation in spaces surrounding living quarters than is found in spaces around cold-storage rooms. Some commercial storage rooms may carry a moderately cool temperature of 65° F. or somewhat lower. Such rooms, although not much cooler than air-conditioned living quarters, should be treated in humid climates as cold-storage space.

Damage from Condensation

Damage from condensation caused by air conditioning occurs in the following forms:

1. Dimensional changes in flooring. Cupping of individual floor boards is the usual deformation; the boards remain attached, but turn up at the edges because the lower surfaces swell more than the upper, making slight ridges at the longitudinal seams. Cups will show through most sheet or tile coverings. Greater and more general deformation may occur if the flooring is laid at low moisture contents without appropriate spacing. The subsequent swelling may buckle the floor and create ridges several inches high in a number of boards.

Cupping or buckling should be taken as a warning to beware of condensation, not as evidence of its presence; these flooring defects can be produced without condensation by elevated wood moistures in equilibrium with the damp crawl-space atmosphere. Crawl-space air next to the floor is cooled and its relative humidity thereby increased. Thus, if the increase in relative humidity adjacent to the floor is great enough, the moisture vapor entering the wood may cause objectionable swelling without condensation.

2. Paint peeling, paint blistering, and molding on walls or ceilings.

3. Plaster failure and rusting of lath. Only occasionally does wall paneling cup or buckle.

4. Loosening of tile or linoleum. The loosening occurs if condensate accumulates at the adhesive line.

5. Decay. Usually is restricted to the top of the subfloor but sometimes includes all of the subfloor, the joists, and the lower face of the finish floor.

Construction and Temperature

Regulation to Minimize Floor Condensation

To minimize condensation in floors cooled by air conditioning, dewpoint temperatures in the floors should be prevented. Three general recommendations can be offered: (1) Have a moderate temperature in the air-cooled space, and maintain it no longer than necessary, (2) keep the humidity of the crawl-space atmosphere as low as practicable, and (3) install a vapor barrier on the warm, under side of the floor to limit vapor migration to the cooled surfaces.

The temperature of air-cooled rooms should be no lower than is necessary for comfort, and it should be maintained only when needed. Assuming a dry crawl space, indoor temperatures of 75° F. or above are safe even with continuous air conditioning. Some minor floor deformation may occur, particularly if floors are laid tight at a low moisture content. In rooms where many people congregate, the temperature may be safely lowered during periods of heavy use to maintain reasonable comfort. Also when conditioners are operated only during daytime, lower temperatures usually are safe. Intermittent cooling effectively precludes condensate accumulation by permitting drying when the conditioners are not in use.

A crawl space can be made dry by site drainage, ventilation, and the use of a vapor-resistant soil cover (as described in "Protecting Foundation and Substructure Wood"). A soil cover is most effective.

The condensate from air-conditioning units should be drained to the outside and provisions made to lead it away from the building, to prevent crawl-space wetting.

It is especially important to keep the crawl

space dry if the crawl space contains hot pipes. Hot pipes can increase temperatures in the space to such a level that, even with comparatively low relative humidities, the dewpoint temperature may be considerably above 70° F. In this case, troublesome condensation in the floor can occur despite moderate air conditioning. The condensation hazard is, of course, increased if the pipes carry steam and are leaking.

Vapor barriers properly placed and correctly installed prevent condensation caused by air conditioning when dewpoint temperatures cannot be avoided. They are especially appropriate for use in walls between an air-conditioned and an adjacent room; they also can protect floors against wetting from the crawl-space atmosphere.

When a vapor barrier is needed below the floor in a crawl space, practical difficulties arise. Installation is complicated by bridging, beams, pipes, and electrical conduits. Pliable films are extremely difficult to maintain if applied to the lower edges of joists; consequently, this type of application is not recommended. Rigid insulation board with a vapor barrier attached is much more dependable. It should be installed with the vapor barrier on the underside. Even better is blanket insulation material with a vapor barrier on one side; this is attached flush against the underface of the subfloor between joists with the vapor barrier exposed on the lower surface.

Construction to Avoid Condensation in Walls

Outside walls of an air-conditioned room do not normally require special construction to avoid condensation. Significant condensation in the outside walls is evidence that the air conditioning is too continuous, the temperature is set too low, or that both conditions exist. There should be little trouble in walls between kitchen or laundry and an air-conditioned room if the warmer room is reasonably ventilated and its walls are painted with one of the more vapor-impermeable paints, and if materials comprising the cold side of the wall are as vapor permeable as possible (to prevent such vapor as gets past the warm face from being trapped within the wall). Plaster on studs with the cold face painted with a latex-emulsion type paint having relatively low resistance to vapor would, for example, be good vapor-

permeable construction. Refrigerant pipes within walls must be adequately insulated or condensate can run down them and seriously wet wall plates.

If large volumes of steam or vapor are released in an adjoining room, forced-draft ventilation of that room is recommended; it may be additionally helpful to install a vapor barrier on the warm side of the separating wall. Requirements are the same as described for the barrier to prevent winter condensation in outside walls.

Indoor Swimming Pool Areas

Frame walls and the roof enclosing an indoor swimming pool are especially subject to condensation, decay, and paint problems unless preventive measures are taken (fig. 27). The basic difficulty with the swimming pool area arises, of course, because the pool has a large surface of heated water that gives off a great deal of warm moisture. In cool or cold weather, the situation is essentially the reverse of cold-storage rooms or air-conditioned rooms: The warm moist atmosphere is in the swimming pool area, and the relatively cold temperatures are on the outside.

