FireWise Construction:

Site Design & Building Materials

Based on the 2009 International Wildland-Urban Interface Code

Colorado State Forest Service

About the Authors

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David developed sections 4 and 5 of this publication based on the 2009 International Wildland-Urban Interface Code.

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Tim was the main author of the first three sections of this publication.

Dedication

Peter Slack of Boulder, Colo., was a practicing architect for 26 years, until his untimely death in June 2000. Peter designed many homes and other buildings in the wildland-urban interface (WUI). His designs emphasized the integration of fire-resistive elements with other important design principles, such as proper site development for limited impact, low energy and water consumption, and the use of appropriate, resource-conserving materials.

Peter developed the first iteration of this publication in 1999.

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Introduction

Two factors have emerged as the primary determinants of a home's ability to survive a wildfire – quality of the defensible space and structural ignitability. Together, these two factors create a concept called the Home Ignition Zone (HIZ), which includes the structure and the space immediately surrounding the structure. To protect a home from wildfire, the primary goal is to reduce or eliminate fuels and ignition sources within the HIZ.

This publication addresses both defensible space and structural ignitability.

Sections 1 – 3 are based on a recent publication developed by the Colorado State Forest Service, *Protecting Your Home from Wildfire: Creating Wildfire-Defensible Space.*

Sections 4 and 5 are based on the *2009 International Wildland-Urban Interface Code*.

In 2003, a growing awareness of wildfire risk led the International Code Council (ICC) to publish the first edition of the International Wildland-Urban Interface Code (IWUIC). This was the culmination of an effort initiated in 2001 by the ICC and the three statutory members of the International Code Council: Building Officials and Code Administrators International, Inc. (BOCA), International Conference of Building Officials (ICBO) and Southern Building Code Congress International (SBCCI). The intent was to draft a comprehensive set of regulations for mitigating hazards to life and property from the intrusion of fire resulting from wildland exposures and adjacent structures, and preventing structure fires from spreading to wildland fuels. Technical content of the 2000 Wildland-Urban Interface Code, published by the International Fire Code Institute, was used as the basis for development of the initial draft, followed by the publication of the 2001 final draft.

This updated publication is based on the 2009 IWUIC. It provides criteria for establishing an area's fire hazard severity as moderate, high or extreme, and spells out prescriptive measures for building within those zones. Local jurisdictions often use the IWUIC or adopt something similar for their communities. It is hoped that the information presented will help homeowners, designers and builders understand the unique issues associated with structure construction in the wildland-urban interface and encourage consistency in the application of provisions.

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1. Wildfire in Colorado

This publication was developed to provide homeowners, building designers/builders and landscape architects with design, building and landscaping techniques for additional protection from wildfires in the wildland-urban interface (WUI).

It is not always possible to control a wildfire. Under extreme conditions, wildfires can threaten homes and other structures, infrastructure and evacuation routes. Planning and preparation can make the difference in personal safety and home protection.

What is the wildland-urban interface?

The wildland-urban interface (WUI) is any area where structures and other human development meets or intermingles with wildland vegetative fuels.

Population growth in the WUI has increased, especially in the Western U.S. The expansion of subdivisions and other high-density developments has created conditions under which local fire departments cannot possibly protect all structures during a wildfire.

Fire suppression and increased fuels

Past fire suppression and limited forest management have produced dangerous accumulations of fuels, causing hotter and more intense fires when they burn. The arrangement of these fuels causes fire to travel to the top of the forest, rather than staying close to the ground. These crown fires are extremely threatening to soils, habitat, property and people.

In some of Colorado's forests, naturally occurring low-intensity wildfires periodically burned through stands of trees, removing fuels and thinning out excess vegetation.

As population in the WUI has increased, so too has the difficulty of protecting that population. When fires occur in the WUI, they are suppressed to prevent the destruction of homes and other values at risk. This creates a problem because historically, some forests have depended on fire to maintain good health. Fire can thin trees and brush, and eliminate dead material. By fighting wildfires to protect homes and people, this natural process has been altered and vegetation density has increased, which provides more fuel for fires. When fires occur, the dense vegetation can burn more intensely, making it more destructive and dangerous.

How can we protect our homes?

Construction in virtually every jurisdiction in the United States is regulated by building codes for the purpose of providing minimum public health and safety standards. Non-governmental model building code organizations, such as the International Code Council (ICC) and the National Fire Protection Association (NFPA), develop and maintain model building codes for use by state and local jurisdictions. A model building code is not enforceable until it is adopted by a state or local jurisdiction, with or without amendments, and becomes law. Several states, including Colorado, are "home-rule states." Under home rule, local governments have the ability to establish their own sets of codes and standards specific to their community. Because Colorado is a home-rule state and no statewide building code has been enacted as law, local jurisdictions adopt and/or adapt their own codes.

Typically, model codes allow the use of given building materials, while creating the parameters under which the material can be used. The concepts presented in this publication are based on the 2009 International Wildland-Urban Interface Code (IWUIC), the most widely adopted code addressing the WUI in the United States.

