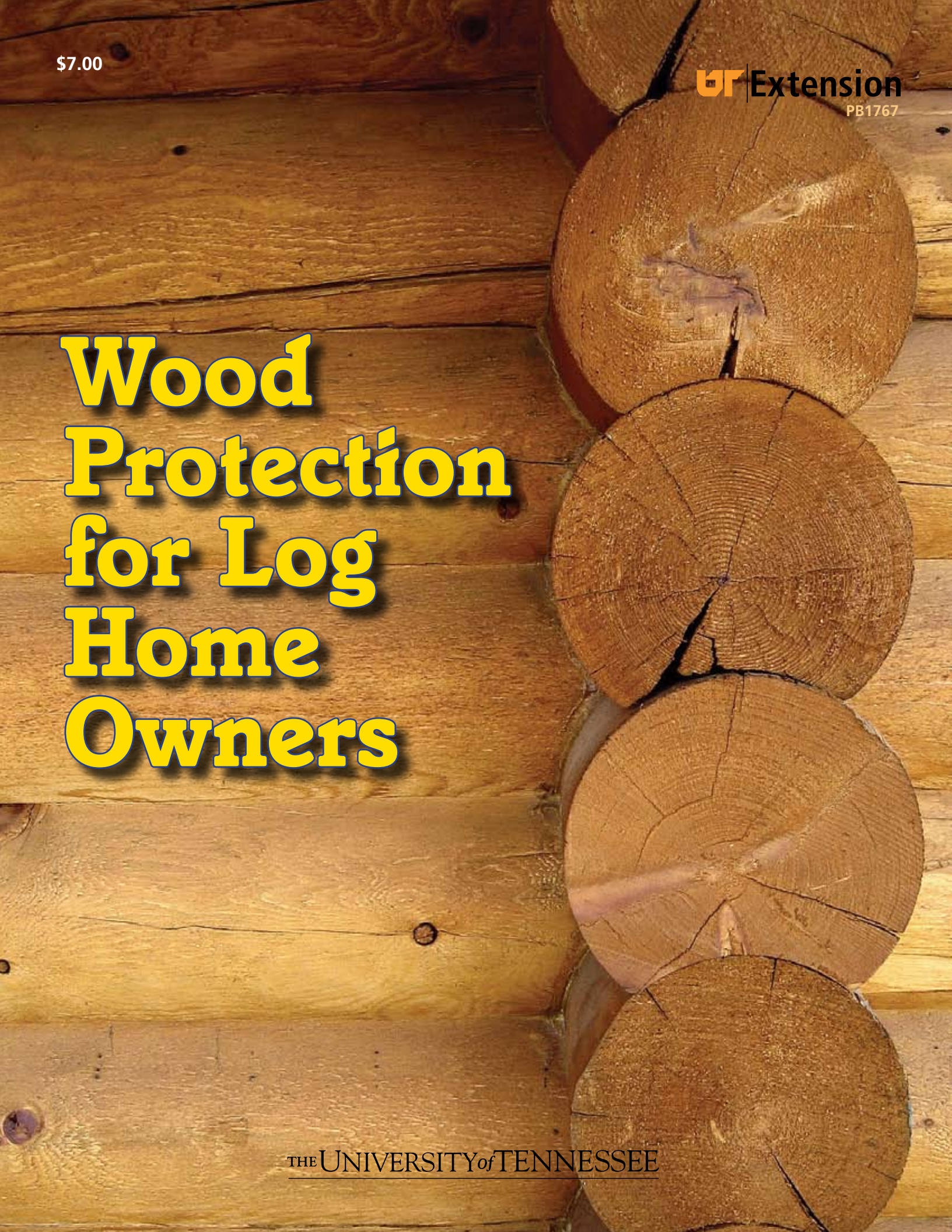
$7.00

UT Extension
PB1767

Wood Protection for Log Home Owners



THE UNIVERSITY of TENNESSEE

Contents

Wood Protection for Log Home Owners

Adam M. Taylor
Assistant Professor
Tennessee Forest Products Center
University of Tennessee

Stephen L. Quarles
Wood Durability Advisor
University of California Cooperative Extension

Karen M. Vail
Associate Professor
Entomology and Plant Pathology
University of Tennessee

Log homes can be beautiful and long-lasting. The most important factor in making your log home a durable structure is a design that keeps the wood dry.

Wood is a beautiful material that has been used for centuries for building log homes. Wood is also a high performance composite with good strength, insulation, fire resistance and durability characteristics. This means that uniquely beautiful log homes can be as efficient and long-lasting as structures made from wooden lumber, steel or concrete.

An understanding of wood properties will help log home owners protect and enjoy their homes. This publication is designed to provide basic information about wood, wood protection and the use of large timbers to build log homes.

Basics of Wood

The role of wood in trees is to provide structural support and to conduct water up from the ground to the leaves. Thus, wood needs to be strong but also porous. Wood in living trees contains a lot of water and, although wood dries and shrinks after harvest, the logs in a home always contain some amount of water. The relationship of water and wood is the most important factor in determining the behavior of wood and how long it will last. In addition, lumber and other wood-based products come from a wide range of tree species that have different properties. Trees also change as they grow older, so wood is highly variable. Finally, wood — an organic material — is biodegradable and can be broken down in many ways into the carbon dioxide and energy (trapped sunlight) from which it was made.

Wood Anatomy

Wood is made of thousands of small cells, which are long, slender tubes. Most of the cells are oriented parallel to the length of the tree trunk, and this gives wood a *grain* in that direction. If you cut across the tree stem, you expose the open ends of thousands of cells. This end grain absorbs (or releases) water much more quickly than the other wood surfaces, which can have important implications for trying to keep wood dry and protected from decay and insects.

Sapwood and heartwood

Sapwood is the outer band of wood that contains some living cells and also conducts water in the living tree. The inner core of heartwood contains only dead cells. The heartwood of some naturally durable tree species contains chemicals (*extractives*)

that repel fungal decay (*rot*) and insects. Examples of naturally durable woods that are used in log homes include cedars, cypress and white oak. Extractives can also result in special colors or odors in the wood. For example, incense cedar heartwood gives pencils their characteristic odor and the heartwood of ebony (used for the black keys on a piano) is black. The sapwood of all species is light in color and is susceptible to decay and insect attack.

Wood Species Differences

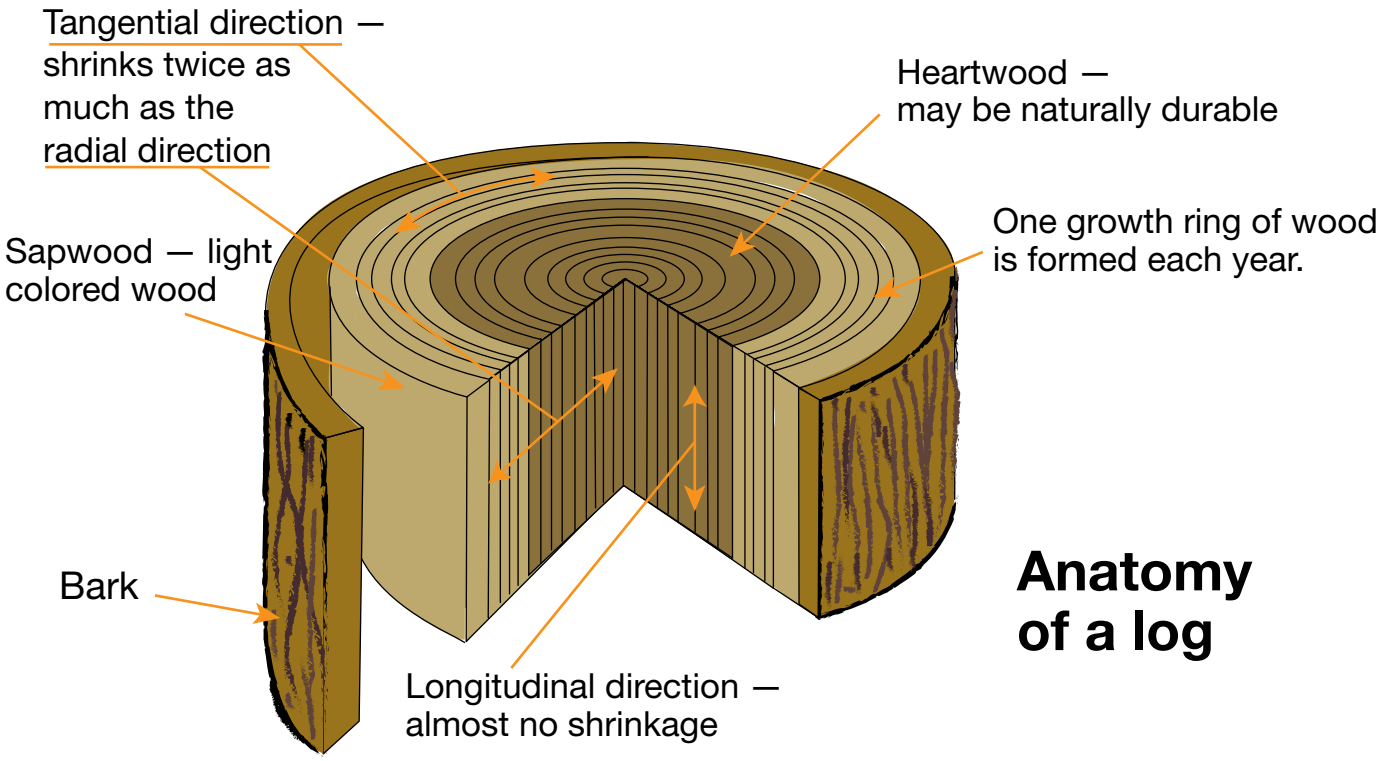
Many different trees are used for making log homes, including various pines, oak, cypress, cedar and others. Logs from these trees vary in appearance, strength, weight, how easily they dry, and their natural resistance to decay and insects. Log home builders can take advantage of the natural features of some species, but given proper design, any species can be used to make an attractive and durable structure.