Wall and Roof Construction for Swimming Pools

To avoid serious condensation in the swimming pool area five measures are suggested (1) Ventilate the area as much as practicable to decrease accumulation of moisture in the air. Forced-draft ventilation is especially helpful and should generally be provided in temperate climates; (2) install an appropriate thickness of thermal insulation within the walls and roof to prevent a dewpoint temperature being reached on the inner surfaces; (3) install a vapor-barrier membrane on the warm side of the wall studding and as near the warm surface of the roof structure as possible to reduce the amount of moisture vapor leaking into the walls and roof; (4) avoid highly vapor-retardant material in the outer part of the wall; and (5) provide for ventilation just below the roof cover. Precautionary measures (4) and (5) allow water vapor to escape to the outside if the vapor-barrier membrane on the inside does not wholly exclude vapor in amounts that might produce condensation.

Preservative Treatment for Wood
Enclosing Swimming Pools

If the foregoing precautions are followed, it should not be necessary to use preservative-

treated wood for sheltering the swimming pool. If treated wood is available at reasonable cost, it might be justified to ensure satisfactory performance, especially for the roof members.

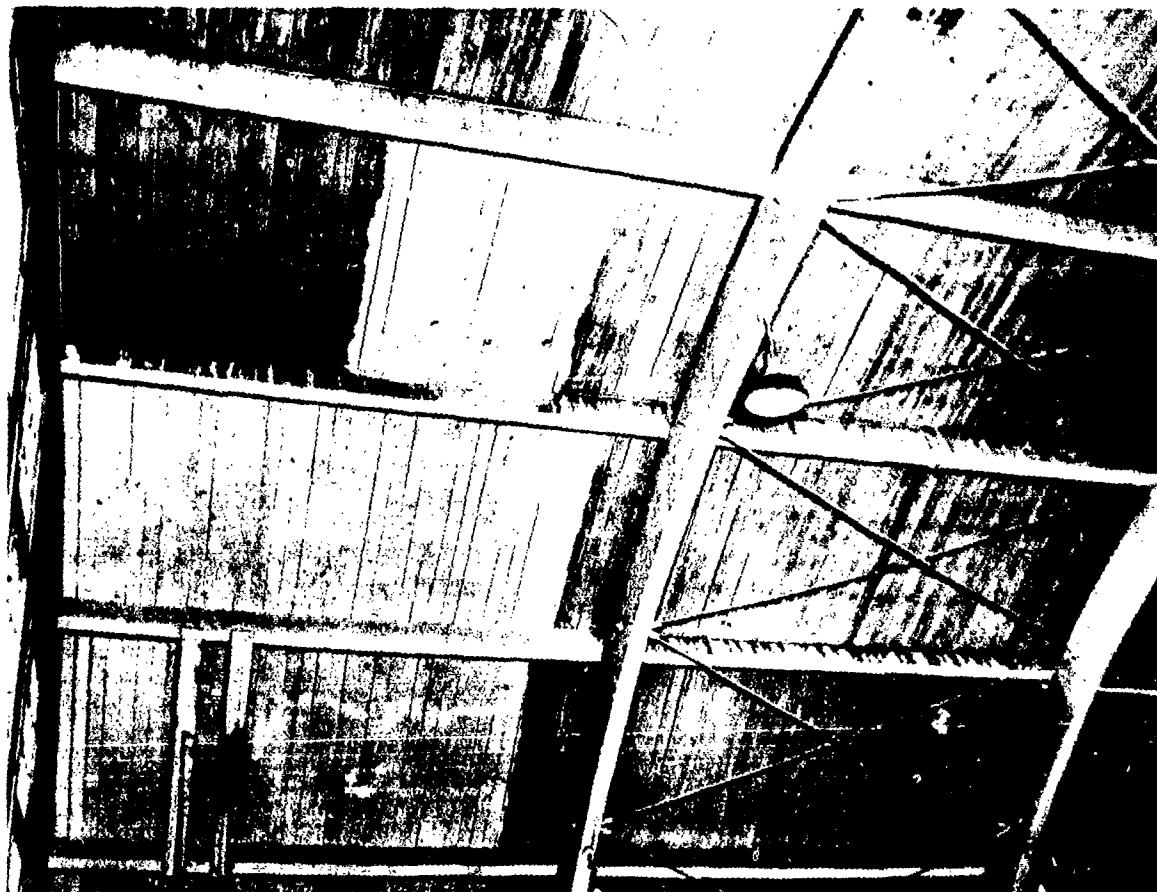


Figure 27.--Condensation promoted decay in inner roof boards (dark color) of a swimming pool. Light-colored boards are replacements for decayed boards. Watermarking on the beams evidences extreme wetness.

(M 110 432)

PRESERVATIVE TREATMENTS FOR BUILDING LUMBER

If a part of a building is vulnerable to decay and cannot be protected by keeping it dry, the alternative is to use wood that is naturally decay-resistant or has been treated with preservative.

Cost is often the decisive factor in determining whether to treat wood, but the cost of not treating may be greater. An example of savings to be

realized from use of treated wood as compared with untreated wood is given in figure 28.