This comprehensive WUI code establishes minimum regulations for land use and the built environment in designated WUI areas, using prescriptive and performance-related provisions. It is founded on data collected through tests and fire incidents, technical reports and mitigation strategies from around the world. The IWUIC references the International Building Code (IBC), rather than the International Residential Code (IRC), the code most often adhered to by builders for home construction. This is because the IRC does not address several of the fire-resistive construction concepts that are necessary to meet the Ignition-Resistance Construction Classification. (*Ignition-resistant building materials are those that sufficiently resist ignition or sustained flaming combustion to reduce losses from WUI conflagrations under worst-case weather and fuel conditions with wildfire exposure to burning embers and small flames.*)

This publication offers a two-part approach to the problem:

1. Build more ignition-resistant structures, and
2. Reduce hazardous forest fuels.

A combination of site/landscape management techniques and appropriate construction materials are necessary to build more ignition-resistant structures in the WUI. The goal is to create structures that can either resist fire on their own, or at least make it easier for firefighters to safely protect structures. Building a noncombustible structure, as often is done in urban settings, can be prohibitively expensive; this publication discusses a combination of cost-effective strategies that increase the probability a structure will survive a wildfire.

Solutions to problems in the WUI involve a two-part approach: Make structures more ignition-resistant and reduce surrounding wildland fuels. Choosing the best combination of these two strategies for a particular site requires a basic understanding of wildfire behavior.

- If we leave the surrounding wildland in its current state, we need to build structures that are resistant to fire. Noncombustible structures are very expensive to build.
- Trying to provide a defensible space large enough for a typical wood-frame structure may not be practical or desirable.

Another goal of this publication is to give homeowners, designers and builders a better understanding of how buildings in the WUI ignite during a wildfire. With this information, it is possible to make better choices when selecting building techniques and materials. However, fire is only one of many factors to consider during construction. There is no single approach, and using alternative materials or landscape management techniques is always possible.

Awareness of the unique issues landowners face when building in the WUI will help direct them toward a more comprehensive solution during the design process. Some design elements and materials may help mitigate fire hazards; some may not. It is possible, however, to compensate for less desirable fire protection choices and still meet design goals.

Fire intensity and duration related to the fire resistance of structures

How ignition-resistant should a structure be? The answer to this question depends on fire intensity (how hot the fire burns) and fire duration (how long the fire will last at your site). If the fire hazard is low to moderate, only a few precautions may be necessary. If the fire hazard is high or extreme, most, or all, of the strategies described may be necessary.

In Colorado, almost any area surrounded by natural vegetation faces some hazard due to wildfire. In mountainous regions between elevations of 5,000 and 10,000 feet, fire hazard increases due to topography and increased vegetation density.

Ember propagation potential in relation to structures

Burning embers, have caused of the loss of many homes in the WUI. Embers in wildfires are produced when conifer trees are consumed by the fire. In WUI fires, burning structures also can be sources of burning embers. Flammable horizontal surfaces, such as wooden decks or shake roofs, are especially at risk for ignition from burning embers.

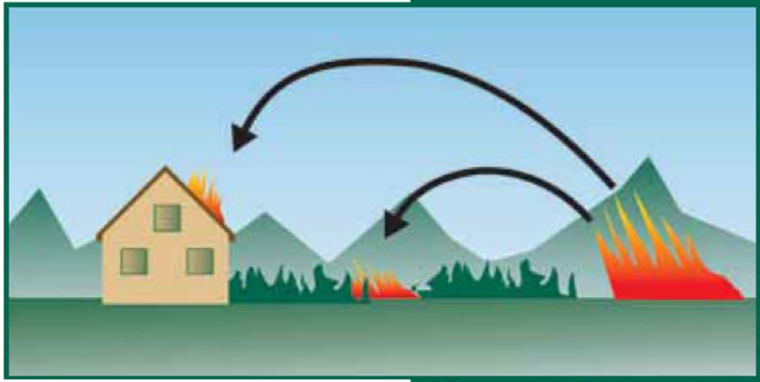

Figure 1-1: Fire brands, transported by convective lifting, create spot fires

Evaluating fire hazards

An effective way to determine the specific fire hazard severity in an area is to look at a fire hazard map or study located in the county building or land use department. Your local fire protection district also may have information. The code officially establishes the fire hazard severity of your site based on section 502.1 (Appendix C) of the IWUIC. If this information is not immediately available, use Figure 1-2 to determine the hazard level of your site.

Slope	Score
Level	0
0° - 10°	1
10° - 20°	2
20° - 30°	3
30°+	4

Vegetation	
water, rock or bare ground	0
grass, shrub, less than 2 feet with no trees	1
grass, shrub, less than 4 feet, widely scattered trees	2
dense young shrubs, no dead wood or trees	2
many trees, touching, some grass and brush	3
dense shrubs with some trees	3
thick, tall grass	3
dense evergreen trees with grass and shrubs	4
dense mature shrub with dead branches	4

After selecting the appropriate slope and vegetation scores, add them together to determine the fire hazard severity.

Scores	Fire Hazard Severity
0 - 2	low
3 - 4	moderate
5 - 6	high
7 - 8	extreme

Figure 1-2: Fire hazard severity ratings

This short evaluation is based on the Wildland Home Fire Risk Meter developed by the National Wildfire Coordinating Group.

Note: The term fire hazard severity in this publication refers to material elements used in building design and the actual design itself.

2. Fire Behavior: Fuels, Weather and Topography

Wildfires and the nature of burning structures

Wildfires can ignite structures in two ways:

1. Direct flame contact with a moving fire. The fire behavior factors that influence a structure's potential for ignition are fire intensity and duration of flame contact.
2. An ignition started by a burning ember landing on a flammable surface, such as a shake roof or wooden deck.