Appearance

Wood varies in color, grain, knot pattern, tendency to split or stain, and other features that can affect the look of a log. The most attractive wood species is a matter of personal choice. The outer wood closest to the bark (sapwood) of all tree stems has a light color, so if round logs are used, the color of the fresh log will be light. The inner wood (heartwood) can be exposed when logs are cut, for example, in squared timbers. In species such as cedar and redwood, the heartwood has a dark color. The color (and odor, in some cases) of these species is prized by some people. Of course, the color of logs can also be changed by using finishes; a wide variety of stains is available for this purpose.

Strength

Wood is remarkably strong. Depending on how strength is measured, wood can be stronger per unit weight than steel. Different wood species have different strength ratings; and, in general, heavier woods (hard hardwoods such as oak) are stronger than less dense woods such as pine or cedar. However, wood is sufficiently strong that the strength of the wood species is not an important consideration for log walls. In general, all species will be strong enough given proper design.



Anatomy of a log

Wood and Water

Moisture content of wood and the fiber saturation point

For wood products, the amount of water in wood is called the moisture content (MC) and is measured as the weight of water relative to the weight of bone-dry wood. According to this method of measuring, unseasoned (*green*) wood can have a moisture content over 100 percent! Fully seasoned wood will have a moisture content ranging from 5 percent to 15 percent, depending on the temperature and relative humidity of its environment.

Water exists in two forms in wood. Liquid, or *free*, water fills the hollow centers of wood cells and other void regions. *Bound* water is chemically linked to the cell wall. As green wood begins to dry, free water is removed. After all of the free water has gone but all of the bound water remains, the wood is at the so-called *fiber saturation point* (FSP). This occurs at about 25 percent moisture content. Further drying below the fiber saturation point is more difficult (requires more energy) because the bound water has a strong attraction to the wood. It should be noted that during drying, moisture is not evenly distributed throughout the wood. Thus the surface of a drying log might be below the FSP at the same time that the inner portions of the log are still very wet.

The fiber saturation point has important implications for wood properties. Below the fiber saturation point, fungal growth (mold or decay) cannot occur and wood is less attractive to many insects. If wood can be dried rapidly and maintained at a moisture content below the FSP, it will be very durable. Fortunately, if wood is kept out of contact with liquid water, it will eventually dry to a moisture content below the FSP.

Green wood and seasoning

When a living tree is cut, the wood is *green* — it contains a lot of water. In some species, there can be more water by (measured by weight) in the wood than there is dry wood. The moisture content of the wood exceeds 100 percent in these situations. After the wood is cut, most of this water (but not all) will evaporate from the wood. Eventually the amount of water in the wood will come to a balance with the amount of water in the air. At that point the wood is dry or *seasoned*. The amount of time that it takes

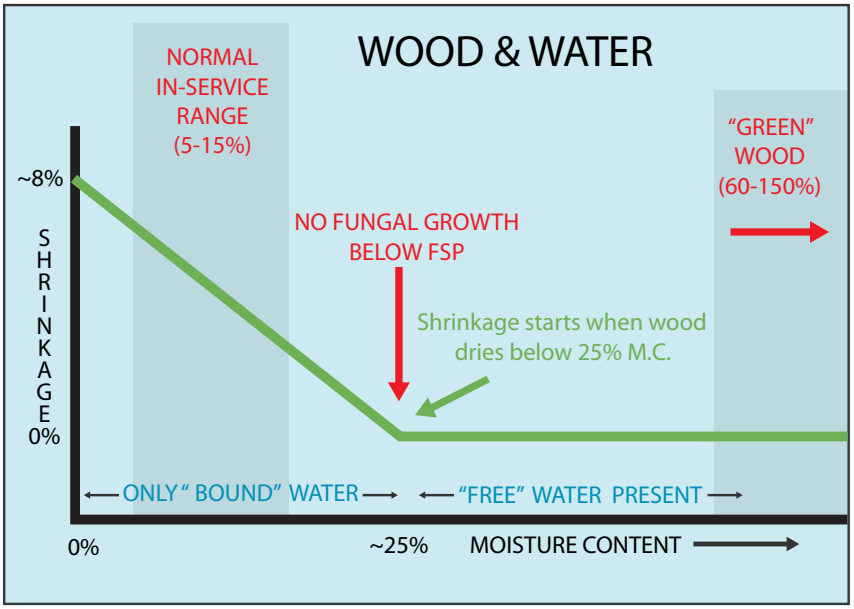
Hardwoods vs. Softwoods

People often refer to some species of trees as soft hardwoods or hard hardwoods. To make matters more confusing, pines can be grouped as hard pines or soft pines, even though all pines are softwoods. So how can wood be hard and soft at the same time?

The classification of tree species as hardwoods or softwoods is based on a botanical distinction. Softwoods (or gymnosperms) are the conifers, or cone-bearing trees, that are often evergreen and have needle-like leaves. Softwoods include the pines, eastern redcedar and cypress. Hardwoods (or angiosperms) are broad-leaved, mostly deciduous trees, that is, they drop their leaves. Oaks and poplar are examples of hardwoods.

The wood of both hardwoods and softwoods varies in hardness, and this is the source of confusion: hard and soft wood occurs in different species of both hardwood and softwood trees. Hardness is a function of the heaviness, or density, of the wood: the amount of wood material compared to air spaces. Hard woods are denser, soft woods contain more air. On average, the wood of softwoods is softer than hardwoods. However, there are many exceptions to this trend. The Southern pines are softwoods, but they are denser than yellow poplar, which is a hardwood. Because of the wide range of wood density in the hardwood tree species, people will often distinguish between hard hardwoods (e.g. hickory, oak, ash) and soft hardwoods (e.g. yellow poplar, gum, willow). Likewise the pines, which are softwoods, can be organized into hard (e.g. Southern, red) and soft (white, sugar) groupings.

Both hardwoods and softwoods are used to make log homes. Factors such as size, cost, natural durability and appearance are generally more important considerations than whether the wood is relatively harder or softer, or a hardwood or a softwood.



Water has a large impact on wood properties. Trees are wet, but the logs in a house are relatively dry. Drying results in shrinkage, but it also helps protect the wood from attack by insects and fungi.

for wood to go from green to seasoned depends on many factors, including the temperature and relative humidity of the air, and the size and species of the piece of wood. In the case of logs, this process can take a few years. If logs are kiln-dried prior to assembly, the time to reach moisture equilibrium will be reduced.

If the logs in a log home are wetted due to rain or other water sources, the moisture content of at least the surface region can eventually become very high. Once the water source is removed, the wood will again dry to an MC that is in balance with the temperature and relative humidity of the air surrounding it. This eventual balance of moisture in wood with conditions in its environment is called the *equilibrium moisture content* (EMC).

Wood shrinkage

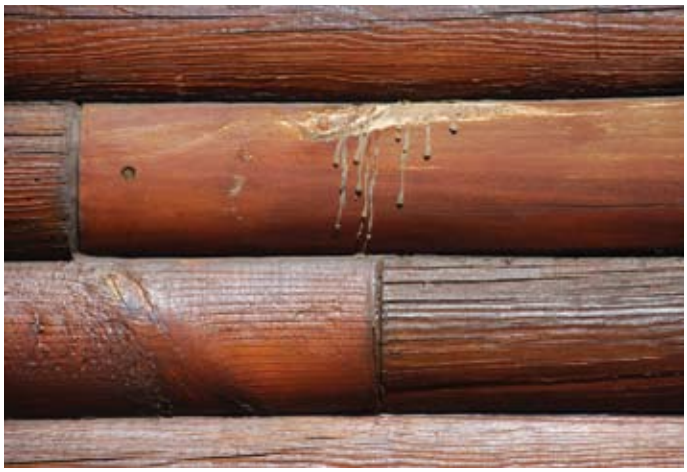
Shrinkage occurs when wood is dried below the fiber saturation point. Above the FSP, the removal of free water simply empties the wood cells and does not change their dimensions. When bound water is removed from the walls of cells, they begin to shrink. As a rule of thumb, for every 3 percent reduction in moisture content below the FSP, the wood will shrink in volume by about 1 percent.