In the preceding sections treated wood has been recommended for particular items under certain climatic and building conditions. Many factors will determine the type of preservative and treating method best suited for a particular part of a

building. Details on chemicals and treating methods can be found in the Additional Reading at the end of the text. The following summarizes the information particularly applicable to buildings.

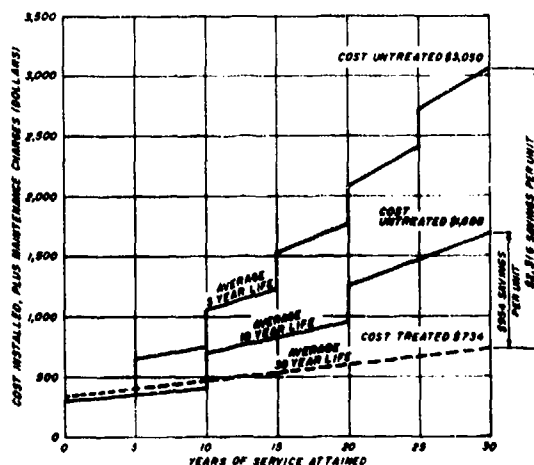


Figure 28.--Example of savings obtainable by using wood treated with a preservative, compared to cost of untreated material.

(M 128 675)

Wood Preservatives

Wood preservatives which are applied to wood to provide protection against fungi and insects are pesticides. Since the registration of pesticides is under constant review by State and Federal authorities, a responsible state agency should be consulted as to the current status of these preservatives and treated wood products.

The use of wood treated with creosote or pentachlorophenol in the interiors of tightly enclosed buildings with poor ventilation generally is not advisable. Vapors may cause injury if adequate ventilation is not assured.

Use only pesticides that bear a Federal registration number and carry directions for uses that you intend to employ. Pesticides used improperly can be injurious to man, animals, and plants. Follow the directions and heed all precautions on the labels. Store pesticides in original containers--out of reach of children and pets.

Creosote, Creosote-Petroleum Mixtures, and Pentachlorophenol in a Heavy Oil

These have a high degree of permanence but have a persistent odor which may be objectionable. Wood treated with them usually cannot be painted or glued satisfactorily, and the oil may creep along nails and stain untreated wood attached to it. These preservatives are used mainly for commercial pressure treating. Vapors from wood treated with pentachlorophenol may be injurious to plants.

Pentachlorophenol in Liquefied Petroleum Gas

Pentachlorophenol also is dissolved for pressure treating in a liquefied (under pressure) petroleum gas. When pressure is released, the gas volatilizes rapidly at ordinary temperature. Consequently, items treated with pentachlorophenol in liquefied petroleum gas do not present paintability or other problems commonly associated with material pressure-treated with the preservative in an oil carrier.

Pentachlorophenol in Light Petroleum Solvents

Light oil solvents, such as mineral spirits, evaporate and leave a clean, paintable surface if applied by such simple methods as brushing, dipping, and spraying. An additional advantage--resistance to rain wetting and the resultant improved dimensional stability and decay resistance--can be secured if a water-repellent ingredient is incorporated in the treating solution.

Ready-to-use solutions of 5 percent pentachlorophenol in light oil with a water repellent meeting Federal Specification TT-W-572 may be available through a variety of local retailers as "water-repellent penta." If "1 to 5" and "1 to 10" concentrates of pentachlorophenol are available, they can be diluted with mineral spirits when a solution stronger than 5 percent is needed to compensate for particularly shallow penetration.

Light-oil solutions are used mainly for on-site treating, but millwork treated with such solutions and including a water-repellent is available on the market.

Pentachlorophenol in a Grease-Like Base

"Penta grease" is used mainly for on-site treating. Surfaces close to the point where penta grease has been applied may not be paintable for several weeks. However, penta-grease permits substantially deeper penetration than can be obtained by other simple treating methods.

Waterborne Salts

Wood treated with a waterborne salt and then dried is clean, paintable, and free of objectionable odor. The treated wood must be redried and can develop additional checking in service from wetting and drying. Waterborne salts are used mainly for commercial pressure treating; such treated wood has many uses in buildings. Some of the waterborne salts are among the most effective and permanent preservatives available. They are especially recommended for wood foundations in contact with the ground.

Degree of Preservative Protection Needed

Types of treatment suitable for building items in various usages and exposures are given in tables 4, 5, and 6. The items are placed in the respective tables according to whether their exposure to wetting is influenced by their distance from the ground, by the amount of roof overhang, or primarily by climate alone. Climate is a factor in all cases. Treatment needs for items other than those listed can be judged from the similarities of service and exposure. The thoroughness of treatment suggested, types A (pressure treatment), B (nonpressure treatment), and C (no treatment), is based in part on the climate index. A formula for climate index appears in "Effect of Climate on Decay" and a contour map of climate indexes in the continental United States appears in figure 6.

For appropriate treatment of items that require pressure treatment with the principal oil-

borne or waterborne preservatives, details can be found in Federal Specification TT-W-571² and in the standards of the American Wood-Preservers' Association. These guides give the minimum retentions considered necessary for various conditions of service. Where treating may differ with wood species, this also is evaluated.