Understanding the potential fire behavior, especially intensity, duration and ember deposition at a building site, will help homeowners, designers and builders determine how ignition-resistant a structure needs to be.

Wildfires have been studied in great detail to help predict fire behavior. Predicting fire intensity, rate of spread, duration, direction and spot-fire production is important for firefighter safety and is the basis for tactical decisions made during the suppression of a fire.

Three factors affect wildfire behavior in the WUI:

1. **Fuels:** The type, continuity and density of surrounding vegetation and, sometimes, flammable structures, provide fuel to keep the fire burning.
2. **Weather:** Wind, relative humidity and atmospheric stability all affect potential fire behavior.
3. **Topography:** The steepness and direction of slopes, and building-site location in relation to topography are features that affect fire behavior.

Fuels are anything that burns in a fire

Wildland fuels are divided into four categories:

1. Grass
2. Brush or shrubs
3. Timber
4. Woody debris

All plants can burn under extreme conditions, such as drought; however, plants burn at different intensities and rates of consumption. The type and density of a specific plant determines how it will burn. Some vegetation rarely burns, while other vegetation burns at different times of the year; and some can burn almost anytime. The amount of moisture in the fuels is the biggest factor affecting flammability.

Grasses: Grass primarily exists in two conditions – green and cured. When grass is green, moisture content is high enough to prevent or decrease fire spread. Firefighters sometimes use green meadows and lawns as safety zones. As the year progresses, plants enter a dormant state and the residual surface vegetation dies. Cured grass has the potential to promote extreme fire rates of spread (ROS); grass fuels have the highest potential ROS of any fuels. Another hazard associated with cured grass is the potential for a rapid decrease in fuel moisture; the ability of air to circulate through standing grass allows the grass to dry rapidly and can result in sudden changes in fire behavior.

Brush: Brush fires spread slower than grass fires, but burn at a higher intensity. The most common flammable brush species in Colorado are oak brush and sagebrush. Brush is least flammable in late spring when new growth occurs.

Timber: Timber burns in two manners – as surface fires and crown fires. Surface fires consume fuels on the forest floor without burning trees, although trees may burn individually, which is called torching. Crown fires occur when entire stands of trees are totally consumed. These fires are the most intense, but tend to move less rapidly than other types of fire. Coniferous trees are more susceptible to crown fire than deciduous trees. Torching and crown fires are the major source of ember production, which can start new fires (spot-fires) in vegetation and structures downwind.

Woody debris: Dead logs, branches and sticks on the ground surface are referred to as woody debris. Debris can result from human activity, such as thinning, or from natural processes, such as wind-throw or beetle-killed trees that have fallen to the ground. Wildfires in these fuels vary greatly, but can produce high-intensity, slow-moving fires that are very difficult to control. Colorado's mountain pine beetle epidemic will result in a major increase in woody debris over large areas.

Complexes: More than one fuel component is present in most wildland areas. Areas containing these fuel complexes are more common than those represented by a single fuel component.

Structures: The effect of a burning structure can significantly impact wildfire behavior. Structures burn with extreme intensity, often launching large burning embers over long distances.

Fuels and fire duration: Fire duration refers to the length of time a wildfire will burn under certain conditions. Fuel type, quantity, temperature and moisture content determine the duration of a fire. Building structures that will resist fires for any length of time is dependent on a good understanding of local conditions that contribute to the duration of fire in a particular area. Different building materials can resist fire for different time periods.

Climate and Weather

Climate: Fire seasons in Colorado's high country and on the Western Slope tend to last from late spring until mid-autumn. Fire seasons on the Front Range and Eastern Plains tend to be split, with most large fires occurring in the spring or fall. It's important to keep in mind that these are generalizations and that large fires can occur anytime conditions are right. The most likely fire season depends on the geographical location of the building site.

Weather is a major factor that affects fire behavior and is highly variable in terms of time, intensity and location. Weather can change dramatically in a short period of time, resulting in rapid changes in fire behavior.

Wind: Surface winds are the most important element in determining fire direction and rate of spread. Wind pushes flames into adjacent fuels, facilitating rapid ignition, and tends to be the common theme in large fire events. High-velocity, warm, dry, down-slope winds, such as a Chinook, can cause fuels to dry rapidly, resulting in extreme fire behavior.

Relative Humidity (RH): RH is a measure of how much moisture is in the air compared to the maximum amount of moisture the atmosphere can hold at that temperature. RH has a major influence on the moisture content of dead fuels. The smaller the dead fuel, the faster it will react to a change in the RH. Cured grass can dry out in less than 15 minutes when a dry air mass moves into an area. Firefighters generally monitor RH on an hourly basis when fighting a fire.

Temperature: Before combustion can occur, fuels must reach ignition temperature (approximately 450° F); fuels heat up and reach ignition temperature more quickly on hot days. In addition, when fuels are preheated, fire expends less energy and will burn at a higher intensity.

Topography and Fire Behavior

Topography is the shape of the land's surface. It influences fire behavior by the effects it has on wind, temperature, moisture and the preheating of fuels.