As mentioned above, fully seasoned wood has a moisture content ranging from 5 – 15 percent, depending on its environment, while green wood has a moisture content well above 25 percent (above the FSP). Thus shrinkage is inevitable when wood is used for houses. Even more importantly, wood shrinkage is not uniform. Wood shrinks very little in length but substantially across the grain (5 – 10 percent from the green size). This means that the walls of a *stick built* house will change very little in height as the wooden studs in the wall cavities dry out. In contrast, a wall made from logs can shrink several inches in height (the width-wise direction in the log) as the wood dries.

It is also important to know that wood shrinks about twice as much parallel to the growth rings (tangential direction) as it does perpendicular to the growth rings (radial direction). This imbalance is the reason why some splitting of the surface of logs is inevitable (see *checking*, below).

Kiln drying

Kiln drying refers to putting wood into a heated enclosure (a kiln) to accelerate the drying process. Kiln drying can reduce the drying times for some lumber species from months to days and can also reduce drying time for logs and other large members.



Resin is bleeding from this pine log. Kiln drying of the logs can prevent this.

An extreme example is the high-temperature drying of pine lumber, which can reduce the moisture content from green (>100 percent) to 19 percent in a couple of days. In addition to the rapid removal of water, the heat in a dry kiln can kill insects and other organisms that might be living in the wood, particularly those that may be in the standing trees, and will also help to *set the pitch*. In resinous species such as pines sticky, defensive liquids (*pitch*), produced by the tree as a defense against insects, can leak out of the wood after it is cut. Exposing the wood to high temperatures will harden the pitch so that it will no longer be an aesthetic problem.

Removing water from wood to lower the moisture content below 25 percent will prevent attack by mold and decay fungi (rot). Kiln drying can shorten the time required for a log to get to this safer condition. Hardwood lumber is kiln dried to achieve a moisture content (5 – 15 percent) that will prevent most future shrinkage (assuming the lumber stays in an interior environment and isn't rewetted). Because logs are not kiln dried to such low levels, shrinkage of logs will continue after a log house is assembled.

Wood Deterioration

Wood can be degraded by both physical factors and living organisms. Wood is an organized, solid combination of carbon dioxide, water and energy from sunlight. The various agents that break wood down are part of the natural recycling of wood that ultimately ends in the release of carbon dioxide, water and energy. With appropriate design and maintenance, deterioration can be delayed almost indefinitely; thus, a log home can last virtually forever.

Physical and Mechanical Damage

Sunlight and weathering

Just as ultraviolet rays (UV) in sunlight can cause chemical changes in our body by tanning our skin or bleaching our hair, they can also cause chemical changes in wood. UV breaks apart compounds on the surface of exposed wood resulting in degraded wood fibers and changes in color. When UV exposure is combined with wind and water exposure, this can result in the slow erosion of wood fibers from the surface of the wood. This process is called *weathering*. Weathering is usually uneven and depends on how much sunlight and water the wood is exposed to and how soft the wood is. Soft woods such as cedar will weather faster than harder woods such as oak. Also, the different parts of the annual growth rings in a piece of wood will weather unevenly because the *earlywood* (wood formed in the spring) is softer than the *latewood* (formed in the summer). This

This building has weathered siding. The darker areas are exposed to more sunlight. In protected areas under the eaves, the wood is closer to its original light color. Finishes can be used to prevent weathering and improve the appearance of exterior wood.

results in rough surfaces on weathered wood — especially on the end grain.

The effects of weathering are limited to the surface of wood, and the process is quite slow overall. Research suggests that wood removal due to weathering is only about ½ inch per century, even with soft woods. Thus weathering is not a structural concern for log homes with walls that are many inches thick. The bigger concern with weathering is the changed and irregular (non-uniform) color of unprotected wood, which is an aesthetic issue.

Weathering can be prevented by protecting the wood from exposure to sunlight and water and by applying finishes that block ultraviolet radiation and shed liquid water. Clear finishes can contain chemicals that are UV blockers. Pigmented (colored) finishes also protect wood against UV exposure.

Settling

As explained above, wood shrinks when it dries. Log homes always continue to dry after they are assembled, so some shrinkage of log walls is inevitable. Because shrinkage is greatest across the grain, log wall shrinkage — or *settling* — can result in a considerable change in wall height. For example, a 10 foot log wall may settle 2 inches or more, depending on the wood species and the moisture content of the logs when they were assembled. Because lumber is oriented in the longitudinal (low shrinkage) orientation, other components in a log home — interior stud walls, windows and doors, and cabinets — do not settle appreciably. Allowances for settling must be made wherever log walls connect to these items.

Checking

Checking is the development of cracks in the surface of wood. Wood shrinks more parallel to the growth rings than it does across the growth rings. This imbalance results in large stresses as logs dry. In logs, these stresses eventually overcome the strength of the wood, which fails, resulting in the development of a check. These checks appear on the surface as wide cracks that extend inward toward the center of the log. These checks are due to natural wood characteristics combined with inevitable drying. Because shrinkage parallel to the growth rings (the *tangential* direction) is approximately

A check in a house log. This kind of split is the inevitable result of the normal drying process and the uneven nature of shrinkage in wood.

Standing Dead Timber for Log Homes

In some areas of the country, thousands of trees have been killed by insect or disease outbreaks. This standing dead timber can be used for log homes. Such logs may have a lower moisture content than normal green wood, which results in lighter logs and potentially a shorter seasoning time. However, even standing dead timber will continue to shrink and check after it is assembled into a log home. Furthermore, standing timber can be attacked by decay fungi or insects before it is harvested. Logs should always be inspected before use, but inspection is particularly important when the use of fallen, or standing dead trees is being considered.

twice that in the direction perpendicular to the growth rings (the *radial* direction), checks are impossible to prevent and should be considered a normal part of the log home look. Logs usually develop one large check instead of several smaller ones. If you can see where the check is starting, it is sometimes possible to rotate the log during installation to hide the check or position it in a less vulnerable location.

Checking can also occur in wood because of rapid drying. When the surface of wood dries, it starts to shrink before the inside of the piece does, causing stresses to develop in the surface layers. If these developing stresses exceed the strength of the wood, a check develops. These checks do not necessarily extend across the growth rings and can be prevented by careful drying.

Dry wood has good insulating and fire-resistance properties. However, the gaps between logs are important in determining the overall performance of the wall. If the *chinking* that fills the gaps is missing, is in poor repair or has low fire-resistance properties, the wall may leak or perform poorly in a fire.

Fire

Wood is a combustible material. This is a good thing when the fire is confined to a fireplace or wood stove, but it also means that log houses can burn. However, the dangers of fire are not usually greater in log homes than in structures framed with other materials. Fires can occur in almost any building when kitchen accidents or electrical problems ignite interior furnishings. The potential combustibility of log walls is not really an additional danger because such large pieces of wood actually burn quite slowly due to the *char layer* that develops. Therefore, logs retain most of their strength during the initial stages of a fire. Because of the protective effect of the char layer, building codes usually assign better fire ratings to larger members.

In wildland/urban interface areas where wildfires are a concern, log walls can be a positive component of a more fire-safe home. The most vulnerable part of the log wall in a log home is the *between log joint*. The joint should be filled to provide protection comparable to the log itself.

In a wildfire, many homes are lost as a result of flame or ember entry into attic or cathedral ceiling spaces. To avoid these exposures, highly combustible vegetation should be removed from near the log walls. Similarly, other items that could result in ignition of the log wall (e.g., gasoline containers), with subsequent flame spread to the eave area, should also be avoided.

Biological Damage

Insect attack of wood

Many kinds of insects can attack wood. Wood provides some insects with suitable habitat (a place to live), for at least part of their life cycle. Examples of these insects include carpenter ants, carpenter bees and some wood-boring beetles. Other insects attack wood because it provides a food source. Examples of insects that eat wood (or parts of wood) include termites and wood-boring beetles.

Termites

Termites are the most serious insect pest of log homes. Termites eat wood and thus can cause major structural damage. Termites either live in the wood they are eating (drywood or dampwood termites) or in the soil in the vicinity of the house they are infesting (subterranean termites). Because subterranean termite colonies are larger than

Drywood termite damage in a fence. Drywood termites inhabit the wood they are eating.

The surface of this log has numerous powderpost beetle entry holes. Powderpost beetles can attack and re-infest logs after they are assembled into a home.

drywood termite colonies, they are capable of doing more damage to a wood structure. Formosan termites are one very destructive species of subterranean termite found in the southeastern Unites States. Formosan termites can be found in the soil, but also in above ground locations in *carton nests* that maintain a moist environment. Carton nests aren't in wood members but can be in wall cavities and hollowed out trees. Because dampwood termites require wet wood, they aren't usually found inside.