On-Site Treating

On-site treating refers to application of the preservative at the building site. If treating is done after construction, it is called in-place treating. Because on-site treating can be timed and tailored to fit a variety of needs, it can be a significant and valuable adjunct to the total measures for protecting buildings. Also it often can be a convenient and adequate means of providing precautionary protection for lumber that is used as a replacement for decayed lumber in situations where the contributing moisture situation presumably has been corrected. It has a place in the maintenance of structures that show signs of needing protection.

Dip and Short-Period Soaking

Dipping and short soaking are the most appropriate methods to treat lumber on the building site before it is placed in the structure. These treatments are effective only in items used aboveground and should be applied to materials after the necessary cutting and boring has been completed.

Where pre-cutting or pre-boring is not practicable, untreated surfaces exposed at the building site should be protected (the same as with pressure-treated wood) by follow-up treating--dipping, brushing, spraying, or spreading with penta grease--whichever is the most practical.

As the name implies, short soaking consists of relatively brief immersion of the item in a preservative solution. The soaking period ideally should not be less than 3 minutes, a standard time widely used in commercial treating of window and exterior door components (Commercial Standard CS 262³). Short soaking is commonly referred to as "dipping" rather than "soaking." Longer treating times up to about 15 minutes are desirable where practicable for many items of exterior woodwork.

Table 4.--Protective measures^{1,2} for interior building items relative to climate and to distance to ground

Item	Climate index ³ greater than 70 and wood-to-ground distance of-- Less than : 8 inches: 8 inches : or more :		Climate index ³ 33 to 70 and wood-to-ground distance of more than : 8 inches 8 inches : or more :		Climate index ³ less than 35 and wood-to-ground distance of more than : 8 inches 8 inches : or more :	
Sleepers in or on concrete laid on ground :	A ⁴	A ⁴	A ⁴	A ⁴	A ⁴	A ⁴
Furring strips below grade level :	A ⁴	A ⁴	B ⁵	A ⁴	A ⁴	A ⁴
Sills or plates on concrete laid on ground:	A ⁴	A ⁴	A ⁴	A ⁴	A ⁴	A ⁴
Sills or plates on concrete or masonry wall foundation :	A ⁴	C	C	C	C	C
Joists, girders, and beams in contact with concrete or masonry wall foundation :	A ⁴	C	C	C	C	C
Permanent wood foundation or foundation components in ground contact or separated from ground by only a water-resistant membrane :	A	A	A	A	A	A
Wood piers in crawl space (on concrete footing) :	A ⁴	C	C	C	C	C
Wood windows, framing and sheathing of shower room walls and floors (where showers are subject to heavy usage) :	A ⁶	A ⁶	A ⁶	A ⁶	A ⁶	A ⁶
Framing and sheathing of cold-storage rooms :	A ⁶	A ⁶	A ⁶	A ⁶	A ⁶	A ⁶

- ¹A, Pressure treat according to Federal Specification TT-W-471 or published standards of American Wood Preservers Association. For items to be painted or that for other reasons must be free of residual oil, use a waterborne preservative.
²B, Nonpressure treat according to standards that equal or exceed those of Commercial Standard CS 263-63 or use specified naturally durable wood.
³C, No treatment.

²Untreated surfaces exposed by cutting, boring, or shaping after an item has been treated should be brush treated at the building site, preferably with double-strength preservative. A protection may be used instead of B. The preservative in some cases obviously must be noncreeping and of a type that will leave the wood clean and paintable.

³See formula under "Effect of Climate on Decay;" also fig. 6.

⁴Protection is variable until additional information is obtained to substantiate or disprove.

⁵If foundation is brick or concrete block, use A treatment.

⁶Climate or ground-distance does not ordinarily apply.

NOTE: This publication includes research information involving pesticides. It does not contain recommendations for their use, nor does it imply that the uses discussed have been registered. All uses of pesticides must be registered by appropriate Federal and/or State agencies before they can be recommended.

The equipment for short soaking may be no more than a trough large enough to accommodate the lumber, preferably with a drainboard attached to recover excess solution carried out on the treated stock. Heating facilities are unnecessary. Ordinary construction lumber that is air dry--therefore dry enough to be soaked treated--will float. A simple means can be used to keep it submerged for the desired time.

Penta-Grease Treating

Experimentation indicates that penta grease can be useful in treating joints and contact zones after construction by laying it in the

exterior angles of the joint. The preservative can be applied rapidly from a calking gun with a nozzle of about 3/4 inch. Commercial applicators variously designed for different forms of spreading are available. The greater the number of external angles receiving penta grease, the more likely the preservative will reach the deepest part of the joint. With external treating, however, one should not expect the preservative to penetrate further into the joint than about 1 inch.

Preconstruction treating with penta grease would be most appropriate for items needing protection chiefly on cross sections where

Table 5.--Protective measures^{1,2} for exterior building items not much affected by roof overhang, in various climates

Item	Climate index greater than 70	Climate index 35 to 70	Climate index less than 35
Posts set in ground	A	A	A
Columns (porch, carport)	A	B ³	C ³
Board panels (fence, carport louvers)	A	B	C
Porch flooring and joists	A	B	C
Rails (porch, step, fence)	A	B	C
Treads and stringers (carriages)	A	B	C
Roof edges (exposed sheathing, molding, fascia)	A	B	C
Exposed rafters	A	B ³	C
Exposed arches	A	A	A ⁴
Access panels	B	B	C
Access frames	A	B	C

¹A, Pressure treat according to Federal Specification TT-W-571 or published standards of American Wood Preservers Association. For items to be painted or that for other reasons must be free of residual oil, preservative should be the waterborne type of an oilborne applied in volatile petroleum solvent.