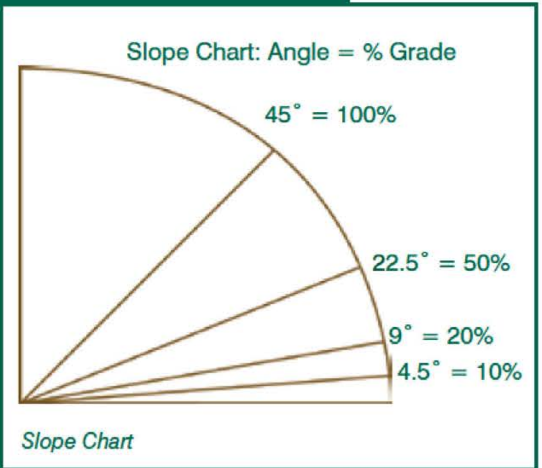

Figure 2-1: Slope chart

Slope: Defined as the angle of the ground relative to the horizon, slope commonly is measured in degrees or as a percent. On calm days, heated air, including flames, rises and preheats the fuels upslope, which causes an increase in fire spread. On gentle slopes, preheating has little effect on fire behavior, but on steep slopes, the effect can be significant. During summer months, preheating generally causes winds to blow upslope. The combined effect of slope and wind results in rapid fire spread.

Aspect: Aspect is the direction the slope faces. South and southwest aspects are warmer and drier than north and northeast aspects.

Saddles and Chimneys: A saddle is a low spot on a ridge. A chimney is a gully or drainage that goes up a slope. Both saddles and chimneys funnel winds and increase fire spread and intensity.

Structures located on steep slopes or in saddles or chimneys require more ignition-resistant components and/or larger defensible space.

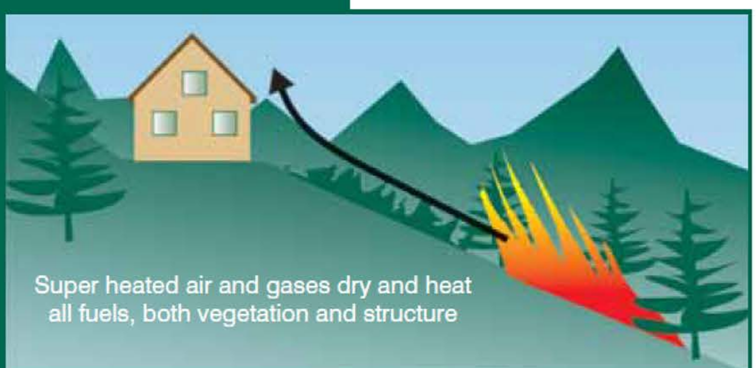

Figure 2-2: Super heated air and gases rise and heat fuels

Fire behavior and ignition of fuels: heat transfer mechanisms

As fuels burn, they release hot gas in the form of flames and smoke. These gases rise and move with the wind. Sometimes embers are carried aloft by this convective lifting. These hot gasses also heat fuels in which they come in contact, bringing those fuels closer to their ignition point. Fires also produce large amounts of radiant energy (like the sun), which heats surrounding fuels. Ignition occurs more easily once flames make contact with the vegetation. This, in turn, accelerates the rate at which the fire moves and increases in intensity.

Several heat-transfer mechanisms from a wildfire are involved in the ignition of a structure:

- Radiant heating that results in an ignition or heats a flammable surface makes structures more susceptible to ignition from another source.
- Direct flame contact with a flammable portion of the structure can cause ignition.
- Convective lifting resulting in ember deposition on a flammable surface can cause ignition.

Understanding these processes will help design structures and landscapes that reduce wildfire risk.

Indirect: radiant heating

The transfer of heat by radiant energy from fire can preheat or even ignite structures. This is the same process that occurs when sunlight heats an object. Radiant heat transfer occurs on a straight line of sight and is not affected by wind.

Vertical surfaces, such as siding, can ignite as a result of this process before fire actually reaches the structure. Curtains can ignite from radiant heat transferred through windows. Torching trees and crown fires nearby can cause high levels of radiant heat for short to moderate durations. Adjacent burning structures create intense radiant heat for long durations. And once ignited, large, heavy fuels burn at high temperatures that amplify radiant energy, creating more potential for ignition through heat transfer.

Radiant energy decreases with distance. It follows the inverse square rule shown in Figure 2-4. Doubling the distance from the heat source will reduce radiant heat by significantly more than half. A torching tree 10 feet from a structure will produce four times more radiant heat than the same tree torching 20 feet from a structure. Radiant heat energy decreases dramatically with increased distance.

Figure 2-3: Radiant heating

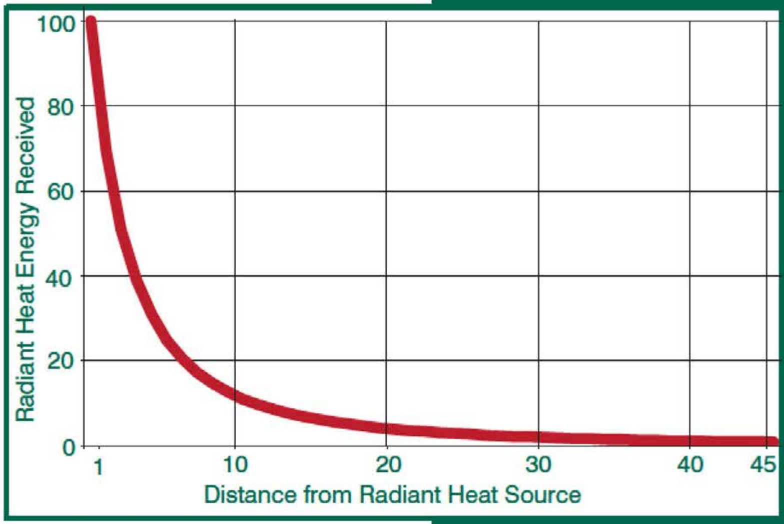

Figure 2-4: Radiant energy decreases with increased distance

Direct contact or impingement

Unmanaged vegetation adjacent to a structure provides continuous and abundant fuels, which can ignite flammable building surfaces. Creating defensible space and fuelbreaks around a structure is specifically intended to reduce this effect.