Fortunately, a number of effective termite pesticides and treatments are available from pest control management professionals. Knowing where the termites live can help you understand the best treatment for a given infestation. Soil treatments (baits and liquid soil applications) can be effective against subterranean termites, including the Formosan, but won't be effective against drywood termites. Similarly, whole house fumigation or local chemical treatments injected into wood members will only be effective against termites residing in the treated member. These treatments are not effective against subterranean termites, where only a small fraction of the colony is in the home at any given time. The best treatment for dampwood termites is to dry out the affected wood members.

A preconstruction termite treatment is recommended for new homes. Homeowners can also take steps to discourage termite infestations in their homes. Keeping potential termite food, such as mulch and firewood, away from log walls can help to prevent termite infestation. Termites are also attracted to moisture or partially-rotten wood, so keeping a log home and nearby areas dry will help to reduce the risk of termite attack in addition to reducing the risk of fungal decay or mold.

The following are a few practical ways to prevent a termite infestation:

- Repair structural and plumbing leaks.
- Clear piles of wood and trash.
- Keep firewood piles away from the structure.
- Keep gutters clean. Ensure that when downspouts terminate at the ground, water is directed away from the foundation.
- Grade around the foundation to draw water away from the building.
- Use preservative-treated lumber when wood is in ground contact and for the structural support members for exposed porches and decks.

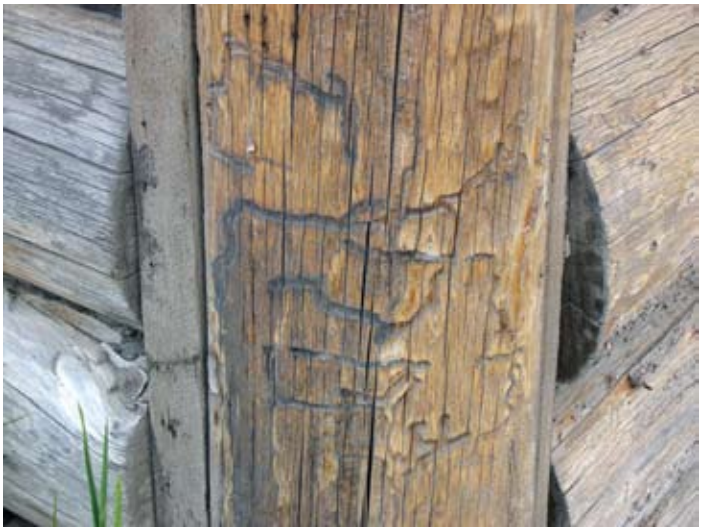
Wood-Boring Beetles

Certain beetles will attack wood. They can be grouped into those that stay near the bark layer (bark beetles) and those that bore into the internal structure of the wood (wood-boring beetles). These insects bore into wood to lay their eggs and feed on carbohydrates (sugars and starch). Signs of a beetle infestation include small holes in the surface of the wood and nearby piles of sawdust mixed with waste (*frass*). Some species can re-infest seasoned wood (logs in this case) while others that infest a living tree will not return once they have left the seasoned wood in a log home. These insects also vary in the amount of damage they cause. For these reasons, it is important

to identify the insect so that the proper control measures can be taken.[1] In some cases, "control" will involve only waiting for the insects to finish emerging from the logs because they will not return.

Reinfesting beetles. Powderpost beetles include lyctid, anobiid and bostrichid beetles. They can be distinguished by the type of wood they attack, the size and shape of the bore and emergence holes and the frass. Powderpost beetles can reinfest dry wood and can eventually cause significant damage; however, this is a slow process. Some powderpost beetles prefer unfinished wood with relatively high moisture content, so keeping the wood dry and applying a finish layer may be enough to keep the insect from returning to the wood. Borate-based wood preservatives or insecticides require unseasoned (wet) wood to penetrate and kill the beetles. Spray- or brush-applied treatments (to logs already in a home) will not penetrate very deeply. Therefore, in order to be truly effective against existing powderpost beetle infestations, borate-based preservatives must be applied, prior to assembly, using a pressure impregnation process. Other dip, brush or spray chemical treatments do not penetrate the wood, but they will provide localized protection and may prevent reinfestation. Certain longhorned beetles (Cerambycidae), such as the old house borer, can also re-infest logs in a home. These insects prefer the sapwood of softwoods such as pine. Large old house borer larvae can be heard as they feed. A stethoscope or other listening device can be used to locate these larvae. Wood near the gallery can be drilled and injected with insecticide. Despite their name, old house borers are usually found in homes less than 10 years old.

Non-reinfesting beetles. Ambrosia beetles, bark beetles, and most flat-headed and round-headed borers are insects that will not re-infest logs in a home. Except for the bark beetles, these are boring beetles that penetrate into the wood. Although the appearance of these insects may be unsightly and alarming, they are not a significant threat. Once they come out of the log, they are gone for good. However, some of these insects can take many years to develop and emerge, so it is important to have the correct identification before considering control measures.



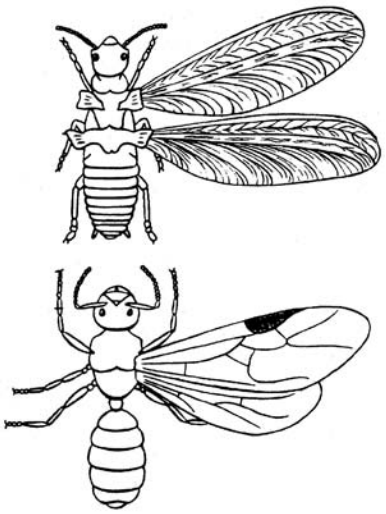
This log shows attack by bark beetles that occurred when the tree was standing. This log is still structurally sound and the beetles will not cause further damage.

A carpenter bee hole in a rafter. Carpenter bees are a common pest of log homes.

Carpenter Bees

Carpenter bees are large flying insects that resemble bumble bees. They do not eat wood; rather, they bore large (½" diameter) holes into logs and other exterior wood surfaces to excavate galleries in which to lay their eggs. Carpenter bees are not aggressive and rarely sting. Although carpenter bees create big holes in wood as brood chambers for their young, they are unlikely to cause structural damage

[1] *If beetle attack is observed, the type of beetle should be determined. Contact an Extension entomologist for help with identification. More information on managing wood-infesting insects can be found in UT Extension's PB1703 Wood Destroying Organisms at http://eppserver.ag.utk.edu/PSEP/second-level/thirdlevel/WDO/WDOindex.htm. Extension personnel in many states have prepared Web-based information on wood-infesting organisms.*



Both termites (top) and ants (bottom) have flying reproductive forms (*alates*). Termites have straight antennae, equal length wings and abdomens that are as wide as the rest of their bodies. Ants have bent antennae, wings of unequal length and constricted waists.

initially; however, repeated use of the same *galleries* over many years may cause significant damage. It is believed that carpenter bees are less likely to bore into wood that has been painted, but the finishes generally used on log homes do not prevent attack. More research is needed to evaluate preventive carpenter bee control strategies. Carpenter bees' galleries (holes) can be treated with dust, spray or foam insecticides and, after a 24-hour waiting period, physically blocked with a wood dowel to discourage further activity. Carpenter bees are also very slow-moving and will often hover around their holes. For this reason, many people recommend a fly swatter or tennis racket as the most effective means of control.

Carpenter Ants

Carpenter ants are large, often black, ants that can nest in wood. They often prefer wet or partially rotten wood. Unlike termites, carpenter ants do not eat the wood and are less likely to cause significant structural damage. Signs of a carpenter ant infestation include flying ants (*alates*) in or around the home and piles of sawdust containing insect parts below ant entry points. Carpenter ants can be a nuisance and can be controlled by locating and treating the nest with spray, dust or foam insecticides; baiting foraging ants; or treating trails and potential entry points with a nonrepellent, professionally-applied insecticide. Cleaning up kitchen waste and other potential food and eliminating water sources will help discourage ant infestations. Trimming vegetation so that it does not touch the structure and sealing wire and pipe wall penetrations can also reduce ant entry into the home

Fungal attack of wood

The fungi, which include the common button mushroom, are organisms that decompose organic matter. They are nature's recyclers and many species of fungi have the ability to attack wood in various ways. The fungi that can attack wood are divided into mold, stain and decay (rot) groups based on the damage that they cause. Decay fungi are the most serious threat; however, the presence of any active fungus means that the wood is wet and at risk. Keeping wood dry will prevent fungal problems.

Mold and Mildew Fungi

Mold can be seen as a fuzzy or discolored layer on the surface of wood. Molds are fungi that grow on certain portions of wood, bread, oranges, or any surface that provides a suitable combination of moderate temperature, moisture and food. Mildew is another term for mold. Molds feed on nutrients found in the storage cells in wood and are predominantly on the surface of wood. They do not eat or weaken the wood itself.