²B, Nonpressure treat according to standards that equal or exceed those of Commercial Standard CS 263-63 or use specified naturally durable wood.

³C, No treatment.

⁴Untreated surfaces exposed by cutting, boring, or shaping after an item has been treated should be brush treated at the building site, preferably with double-strength preservative. A protection may be used instead of E. The preservative in some cases obviously must be noncreeping and of a type that will leave the wood clean and paintable.

⁵Penta-grease treatment of ends (end grain) would be a good precaution.

⁶Protection is desirable until additional information is obtained to substantiate or disprove need.

NOTE: This publication includes research information involving pesticides. It does not contain recommendations for their use, nor does it imply that the uses discussed have been registered. All uses of pesticides must be registered by appropriate Federal and/or State agencies before they can be recommended.

the end grain is exposed. The base of a post or column that is to rest on concrete exposed to the weather is a good example of the part of an item that might be particularly benefited by penta-grease treating. The grease should be spread on the cross section in a 1/4- to 1/2-inch layer, the thickness depending on the decay vulnerability and on the time that can be allowed for the preservative to be absorbed. Essentially complete absorption is indicated when the layer of penta grease ceases to shrink in thickness; this will typically require several days, although the ab-

sorption obtained over a period of several hours will be worthwhile.

Precautions For On-Site Treating

To treat lumber on the building site, some planning is necessary to schedule and to complete the treating without delaying construction. The following procedures should be observed if the treating is in conjunction with construction:

1. The item should be cut to size and shaped and bored prior to treating if feasible.
2. For treating with a solution, the items should

Table 6.--Protective measure^{1,2} for exterior building items relative to climate and to amount of roof overhang

Item	Climate index : greater than 70 : and roof overhang of-- : less than: 2 feet: 2 feet or more:		Climate index : 35 to 70 : and roof overhang of : less than : 2 feet :		Climate index : 35 to 70 : and roof overhang of : any amount :	
	A	B ³	B	C	C	D ⁴
Exposed, load-bearing structures	A	B ³	B	C	C	D ⁴
Siding and trim	B ⁵	B	C	C	C	C
Window sash	B ⁵	B	B ⁶	C	C	C
Frames and trim (windows, screen, doors)	B ⁵	B	B ⁶	C	C	C
Shutters	B ⁵	B	B ⁶	C	C	C

¹A, Pressure treat according to Federal Specification TT-W-571 or published standards of American Wood Preservers Association. For items to be painted or that for other reasons must be free of residual oil, preservative should be the waterborne type of an oilborne applied in volatile petroleum solvent.

²B, Nonpressure treat according to standards that equal or exceed those of Commercial Standard CS 263-63 or use specified naturally durable wood.

C, No treatment.

³Untreated surfaces exposed by cutting, boring, or shaping after an item has been treated should be brush treated at the building site, preferably with double-strength preservative. ⁴ protection may be used instead of B. The preservative in some cases obviously must be noncreeping and of a type that will leave the wood clean and paintable.

⁵Protection valid only for 1-story house; if house is higher, value of 2-ft. overhang is diminished, and situation should be considered same as for overhang less than 2 ft.

⁶Protection is desirable until additional information is obtained to substantiate or disprove need.

⁷Decay hazard is greatest at joints of item where most serious wetting is by end-grain absorption. Therefore adequate penetration of preservative can be obtained by protection B. Exception: Items going into tropical service may need A protection.

⁸Where overhang is 2 ft. or more and the house has but 1 story, no preservative treatment is needed.

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be submerged not less than 3 minutes; 15 minutes is preferable.

3. The item should be set aside briefly after removal from the treating solution to allow the surface to dry before it is handled by carpenters.

4. If any cutting must be done after treating, the cut surface should be retreated. The best procedure is to brush-coat the newly exposed surface. Most siding and trim items are cut to length just before they are attached, which usually necessitates delaying the retreating--by brushing or spraying the end grain joints--until after the items are attached to a building.

Unless enough time is available to get the preservative solution deep into joints by repeated flooding, in-place treating of exterior parts of older buildings does not appear worthwhile. Items like porches, steps, and railings have numerous joints that are particularly vulnerable to decay, but flooding treatment--as with a coarse spray--usually does not get the preservative deep enough into the joints to reach all existing infections. Another complicating factor is paint in the joints, which acts as a barrier to the preservative.

Flooding treatment and external application of penta grease have some potential for treating new aboveground structures in place. Success with these types of in-place treating apparently varies with types of construction and forms of joints. Generally, however, results cannot be expected to be as good as those obtained by treating before construction. It is reasonably well established that the end cuts of pretreated board siding can be effectively protected by flooding the vertical joints after the siding has been attached. The butt joints of panel siding can be similarly protected.

If a natural-finish or a painted or stained surface is desired, a "clean" treatment is necessary. Five percent pentachlorophenol with water repellents in mineral spirits does not discolor wood and if applied without pressure it leaves the surface paintable. If a stain is desired, a pigment can be added to the solution.