Figure 2-5: Fire directly impinging on a house

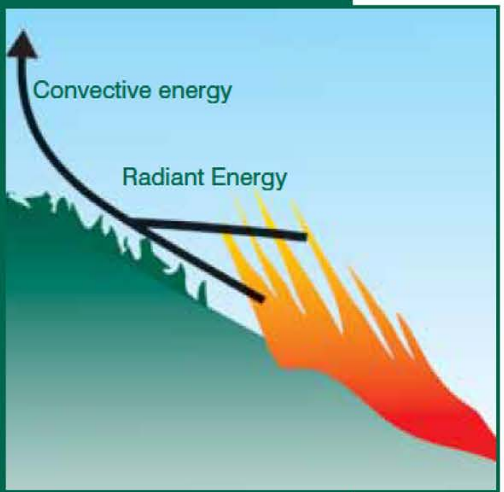

Figure 2-6: Convective and radiant energy from a fire

Convective lifting

Fire produces hot gases that rise into the atmosphere. During a wildfire, this atmospheric effect can be very strong, even causing its own wind as cooler air rushes in to replace the rising hot air.

Convective air currents also lift burning materials or embers. Winds can carry embers horizontally for long distances from the fire.

Embers can fall onto horizontal surfaces, such as combustible roofs, decks and dry vegetation around structures. When this results in a new ignition, it is called spotting and can be very widespread. Embers often travel hundreds or even thousands of feet ahead of the actual fire.

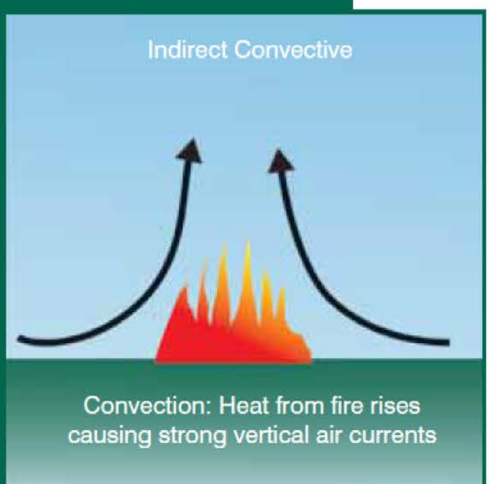

Figure 2-7: Convective lifting

Indirect: convective heating

The same hot air and gasses that dry and preheat vegetation have the same effect on structures, predisposing combustible materials to ignition as the fire gets closer.

3. Building-site Location and Landscaping

Topography and vegetation: fire behavior and intensity

Structure location influences the potential fire intensity and duration to which that structure may be exposed. The information in the fire behavior section (Section 2) discussed how to estimate fire intensity and duration. This information can be used to determine the building site that will allow the highest probability of survival in the event of a wildfire. When choosing a site or determining the level of ignition resistance a structure requires, homeowners, designers and builders should be aware of how local vegetation and topographic variations affect fire behavior.

Aspect

Aspect is the direction that the slope faces. Vegetation varies widely between the extremes of south-facing and north-facing slopes.

South and west slopes tend to have the least vegetation because they quickly dry out and have less available moisture for plants. Southwest slopes tend to have the fastest moving fires.

East aspects generally have more vegetation than southwest slopes and tend to dry out in later in the summer.

North slopes typically have the densest vegetation because there is more water available for plants. Because the moisture content of the vegetation on north slopes is higher, fires tend to burn with less intensity. However, when fires occur during times of drought, they can burn with greater intensity because of the increased amount of fuels.