Mold on Wood

Recently there has been increased concern about mold on wood. Reports of so-called *toxic* molds, in particular, have caused people to be more interested in preventing, detecting and eliminating mold on the wood and other materials in their homes.

Under some conditions these molds can produce mycotoxins — special chemicals that can be toxic. Despite the alarming name, the dangers of toxic molds are often over-emphasized. The musty smell of mold is not caused by mycotoxins. Most molds don't produce mycotoxins, and even those molds that can produce mycotoxins don't produce them all the time. In general, while moldy wood may be unsightly or trigger allergic reactions in sensitive individuals. Typical exposures don't pose a health hazard for most people.

Molds (and other fungi) produce millions of microscopic spores. The spores from most species of mold are disseminated by the movement of air. The spores of some species attach themselves to the bodies of insects (usually beetles) and are deposited when the insect lands. However they arrive, once these spores land on the surface of wood (or other materials) when conditions are right, a new growth of mold will result. Air-borne mold spores are all around us and in the air we breathe. High concentrations of mold spores may cause allergic reactions in sensitive individuals.

The best way to prevent or stop mold from growing on wood and wood-based products is to keep the surface dry. This means that bathrooms, kitchens and basements should be well ventilated. Existing mold can be removed by washing with water, and bleach or detergents can be used to eliminate discolorations. Unfortunately, if the conditions conducive for mold growth remain, new spores will land on the wood and fresh mold will grow.

Chemical treatments that can help prevent mold growth do exist. However, the warm, wet conditions that lead to mold may also lead to wood rot, so preventing the elevated moisture content necessary for mold growth is the best solution.

Stain Fungi

Unlike most molds, stain fungi can penetrate below the surface by following naturally occurring void spaces and openings in the wood cells (rays) that extend from below the bark to the center of the tree (*pith*). Because of their pigmented *hyphae*, stain fungi cause blue, black or brown discoloration in infested wood. These fungi do not substantially weaken the wood. Stain fungi — also known as bluestain or sapstain — are restricted to sapwood, which contains the sugars and starches that are food for the fungi. Spores of stain fungi can quickly attack freshly fallen logs. Rapid drying of the surface of the wood (to prevent spore germination) or surface application of fungicides can prevent stain fungi from becoming established. Once logs have been seasoned, rewetting will not usually lead to staining by fungi; however, other fungal problems (mold fungi, whose spores are more readily airborne, and decay) will develop. Because the discolorations caused by sapstainers extend deep into the wood, they cannot be removed.

Bluestain has penetrated the sapwood of this pine log. The heartwood is not affected. The stain cannot be removed but the log is still structurally sound.

Non-microbial Stains

In addition to sunlight and fungi, wood can be discolored by chemical reactions. When a tree is harvested, the living cells within the sapwood continue to live for a while. These cells produce substances that can later oxidize and discolor the wood. Formation of these stains, which are also known as *kiln burn*, can be influenced by heating, and they may not appear until after kiln drying. The color and extent of the stain can be influenced by species (e.g. *brown stain* is characteristic of white pine and sugar pine) or localized variations in moisture content (e.g. *sticker shadow* or *sticker stain* under, or adjacent to, the spacers that separate boards in lumber piles). Regardless of the color or pattern, non-microbial stains do not weaken wood and will not expand after the wood is seasoned.

Some species of wood, including oak and cedar, can also become discolored when chemicals in the wood react with iron. Iron is present in sawmill processing equipment and in nails. Stainless steel, hot-dipped galvanized or other protected screws and nails should be used on exposed wood surfaces to minimize iron stain. Iron stains can be removed from wood using an oxalic acid solution. (For more information on these discolorations, please refer to Chapter 16 in the *Wood Handbook*. The URL for the online version is listed in the references at the end of this manual.)

Bleaching the surface of the wood may make the stain less noticeable by removing and lightening the colored part of the fungus. Application of pigmented finish to the surface of a log can also hide the presence of the stain.

Decay Fungi

Unlike mold and stain fungi that can discolor, but do not weaken wood, wood rotters – or decay fungi — consume parts of the wood cell wall. There are many species of decay fungi that are grouped by the appearance of the wood after attack. The two main types of decay fungi are *brown rot* and *white rot*. Regardless of the type of wood decay (or the common names that are used to describe it), all require that the wood be wet.

Brown rot fungi utilize the cellulose and hemicelluloses in the wood cell wall. A brown, crumbly residue of lignin is left behind and thus the name brown rot. Brown rotters are most often associated with softwoods, but they can attack hardwoods, too. White rot fungi tend to eat all components of the wood cell wall; and, when advanced white rot decay is present, the wood is turned into a white, stringy mass. Both white and brown rot fungi destroy the structural integrity of the wood. Significant strength losses can occur in the very early stages of attack, even before visual indicators are present. Fortunately, when decay is present

This log has been weakened by fungal decay. Butt joints are especially vulnerable areas because water that enters the joint is absorbed by the porous end-grain of the logs.

Dry Rot Isn't Dry

Water is the basis of life. This is true for animals and plants, and it is also true for the fungi. So what do people mean by dry rot? Usually when wood decay is identified as dry rot, it is a misidentification of brown rot. In the advanced stages of brown rot, all that remains of the wood is a spongy brown material that can easily be broken by hand. If this dries out after the fungus has run its course, the dusty, crumbly residue will then be both "dry" and "rotten," but it is still correctly referred to as brown rot.

Most decay fungi feed on wood that is exposed to a steady source of water. This can occur if wood is in contact with the ground or if a leak in a building traps water in contact with the wood. There are however a few, relatively rare fungi that can transport the needed water to the wood. These species may be called the dry rot fungi, but they are actually water-transporting brown rot fungi. *Meruliporia incrassata*, or "Poria" is one such fungus that is found in the United States, in particular in the southeast and southern California. Poria produces specialized water-conducting tubes called rhizomorphs that can transport water from wet areas (e.g. the ground) to nearby wood.

Poria is very susceptible to drying out (desiccation), so it is unlikely to become established on wood that is in a dry environment. Poria gains access to a home because of construction details that allow the water-conducting rhizomorphs to reach wood members without drying out. Rhizomorphs are initially small and grow only in diameter once they become established. This is one reason why they are susceptible to dehydration. Examples of construction details that allow access to the structure include siding that extends below grade, a humid crawl space, low earth-to-wood clearance and planter boxes that are attached directly to the exterior wall.

Wood is a remarkably durable material, and wooden buildings exist that are many centuries old. The key to this longevity is keeping the wood dry. This not only prevents attack by decay fungi but also prevents mold and stain and reduces the risk of insect infestation and weathering.

at this level, the extent of decay is usually localized, with most of the member being sound.

There are two practical methods for preventing rot of wood: 1) keep the wood dry (below 25 percent MC, the nominal fiber saturation point), or, in cases where that is not possible, 2) make the wood toxic to the fungus. Wood that is kept out of contact with liquid water — i.e., inside or under cover and not touching the ground — will remain dry enough that decay will not be a problem. In areas where wetting is unavoidable — for example, decking lumber or posts in the ground — preservatives can be added to the wood to considerably extend the useful service life of the wood member. The heartwood of naturally durable species contains natural preservatives that can help protect the heartwood against insects and fungi.

Wood Protection for Log Homes

The Importance of Keeping Wood Dry

A log house is a showcase for the natural beauty of wood. Imperfections such as knots and color variations are part of this beauty. Likewise, checking and settling are normal features of log walls. These irregularities are unique character marks that should be accounted for in design but otherwise embraced as part of the log home lifestyle.

The most important factor in protecting wood is keeping it dry. Wood that is protected from long-term wetting will not be attacked by fungi and will be less attractive to wood-inhabiting insects. Most of the steps that can be taken to keep wood dry are taken in the design stage, e.g., by having large roof overhangs (and a design that keeps the logs from extending beyond that overhang), keeping log walls well above ground level, and providing good drainage away from the foundation.

Proper construction practices are also important to ensure that water is kept out of the building. Wall penetrations (e.g., holes cut for electrical wires) and openings such as windows and doors are areas where poor installation and material choices often result in leaks in the building enclosure. After the log home has been designed and built, timely inspection and maintenance plays an important role in keeping wood dry. Gutters should be kept clean to avoid overflowing and allowing water to

This is an example of poor design. The log roof beams and their supports are exposed to wetting. Fungal attack is likely. Because of the greater permeability of wood in the longitudinal direction, fungal damage is especially likely to occur in the exposed logs ends.

splash on the walls of the building. Trees and shrubs should be kept trimmed away from the building. Crawl spaces, kitchens, bathrooms and other humid areas should either be vented, or specific design measures should be implemented to control and limit moisture development.