Good paintability generally can be assured if the

water-repellent preservative is applied by short soaking or by short vacuum treatment. Common commercial treatment of this kind for exterior woodwork such as window sash and frames or doors is covered by Commercial Standard CS 262.²

Occasionally, a single board will be abnormally permeable because of bacterial or inconspicuous mold infection and will absorb enough oil by a dip treatment to be unpaintable. These boards frequently can be detected after treating by a dark oil-soaked appearance; they can be set apart and used in places where paintability is not important. This overtreatment induced by fungal and bacterial action is largely a problem of pine sapwood from logs that have been stored under water for considerable time.

A simple test can show whether treated wood is sufficiently oil-free to be successfully painted. A cross section of the treated lumber is taken at least 3 feet from the end of the piece, and placed end grain down on a sheet of asphalt laminated paper (30-30-30 weight). If the paper under the wood discolors in 15 minutes at 100° F., a paint-harming amount of residual oil remains in the wood. The disadvantage of this test is that a freshly cut cross section is required; therefore, testing cannot be done on assembled structures.

Safety Precautions.--The following safety precautions should be followed:

1. Follow the directions and heed all precautions on the labels for the wood preservatives that you use.
2. Wear unlined protective gloves and aprons when treating or when handling lumber that is still wet with treating solution. Gloves should be frequently washed on the inside with soap and water.
3. Be concerned about possible damage to plants and to others that might arise from drifting sprays. Do not breathe dusts or sprays or allow any significant amount of them to contact the face.
4. Hands and other skin areas wetted by preservative should be washed with soap and water immediately.

PROTECTING BUILDINGS AFTER CONSTRUCTION

Regular Inspections

The cost to protect a frame home or other building from serious decay can be minimal if buildings are inspected regularly and trouble is corrected early.

At least once a year, places and items most vulnerable to wetting should be inspected. Particular attention should be paid to roofs, roof edges (facia, soffits, rafter ends), joints in and adjacent to window and door frames, and appendages such as porches, steps, and rails. Any signs of repeated wetting and traces of decay should be investigated.

The crawl space, though it can be difficult to inspect, should not be neglected. In milder climates it is vulnerable to decay by the water-conducting type of fungus. In colder climates it is subject to wetting by winter condensation--especially in the corners. During the summer in warm humid climates the floor may get wet from condensation created by summer air conditioning. The framing in the crawl space merits particular attention because it makes up the basic load-bearing members of the building. Any evidence of plumbing leaks should be looked for and any leaks promptly corrected.

Inspection for winter condensation in the crawl space should be made in the late fall and winter, and for condensation from air conditioning in the late summer. Wetting caused by air conditioning should be looked for especially on the subfloor. Cupping or buckling of the finish floor is a sign that condensation may be occurring.

The presence of a water-conducting fungus may or may not be revealed by strandlike surface growths of the fungus.

Inside a building, places to watch most carefully are shower rooms--for water leakage into walls or floor; kitchen areas--for plumbing leaks; and cold-storage rooms--for condensation within the walls, floor, or ceiling. To find the source of a leak is sometimes baffling, because water may travel some distance from the point of leakage within the walls or beneath flooring before it is noticeable. Watermarking of walls or floors near outside walls and damp-appearing surfaces indicate leaking water. Often a damp surface will be accompanied by molding. Steam radiators should be routinely checked for leaks.

A moisture meter (fig. 15) is helpful in locating wet zones within walls or in similar places. A type of meter employing nonpenetrating electrodes can be used to measure moisture content of plaster and finish items.

Recognition of Decay and Serious Wetting

Persistently wet places should be noted, and the cause corrected promptly. Various indications of wetting and decay are shown in figure 29. Advanced decay is easily recognized; early decay may not be. Yet even a small amount of decay is cause for concern because serious strength losses usually accompany it; hence those who build or maintain wood structures should be acquainted with the ordinary signs of decay infection, particularly in load-bearing items.

Discoloration of the wood.--As decay progresses it usually imparts an abnormal color to wood. This change in color can be a useful diagnostic of decay if the inspector is reasonably familiar with the color or color shades of the sound wood. On surfaced wood the discoloration commonly shows as some shade of brown deeper than that of the sound wood. Some decays, however, produce a lighter than normal shade of brown, and this change may progress to a point where the surface might be called white or bleached. If this bleaching is accompanied by fine black lines, "zone lines," decay is virtually certain (fig. 4). Often, an abnormal variation in color creating a mottled appearance is more helpful in detecting early decay than actual hue or shade of discoloration. Highly indicative of decay, and especially conspicuous, is variable bleaching on a dark background of blue stain or mold.

Accompanying the color change, there may be an absence of normal sheen on the surface of infected wood. Here also, familiarity with the normal appearance of the wood can be of great help in recognizing the loss of sheen. Occasionally, in relatively damp situations, the presence of decay infection will be denoted by surface growth of the attacking fungus; in these cases the wood beneath usually is weakened--at least superficially.

Stain showing through paint films, particularly on exterior woodwork, is evidence of serious



Figure 29.--Various indications in building components of moisture accumulation and decay: A, Rust around nail. B and C, Surface mold on wood, and failure of paint on areas near absorbent end grain. D, Sunken surface or visibly deteriorated wood, often with paint failure. E, Fruit bodies of fungi (evidence of advanced decay). F, Nail pulling (evidence of alternate shrinking and swelling).

(M 128 124)

wetting and probable decay beneath the film. Rust around nail heads suggests that wetting has been sufficient for decay to occur.