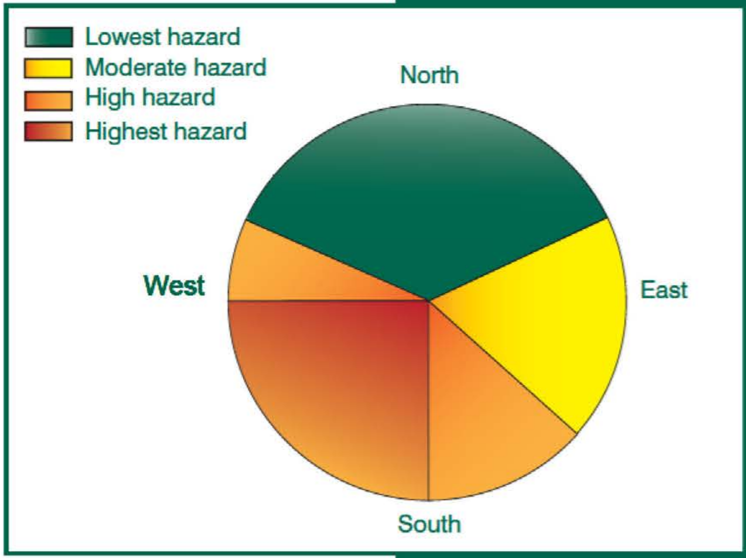

Figure 3-1: Fire hazard varies widely from aspect to aspect

Dangerous topographic features: areas of more intense fire behavior

Variations in topographic features such as valleys, ridges, canyons and saddles present hazards that further intensify or attract fires. A **valley**, as a concave form, tends to collect and concentrate winds. This means that the intensity of a wildfire can increase as it moves through a valley. In **canyons**, this effect is even more pronounced. **Ridges** experience more wind primarily because they are elevated above the surrounding land. When a fire moves up a slope toward a ridge, it gathers speed and intensity. A low point between the higher parts of a ridge is called a saddle. Like a valley, saddles will channel, intensify and increase the fire's rate of spread. These areas often are popular building sites because they offer some shelter and tend to be flat. **Saddles** are natural pathways for fire; fire often travels first and with increased intensity in saddles. As wind crosses a ridge, a leeward eddy can occur, where the wind rolls around and comes up the leeward side, exposing both sides of a structure to wind and fire. Ridges usually offer no protection from fire.

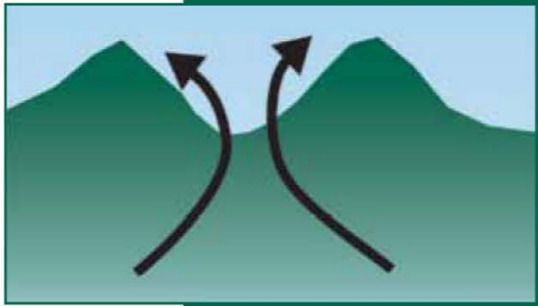

Figure 3-2: Saddle, or low area, on a ridge

Figure 3-3: Ridge with wind exposure

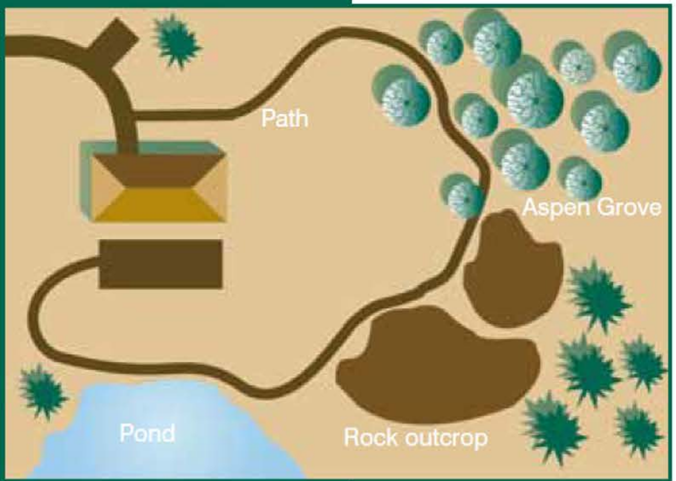

Figure 3-4 Site: House located relative to natural features that buffer against fire

Natural barriers and buffer zones

Some physical features reduce fire behavior and can be used to slow, reduce or deflect a fire. Examples include natural rock outcroppings, wetlands, streams, lakes and deciduous tree stands, (aspen, cottonwood, etc). It is advantageous to locate the structure between the natural barrier and the anticipated path of a fire. Some areas, such as meadows or lawns, can be barriers at certain times of the year, but serve as fuels after they cure.

How this affects building location and design decisions

On large parcels of land, consider the physical features previously discussed when choosing the final location of a structure. Many factors will affect decisions regarding building-site location, such as privacy, views, access and aesthetic values; fire is just one of these factors. Determining whether fire is the primary consideration will depend on the severity of the fire hazard in the area.

On smaller parcels, only one suitable building location may exist. The physical features of the site will determine the probable fire intensity and dictate what combination of site modifications and fire protection is necessary to prevent the structure from igniting.

Site Evaluation, Design, and Modifications to the Vegetation

When selecting a building site, several questions should be answered:

1. Is there adequate ingress and egress in the event of a fire?
2. Can fire engines and other emergency equipment safely access the property?
3. Can close-in fuels be modified to reduce fire potential (defensible space)?
4. What is the potential fire behavior and ember production in the fuels further out?

After evaluating the fire hazard severity of a site, develop a plan to manage the surrounding vegetation and defensible space. This is the first part of the two-part strategy to build an ignition-resistant structure. Defensible space is defined as an area where material capable of allowing a fire to spread is modified to slow the rate and intensity of an advancing wildfire, and create an area for firefighters to safely work. It also can work in reverse by helping to prevent a structure fire from spreading to surrounding vegetation.

In diagramming the features of a building site, it is apparent that the features gradually shift from man-made to natural, as the distance increases from the structure into the wildland; this area should be divided into zones. Developing a defensible space plan requires an inventory of the existing site features and their hazards. Man-made elements include landscaping features, such as masonry walls, patios, footpaths and driveways. These features create fire barriers and buffer zones. Three zones need to be addressed when creating defensible space:

Zone 1 is the area nearest the home and requires maximum hazard reduction.

Zone 2 is a transitional area of fuels reduction between Zones 1 and 3.

Zone 3 is the area farthest from the home, where traditional forest management techniques should be used. It extends from the edge of Zone 2 to the property boundaries.