Wood Preservatives (if you can't keep the wood dry)

As mentioned above, keeping wood dry is often the simplest and always the best wood protection method. In some circumstances, however, extra protection is required. Various chemical treatments are available for protecting wood from insects and fungi. The proper wood preservative choice depends on the intended use. With the exception of a few over-the-counter preservatives and mold-inhibiting chemicals that are sometimes included in finishes, home owners do not apply wood protecting chemicals themselves. Wood preservative treatments are either applied during the manufacturing process for temporary protection against temporary problems (e.g., anti-sapstain chemicals), or they are applied to wood using special equipment to provide long-term protection. The major wood preservative types are described below.

Sapstain chemicals

As discussed above, sapstain or bluestain are fungi that can rapidly discolor the sapwood of freshly-cut logs. Some manufacturers dip or spray unseasoned (debarked) logs or lumber with preservatives to provide protection against sapstain fungi. This surface treatment is designed to protect the wood temporarily until the surface is dry enough so that sapstain is no longer a risk. There are many types of sapstain chemical but none of them provides long-term protection to wood.

Restricted-use preservatives

Decay fungi and termites cause structural damage to wood, so it is important to protect against these organisms if exposed wood is going to be repeatedly wetted (e.g., exposed decking and the underlying structural support members) or is touching the ground (e.g., columns and posts). A number of heavy-duty preservative systems are available to provide long-lasting and effective protection for wood. Creosote and pentachlorophenol are two dark-colored, oil-based preservatives that are used to protect railroad ties and utility poles. Creosote has a strong smell, and both preservatives leave the wood with an oily surface, so neither is commonly used in homes (old creosote-treated railroad ties have occasionally been used). A number of copper-based preservatives exist. These chemicals give the wood the familiar greenish color that characterizes the treated wood commonly available in home improvement centers and lumber yards. These preservatives are water-based, so the surface

Durable materials should be used when the wood cannot be kept dry. Preservative treated wood (bottom); western redcedar, a naturally durable wood (middle); and wood/plastic composite or WPC decking boards (top) are some of the options for exposed decks. Each of these materials should be used with care. Note that the inner core of the treated pine is not green in color. This means it was not penetrated by the preservative treatment and is relatively susceptible to attack by decay and insects. The western redcedar board contains sapwood (the whitish wood on the left-hand edge), which is not naturally durable. Wood plastic composites are not suitable for structural elements and some formulations have poor fire-performance characteristics.

of the treated wood is clean and paintable. In some parts of the country, treated wood is often used for decking and exposed railings. Treated wood is also commonly used for structural joists, beams and columns that support decks. Treated lumber is occasionally used for framing houses in areas with high termite or decay hazards, but it is rarely used for the logs of log homes. Except when incorporated into pressure-impregnated (treated) members, heavy-duty preservatives generally are not available to homeowners; these treatments are applied in factories, using pressure cycles to force the chemicals beyond the surface of the wood.

Copper naphthenate is an effective wood preservative that is available to the general public. This dark green or brown liquid is the over-the-counter "wood preservative" that is available at hardware stores. Zinc naphthenate is also available to the public and is clear in color. Although copper (or zinc) naphthenate is effective against a wide range of insects and fungi, the limited penetration available through brush-on or dip treatments in the field provide only slight protection. This is because the chemical stays near the surface of the wood. Because it also has an odor that is disagreeable to some, its use is limited to exterior applications.

Manufacturers of treated wood sometimes recommend a field treatment, such as brushing on copper naphthenate, to provide extra protection on the cut ends of treated wood. Especially in western species, field cuts usually expose an untreated core. In these situations, use of a field-applied preservative will supplement the durability of the treated lumber. The amount of copper in copper naphthenate is specified as a "percent copper as metal." The maximum amount available in an over-the-counter formulation is 2 percent (copper as metal). This amount should be obtained to maximize the protection. A dip treatment will typically result in deeper penetration than a brush application.

Considerable work is currently underway to develop non-copper-based preservatives. These new preservatives generally consist of two or more *co-biocides* to enhance protection against fungi and insects. New generation preservatives can be found in exterior coatings (e.g., paints and stains) and other anti-sapstain and mold formulations.

Boron-based preservatives

Boron-based wood preservatives (*borates*) can also provide protection against a wide range of insects and fungi. Borates have a number of potential advantages: they are colorless, odorless, have low mammalian toxicity and are inexpensive. Borates do not provide good protection against mold, thus borate formulations often contain an additional biocide to provide protection against mold fungi (an example of a co-biocide). Borates are water-soluble, which means that they can be applied to the surface of wet wood and the chemical will diffuse into the wet areas of the log. This results in protection beyond the surface. Some log home manufacturers apply borate preservatives to logs using a pressure treatment cycle but most often borates are brushed or sprayed onto the exterior of log houses after assembly. Borates can also be formed into rods that are inserted into holes drilled

Only the heartwood of naturally durable wood species is resistant to decay and insect attack. The sapwood (the outer band of light-colored wood) of this eastern redcedar post has been almost completely destroyed, while the heartwood remains sound.

into logs. If borate rods are used in your log home, they should be inserted into holes drilled at an upward angle to avoid water moving into the log down the length of the hole.

If borate preservatives are applied to dry wood (moisture content <25 percent or no free water), they cannot diffuse, and the protection will be limited to the surface of the wood or the area around the borate rod. Because borates are water-soluble, they will eventually move out (leach) from wood that is exposed to long-term wetting. For this reason, borates should only be used on wood that is protected from continuous wetting. Some borate-based products contain glycol. Glycol may improve the efficacy of the preservative against termites, but it has little documented impact on the diffusion or retention of the borate.

Natural durability

Some tree species grow wood that is naturally resistant to attack by insects and fungi. This *natural durability* is due to chemicals that the tree deposits in the heartwood as it is formed. Redwood, cypress and cedar are examples of species with a durable heartwood. It is important to note that only the heartwood (the inner core wood from the living tree) is durable. The sapwood of all species is susceptible to decay and insect attack. The heartwood in most naturally durable species is darker in color than the sapwood, which is generally white or tan. Bark should be removed from all logs used for log homes — bark increases the risk of decay and problems with insects.

Finishes

Finishes, which include paints, penetrating stains and water repellents, are liquid mixtures that are brushed or sprayed onto wood. Finishes are not wood preservatives, but they can help to protect wood. Finishes serve two purposes. The first is to protect the surface of the wood from weathering and short-term wetting. Pigments (color particles) and other additives can help protect the wood from damage by the ultraviolet rays in sunlight. The waxes and resins in finishes can help to repel liquid water and thus protect the wood from weathering and the wetting and drying cycles that can eventually result in surface checking. The second function of a finish is to change or maintain the look of the wood. A wide variety

The Weathered Look — A Traditional Finish for Log Homes

In the past, log homes and other structures with exposed wood were often unfinished. These buildings quickly turned brown or grey due to the action of sunlight. But, because wood is very durable if it is kept dry and because weathering is a very slow process, some of these buildings have lasted for hundreds of years. So, if a log home is well designed and the discolored and non-uniform appearance of weathered wood is acceptable, the home owner can dispense with finishes altogether. This will save the homeowner the time and expense of finishing and refinishing, and will provide a traditional look to the home.

This wood has been finished with a semitransparent penetrating stain. The pigments provide some color, but the grain of the wood is still visible. Similar finishes are commonly used on log homes. Refer to Chapter 16 in the Wood Handbook for more information on wood finishes.

of pigment colors and concentrations is available. Darker finishes, with more pigments, provide greater protection but also tend to hide the natural look of the wood.

Finishes can be organized into two groups: film-forming and penetrating. Film-forming finishes include paint and solid-color (or heavy-body) stains. These finishes remain on the surface of the wood and often contain high levels of pigments that can protect the wood and the finish itself. Penetrating finishes are absorbed into the surface layers of the wood; examples include some water repellents and semi-transparent stains. Penetrating stains have the advantage that they won't peel like the film-forming finishes can. The most common finishes applied to log homes are penetrating semi-transparent stains, which have some pigment to protect the wood and provide color but also allow the wood grain to show.

Water repellents can be stand-alone finishes or can be used as a primer before applying other finishes. The difference is in the amount of wax they contain, so it is important to know which type you are using. Water repellents can also contain a preservative, which is incorporated to help control mold/mildew. However, finishes are not true wood preservatives, not even the water repellent/preservatives. Finishes are intended only to protect the surface from liquid water and sunshine — they do not provide long-lasting protection against insects or fungi.

Application of finishes & refinishing

In general, following the application directions on the container will ensure the best results. General finishing tips include:

- Finishes should be applied to clean, dry surfaces.
- Avoid applying finishes in very hot or very cold weather.
- Complete entire walls in one application. This is especially important with pigmented (colored) finishes to avoid *lap marks*, which can reveal the overlap of different applications.