Loss of wood toughness and hardness.--Wood can also be examined for decay by simple tests for toughness of the fibers and for hardness. Toughness is the strength property most severely reduced by early decay. The pick test is a helpful and widely used simple means of detecting diminished toughness. It is made most reliably on wet wood. An ice pick, small chisel, sharpened screwdriver, or similar sharp-pointed or edged instrument of tough steel is jabbed a short distance into the wood and a sliver pried out of the surface. The resistance offered by the wet wood to prying and the character of the sliver when it finally breaks are indicative of toughness.

In the pick test, sound wood tends to break out as one or two relatively long slivers and the breaks are of a splintering type (fig. 30): Where loss of toughness has been appreciable, the wood

tends to lift out with less than usual resistance and usually as two relatively short pieces. Moreover, these short pieces break brashly at points of fracture; that is, abruptly across the grain with virtually no small splinters protruding into the fracture zone.

On planed lumber, the reduced toughness of wood with early decay is sometimes indicated by abnormally rough or fibrous surfaces. Similarly the end grain of a board or timber may be rougher than usual after sawing.

Toughness may also be reduced by certain other factors such as compression wood, tension wood, or compression failures. There usually is little doubt of decay infection if the weakening is accompanied by a decay-induced type of discoloration.

In many cases the reduced hardness of infected wood can be detected by prodding the wood with a sharp tool. Softening, however, usually is not so obvious or so easily detectable with early decay



Figure 30.--The "pick test" for early decay. Wetted wood if sound (left) lifts as a long splinter or breaks by splintering; if infected (right) it tends to lift in short lengths and to break abruptly across the grain without splintering.

(M 124 721)

as is a decrease in toughness.

Shrinkage and collapse.--Decay in the more advanced stages frequently causes wood to shrink and collapse. Under paint, this may first be manifested by a depression in the surface. Often the paint will acquire a brown-to-black discoloration from soluble materials migrating from the interior zone of decay to the outside; also, fruit bodies of the attacking fungus sometimes appear on the surface.

In exterior woodwork, wetting is often evidenced by brown-to-black discoloration or loosening of paint, particularly at joints. If there also has been substantial decay, the discoloration may be associated with interior collapse and surface depression.

Surface growths.--Decay in crawl spaces invaded by a water-conducting fungus may be evidenced by fanlike growths, vinelike strands, or by a sunken surface of wood resting on foundation walls or piers. Such decay is usually most advanced near the foundation, because the fungus usually starts there. The fanlike growths are

papery, of a dirty white with a yellow tinge. They may spread over the surface of moist wood, or--more commonly--between sub- and finish-flooring or between joists and subfloor (fig. 31). These growths may further appear under carpets, in cupboards, or in other protected places. Water-conducting, vinelike strands grow over the foundation, framing, the underside of flooring, inside hollow concrete blocks, or in wall voids.

The fungus carries water through these strands from the damp ground or other source to the normally dry wood being attacked. Usually the main water conductors are 1/4 to 1/2 inch wide although they sometimes reach 2 inches. They are similar in color to the fanlike growths although they sometimes turn brown to black. During dry weather, shrinkage cracks in floors often outline the extent of an attack. Rotted joists and subflooring in relatively dry crawl spaces usually have a sound shell even when the interior wood is essentially destroyed.



Figure 31.--Advanced stage of decay by water-conducting fungus Poria incrassata showing fanlike surface growth and typical decay pattern of wood. (M 3613F)

Corrective Measures Where Wetting or Decay Occurs

Eliminating Conditions Responsible for Wetting

The cause of excessive wetting of any wood members in a building should be investigated, and measures to correct the situation should be taken as soon as practicable. Ordinarily, alterations or repairs to stop the wetting and to keep the damaged item dry are sufficient. If there is any question about not eliminating the wetting, the replacement wood should--as a precautionary measure--be treated with preservative. For preventing decay-producing situations, it is important to remember that wood will not decay if its moisture content is no more than about 20 percent. To decay it must be contacted by water; moisture imparted by damp air alone can cause objectionable swelling, but cannot support decay.

In making repairs required because of decay, it usually is necessary to replace only wood so weakened that it is no longer serviceable. Infected wood will not endanger adjacently placed sound wood so long as both are kept dry.

Because of the high decay hazard of the roof edge, it should be watched for signs of wetting and decay. With flat roofs, gravel stops cannot be kept

watertight for appreciable lengths of time unless regular attention is given to the joint seals. These should be resealed at the first sign of leakage. If eave gutters show corrosion, they should be covered with a corrosion-inhibiting paint. This is particularly necessary with recessed gutters because considerable hidden decay can occur before leakage is evident. Where no edge flashing has been used, it should be installed if there is evidence of sufficient wetting to cause staining of the last sheathing board, rafter ends, or facia.

Maintenance by Preservative Treatment of Items in Place

New wood for replacing areas of decay in buildings should receive the same type of preservative treatment that would be recommended for new construction in those areas. Flooding treatment with brush or spray of items that have been in service for a considerable time is not likely to prevent or arrest decay if the job is so big that it must be done on a large scale. It can be effective, however, if it is a home operation, where the owner can give the time needed to get the preservative solution sufficiently deep into joints and cracks.