Zone 1 – The width of Zone 1 extends a distance of 15 - 30 feet minimum from a structure depending on property size. Increasing the distance of Zone 1 will increase structural survivability. This distance should be increased five or more feet for fuels downhill from a structure. Remove most flammable vegetation, with the possible exception of a few low-growing shrubs or FireWise plants (plants that are comparatively fire resistant). Avoid landscaping with common ground junipers. The distance should be measured from the outside edge of the home's eaves and any attached structures, such as decks. Several specific treatments are recommended within this zone:

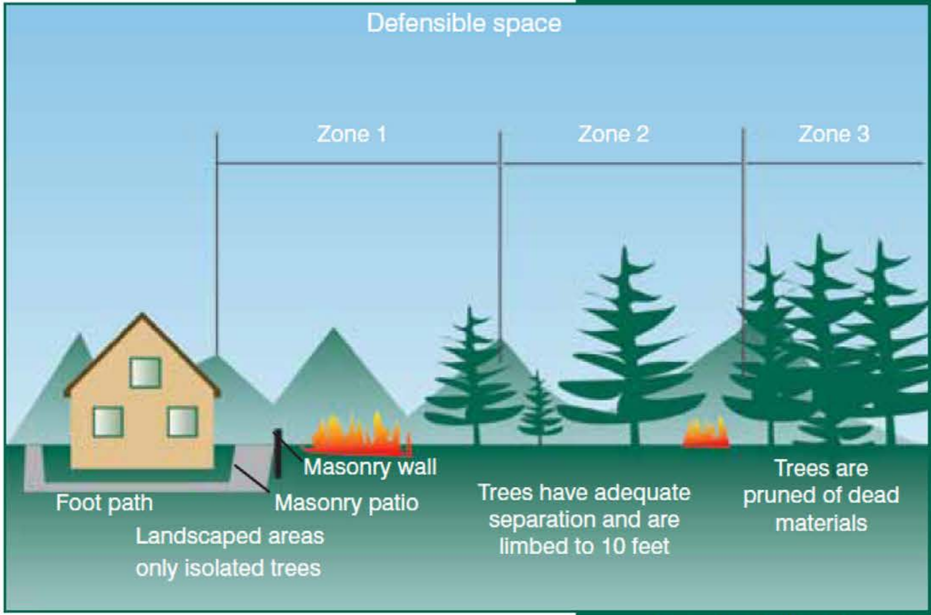

Figure 3-5: Defensible space

- Install nonflammable ground cover and plant nothing within the first 5 feet of the structure and deck.
- If a structure has noncombustible siding (i.e. stucco, synthetic stucco, concrete, stone or brick), widely spaced foundation plantings of low-growing shrubs or other FireWise plant materials are acceptable. Do not plant directly under windows or next to foundation vents.
- Prune and maintain plants and remove all dead branches, stems and leaves within and below the plant.
- Irrigate grass and other vegetation during the growing season if possible. Keep grasses mowed to a height of 6 inches or less.
- Do not store firewood or other combustible materials in this zone. Keep firewood at least 30 feet away from structures, uphill if possible.
- Enclose or screen decks with at least 1/8-inch metal screening (1/16-inch is preferable). Do not use areas under decks for storage.
- Ideally, remove all trees from Zone 1 to reduce fire hazards. The more trees you remove, the safer the home will be. If you do retain any trees, consider them part of the structure and extend the distance of the entire defensible space accordingly.
- Remove any branches that overhang or touch the roof, and remove all fuels within 10 feet of the chimney.
- Remove all needles and other debris from the roof, deck and all gutters.
- Rake needles and other debris at least 10 feet away from all decks and structures.
- Remove slash, chips other woody debris from Zone 1.

Zone 2 – Zone 2 is an area of fuels reduction designed to reduce the intensity of any fire approaching structures. The width of Zone 2 depends on the slope of the ground where the structure is built. Typically, the defensible space in Zone 2 should extend at least 100 feet from all structures. If this distance stretches beyond the property line, try to work with the adjoining property owners to complete an appropriate defensible space.

The following actions help reduce the continuous fuels surrounding a structure, while enhancing home safety and the aesthetics of the property. It also will provide a safer environment for firefighters to protect homes.

- Remove stressed, diseased, dead or dying trees and shrubs.
- Remove enough trees and large shrubs to create at least 10 feet between crowns. Crown separation is measured from the farthest branch of one tree to the nearest branch on the next tree. On steep slopes, increase the distance between tree crowns.

- Remove all ladder fuels from under remaining trees. Prune tree branches to a height of 10 feet from the ground or 1/3 the height of the tree crown, whichever is less.
- Extend tree thinning out 30-feet along both sides of your driveway all the way to the main access road, even if it is over 100 feet from your home. Thin all trees to create 10-foot spacing between tree crowns.
- Small groups of two to three trees may be left in some areas of Zone 2, but leave a minimum of 30 feet between the crowns of these clumps and surrounding trees.
- As noted in Zone 1, the more trees and shrubs removed, the more likely the structure will be spared in a wildfire.
- Isolated shrubs may remain, provided they are not under trees.
- Keep shrubs at least 10 feet away from the edge of tree branches. This will prevent the shrubs from becoming ladder fuels.
- Minimum spacing recommendations between clumps of shrubs is 2 1/2 times the mature height of the vegetation. The maximum diameter of the clumps themselves should be twice the mature height of the vegetation. As with tree-crown spacing, all measurements are made from the edge of vegetation crowns.
- Periodically prune and maintain shrubs to prevent excessive growth; remove dead stems from shrubs annually.
- Mow or trim grasses to a maximum height of 6 inches. This is critical in the fall when grasses dry out.
- Avoid accumulations greater than 4 inches deep of surface fuels such as logs, branches, slash and chips.
- Stack firewood and woodpiles uphill from or on the same elevation as any structures, and at least 30 feet away.
- Clear, mow and remove all flammable vegetation within 10 feet of woodpiles.
- Do not stack wood against your home or on/under your deck, even in winter.
- Locate propane tanks and natural gas meters at least 30 feet from any structures, preferably on the same elevation as the structure. The containers should not be located below your home because if it ignites, the fire would tend to burn uphill. Conversely, if the tank or meter is located above your structure and it develops a leak, gas will flow downhill into your home.
- Clear and remove flammable vegetation within 10 feet of all tanks and meters.
- Do not visibly screen propane tanks or natural gas meters with shrubs, vegetation or flammable fencing. Instead, install 5 feet of nonflammable ground cover around the tank or meter.