Finishes should be reapplied when they stop doing their job — those functions being shedding water and keeping the wood looking good. Finishes do not last very long in exterior applications: six months to no more than a few years is a normal lifetime. The residual water repellent characteristics can be tested by sprinkling water on the wood: if the water doesn't bead on the surface, the treatment should be reapplied. Because penetrating finishes such as semi-transparent penetrating stains fail gradually, refinishing is accomplished by applying new finish over the old finish.

Refinishing film-forming finishes is more difficult; the old finish must be scraped and sanded to provide a suitable surface for the next application. Depending on the finish being applied, an initial primer coat may be required. Follow the instructions that pertain to the finish being applied.

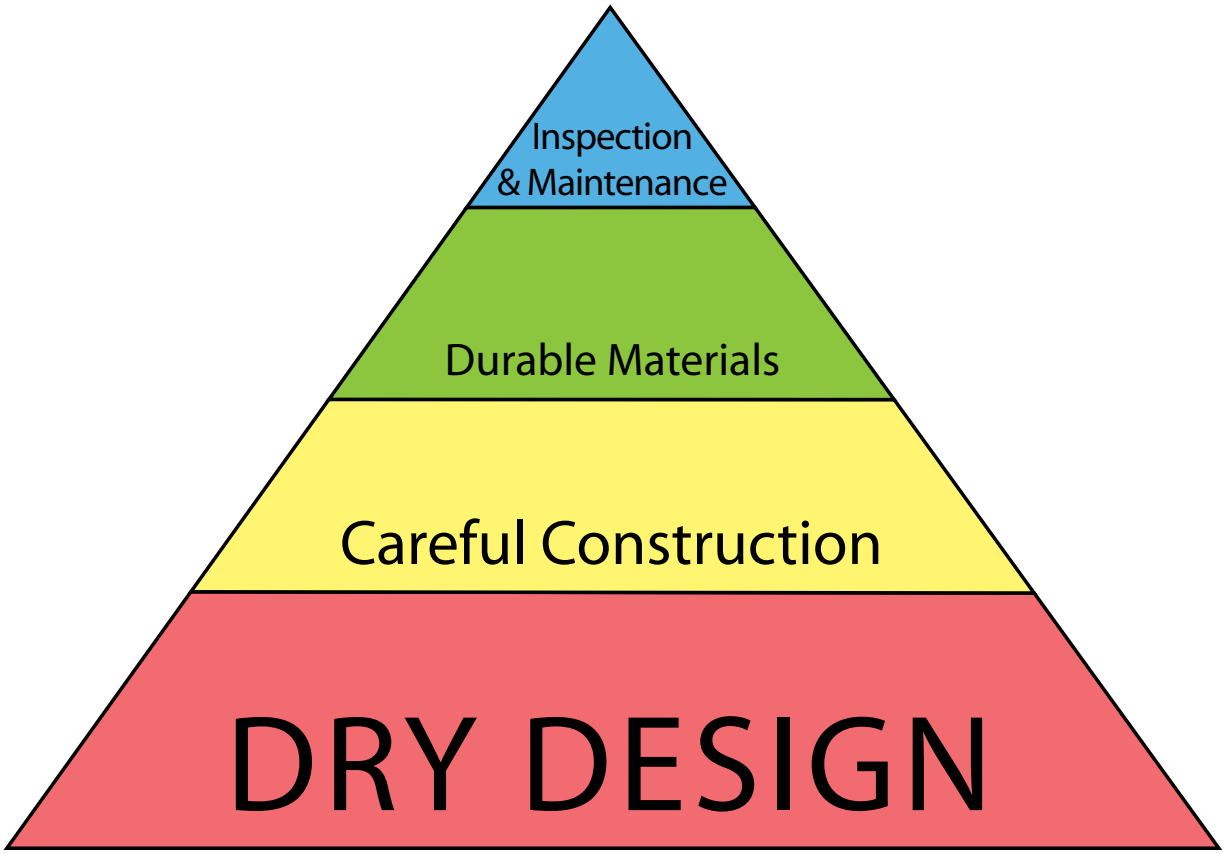
Cleaning may be required to provide a clean and attractive surface prior to refinishing. A number of suitable chemical washes are available for this job. Logs walls can also be cleaned using pressure washers or sand (or other abrasive media) blasting. These methods remove the surface layers of the wood, so care should be taken not to damage the wood.

The Durability Pyramid

Although proper construction, durable materials and maintenance are necessary for a durable log home (i.e., one that will perform well over the long run), starting with a *dry design* is critical.

Dry design

The specific aspects of dry design will vary somewhat on the type of log home but will consist of design measures that keep water away from the walls



The log home durability pyramid. Inspection and maintenance cannot compensate for bad design, poor construction details or the failure to use durable materials.

of the home (for example, by providing for a wide roof overhang) and by incorporating wall features that allow a wetted wall to dry.[2]

Many log homes use round logs, but logs can be processed into different shapes (*styling* and *profiling*) with the building still being referred to as a *log home*. For example, logs can be processed such that a vertical (flat) surface is observed on the inside and/or outside of the home. Many terms are used to describe how the log will look after processing (either before or after construction). Logs can take on a "D" shape (flat on the top and bottom, rounded on the inside and/or outside), flat on all surfaces (square or rectangular), fully round, or round with a concave bottom. The final shape of the log will determine how the members will fit together at the horizontal joints and vertically at the corners. Regardless of the log profile, the goal is a dry design — either prevent the logs from getting wet in the first place or follow a design that will allow the wall to shed water and dry quickly.

Most moisture related problems in homes are associated with water leaks at penetrations and joints (i.e., at windows, butt joints of logs). Logs (and heavy timbers in general) have the additional challenge of the potential to develop cracks (checks) as a result of stresses that develop during wetting and drying cycles. Log structures usually have more joints than other framed construction systems, and so more care must be taken during design and construction and also during post-construction inspections as part of a routine maintenance program.

Careful construction

Careful construction means that all materials and components are assembled and installed

[2]*This practice can be summarized by the "4 Ds" of wood construction: Deflection of moisture away from the exterior walls, Drainage of moisture, Drying of wetted materials and use of Durable materials. This concept was developed by researchers in Vancouver, Canada, in response to numerous water-related building problems in that city. More information can be found at http://www.durable-wood.com/pdfs/The_4_Ds.doc*

Durable materials should always be used when wood will be exposed to wetting. The decking shown here is made from preservative-treated wood; but the railing is made from non-durable, untreated wood. Despite the finish that has been applied and the end caps on the posts, this railing is at very high risk of decay.

properly. Poor installation can result in leaks at windows, doors and other penetrations. Water vapor can also be trapped and condensed inside the building enclosure if construction details are overlooked or incorrectly applied. In log homes, the logs will constitute a large portion of the building enclosure. Water entry into the logs (at cracks, butt joints, etc.) will result in internal decay and possibly also insect damage. Careful construction also means that connections where rigid components (doors, windows, stud walls) meet log walls, which will settle during initial drying, allow for the inevitable movement.

Durable materials

In locations where wood will inevitably be exposed to wetting, durable materials should be used. These locations include any ground contact exposures as well as decking and railings not protected by a roof or covering. Durable wood products include preservative-treated wood and naturally durable woods such as the heartwood of cypress, redwood, cedars and white oak.