In flood treating the object is to get the preservative deep into joints and crevices where rain-

water is likely to be trapped and to have the penetration equal that reached by the water. Treating every few years will add to the margin of safety. Examples of items that can be protected by flood treating in place are the bases of porch pillars and carport posts resting on concrete, plank porch floors, shutters, window boxes, and lookouts. Where rain seepage into a joint is indicated by failure of nearby paint, trouble from this source can be minimized if the joint is flooded by spraying or brushing with a water-repellent preservative prior to repainting. In treating, the preservative should be kept off plants and grass and not permitted to accumulate on the skin. A suitable preservative for most maintenance treating is 5 percent pentachlorophenol with water repellents in mineral spirits. It is widely obtainable and is identifiable by the label.

Eradicating the Water-Conducting Fungus

Decay caused by the water-conducting fungus is easily prevented by incorporating the building procedures that have been discussed in previous sections. However, if attack has already occurred, special control measures are required. If the fungus is well established and conditions supporting it are not removed, large areas of flooring or walls may have to be repeatedly replaced. Cases are reported in which replacements were necessary at 1- and 2-year intervals.

The water-conducting fungus is susceptible to drying; therefore, it should be permanently separated from its source of water. When this is accomplished, the affected wood soon dries, and the fungus dies within a few weeks. Then only wood that has been too weakened to safely support its load needs replacement. However, if there is any doubt that the fungus has not been eliminated, it is safest to replace all infected wood with wood that has been pressure treated with a preservative.

Usually the fungus gets its water from the ground or--less frequently--from wet wood or masonry in the general area where the decay occurs. The following are the most common measures to control the water-conducting fungus; some will be recognized as measures that should have been taken at the time of construction.

1. Irrespective of the location of the decay, seek out and remove any wood forms left from pouring concrete steps or foundations and any other wood, building paper, insulation board, or similar cellu-

losic material that may be making a direct bridge from the soil to the wood of the building. Also, eliminate stumps and all building debris. If necessary, regrade the crawl space or soil outside the building to provide wood-soil clearance.

2. Provide for drainage of surface water away from the outside foundation and the crawl space. If the ground in the crawl space is not dusty dry, include better ventilation or a soil cover, with the aim of making the air in the space dry enough to restrain the fungus in its development of water-conducting strands. A polyethylene film sheet is better than roll roofing for a soil cover when the water-conducting fungus is present, because this fungus will attack asphaltic papers.

3. Open the foundation of the porch and remove enough soil from the fill to expose the entire sill under the slab. The opening should be sufficient to permit inspection of the sill and provide ventilation to it. If the sill needs replacement, use pressure-treated wood. Termite-control operators are familiar with the technique of excavating fills.

4. If water-conducting strands or other growths of the fungus are observed on concrete or brick foundations, scrape off the larger strands and brush off the remainder with a steel brush. Finally, the cleaned surfaces should be thoroughly flooded with a preservative. This treatment also is applicable to situations in which the fungus is found on concrete exposed by excavating fills or by removal of forms. Always examine the treated areas and re-treat if any evidence of new growth appears. Where it is apparent that water-conducting strands are hidden inside concrete blocks or in loose mortar in brickwork, insert a metal shield between the foundation and substructure wood or, if the construction is brick, reset a few upper courses using cement mortar.

5. If the source of the decay is traced to a plumbing leak, repair the leak. Where the trouble is associated with shower stalls, a completely new watertight lining may be needed. If the framing and sheathing for the floor and walls of the shower are exposed during repairs, replace them with pressure-treated wood. The most dangerous leaks are the small ones that are difficult to detect.

6. If attack occurs in a slab-on-ground supported building that does not meet waterproofing and ground-clearance standards, replace all basal plates with pressure-treated wood and use non-wood flooring. Provide as good outside clearance as possible and chemically treat the slab edge and adjacent soil. Attack seldom occurs in slab-supported houses with adequate waterproofing of

the slab and adequate ground clearance, except when unusual wetting occurs, such as that caused by excessive lawn sprinkling or by elevated flower beds.

7. If attack occurs in a basement, replace wood in contact with a wall or the floor with pressure-treated wood. Do not have any enclosed stairs, partitions finished on both sides, cupboards, or paneling on the outside walls in moist basements. This type of construction creates "dead air" spaces that promote growth of the fungus.

8. If preservative-treated wood is specified, use creosote, pentachlorophenol, or a noncopper waterborne compound, applied under pressure. Although all heartwood of decay-resistant species is acceptable for some items and exposures in well-designed new buildings, do not use such wood to replace wood that has been attacked by the water-conducting fungus. This fungus will attack the heartwood of most decay-resistant woods including redwood and cedar.

ADDITIONAL READING

- American Society for Testing and Materials. n.d. ASTM Standards, published annually. Philadelphia.
- American Wood-Preservers' Assoc. n.d. AWP Standards (loose-leaf), currently revised. Chicago.
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Specific information on preservative treatment
is available from:

American Wood-Preservers' Association
1625 Eye St., N.W.
Washington, D.C. 20006

and

American Wood Preservers' Institute
1651 Old Meadow Rd.
McLean, Va. 22101

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U.S. Forest Products Laboratory.

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Pesticides used improperly can be injurious to man, animals, and plants. Follow the directions and heed all precautions on the labels.

Store pesticides in original containers--out of reach of children and pets.

Homeowners are advised to use only pesticides that bear a Federal registration number and carry directions for home and garden use.