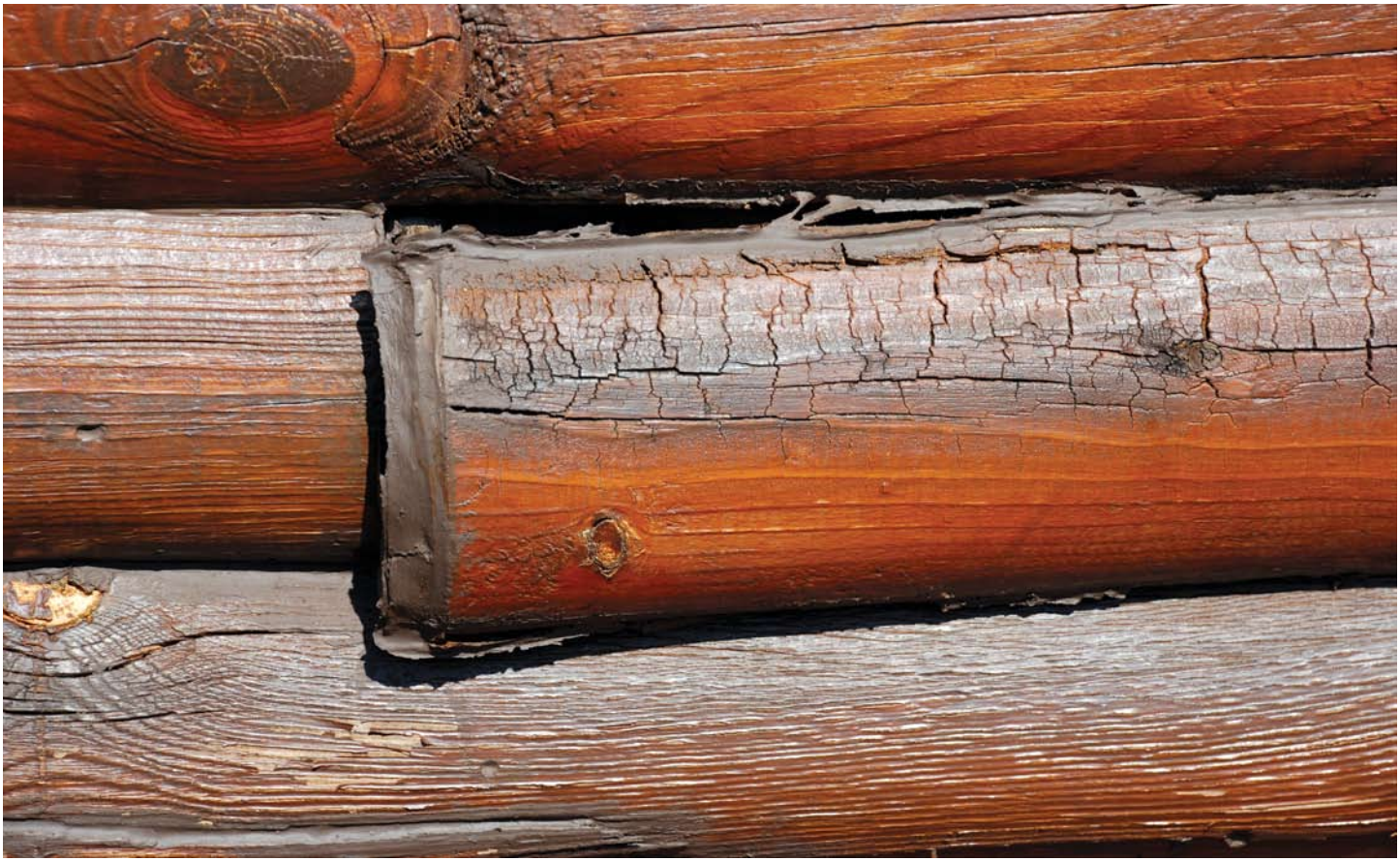
The use of durable materials can also provide an additional layer of protection for components that are mostly protected from the elements. The use of less durable raw materials puts more importance on the other three components of the durability pyramid.

Inspection and maintenance

Regular inspection and maintenance is also important because of the differences in service life between the many components and assemblies that make up a log home. For example, a roof covering will not last as long as the siding of a home (the log walls in the case of a log home). In particular, finishes have a relatively short life-span and should be inspected, and reapplied if necessary, on an annual basis.

The most important factor in protecting wood is keeping it dry. With this in mind, maintenance of a log home should focus on practices ensuring that rain does not get into the house and that excess water vapor is allowed to get out (or prevented from getting in, depending on the climate). Gutters should be kept clean and vegetation trimmed away from the building. Kitchens, bathrooms, basements and crawlspaces should be well vented or ventilated. Maintenance should also include regular inspection to find — and fix — any water leaks. Even small leaks in a roof or around a window can bring in large amounts of water, resulting in big problems that may reveal themselves far from the source. Inspections should also look for evidence of termites — significant damage can occur if termite activity goes undetected.

Modern log homes are large, comfortable and attractive buildings. A good design that is well executed and includes the appropriate use of durable materials will ensure that only regular maintenance will be required to keep a log home standing and looking good for many years.



Despite repeated applications of finishes and caulking, these logs are failing due to fungal decay. This wall is exposed to rain because of an insufficient roof overhang. Homeowner maintenance could not compensate for a poor design.

References

The Wood Handbook. A downloadable reference with information on wood properties. www.fpl.fs.fed.us/documnts/fplgtr/fplgtr113/fplgtr113.htm

Wood Design Focus, Volume 14, Number 1, Spring 2004. Published by the Forest Products Society (quarterly).

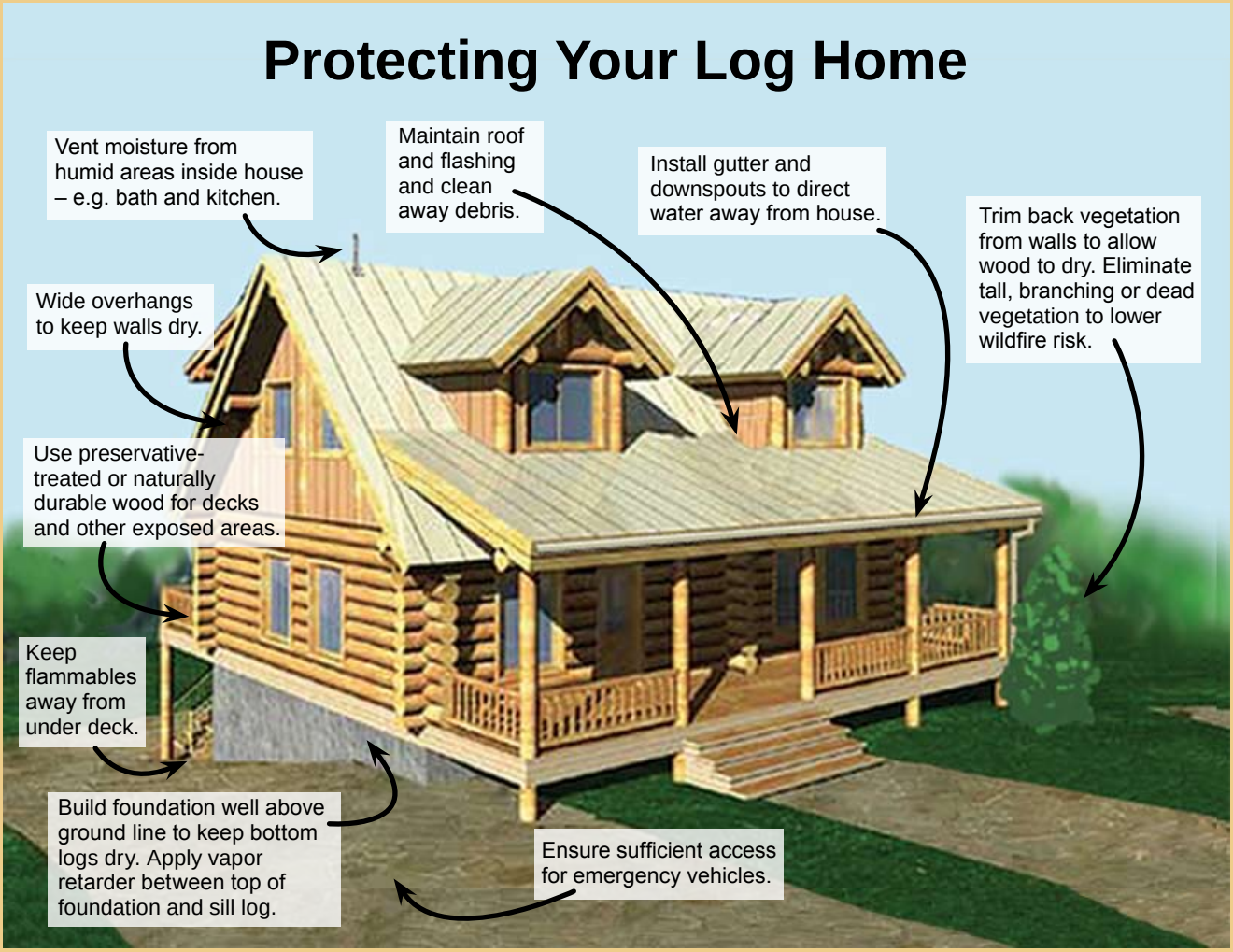
Log Construction Manual: The Ultimate Guide to Building Handcrafted Log Homes. Chambers, R.W. 2003. Deep Stream Press, River Falls, Wis. 272 pp.

Preservation & Maintenance of Log Structures. Prepared by The Log Homes Council (www.loghomes.org/) a log home manufacturers group. Available for download at http://www.loghomes.org/uploads/Preservation%20%20Maintenance%20of%20Log%20Structures%2010-15-03.PDF

The Log Home Maintenance Guide: A Field Guide for Identifying, Preventing, and Solving Problems. Schroeder, G. 2003. The Country Press. Woodstock, Vt. 176 pp.

Wood Destroying Organisms. Vail K., Burgess, G., Pless, C. and Taylor, A. [eds]. 2006. University of Tennessee Extension PB1703. 76 pp. A training manual for pest management professionals that has information on identifying pests — see chapter 2. http://eppserver.ag.utk.edu/pat/PATinfo/WDO/WDOindex.htm

Weathering and Protection of Wood. Feist, W.C. Proceedings of the 79th Annual Meeting of the American Wood Preserver's Association, 79:195-205. 1983. http://www.fpl.fs.fed.us/documnts/pdf1983/feist83a.pdf



PB1767-1M-5/07 E12-4915-000-015-07 07-0101