Zone 3 – Zone 3 has no specified size. It should provide a gradual transition from Zone 2 to areas farther from the home that have other forest management objectives. Your local Colorado State Forest Service forester can help you with this zone.

Forest management in Zone 3 provides an opportunity to improve the health of the forest. With an assortment of tools and alternatives, it is possible to proactively manage forest land to reduce wildfire intensity and protect water quality, increase habitat diversity for wildlife, increase the health and growth rate of trees and increase the survivability of trees in a wildfire.

For additional information about defensible space, see *Protecting Your Home from Wildfire: Creating Wildfire-Defensible Space* or visit http://csfs.colostate.edu/pages/wf-publications.html.

4. Building Design

So far, we have discussed elementary fire behavior and how to manage the wildlands surrounding a home in the interface. The second part of our approach to building ignition-resistant structures is learning about appropriate design and material choices.

Simple vs. complex forms

Simple building forms have less surface area relative to the volume of the structure. Complex building forms have much more surface area relative to volume. Simple building forms are less expensive to build, more energy efficient and easier to protect from wildfires. There is simply less exterior surface to protect.

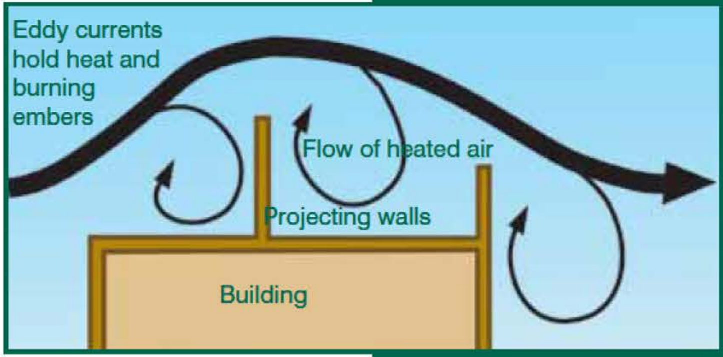

Figure 4-1: Heat traps around walls

Complex forms not only increase the surface area of the structure, but also create shapes that trap the fire's heat; these areas are called heat traps. Transitions between vertical surfaces and horizontal surfaces, inside corners between two walls or abrupt intersections of different solid planes form pockets where wind velocity drops and eddy currents form.

Parapet walls, solar collectors, intersecting roofs and walls, roof valleys and decks are examples of heat traps. These forms cannot be avoided, therefore their locations require much more attention to ignition-resistant materials. Burning embers most often fall in these locations when wind velocity decreases.

Roofs are very susceptible to embers in a wind-driven fire. A simple roof form such as a hip or straight gable is best. Complicated roofs with intersecting planes and valleys form dead air pockets and areas where currents eddy. The use of complicated forms further highlights the importance of a truly ignition-resistant roof.

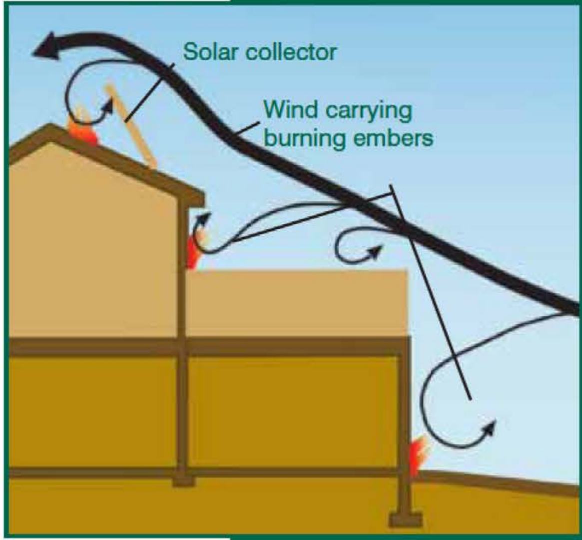

Figure 4-2: Heat traps around roofs

Some roof coverings have gaps that allow ember intrusion under the covering and can result in ember intrusion and ignition of the structure under the roof covering. The worst types of roof coverings allow combustible debris to blow or rodents and birds to build nests under the roof covering. This can occur in clay (Spanish or straight-barrel mission) tile roof covering unless eave closures or "bird stops" are used to close the convex opening created by the shape of the tile at the eave. If you can see wood through gaps in the roof covering, embers can penetrate and ignite the structure.

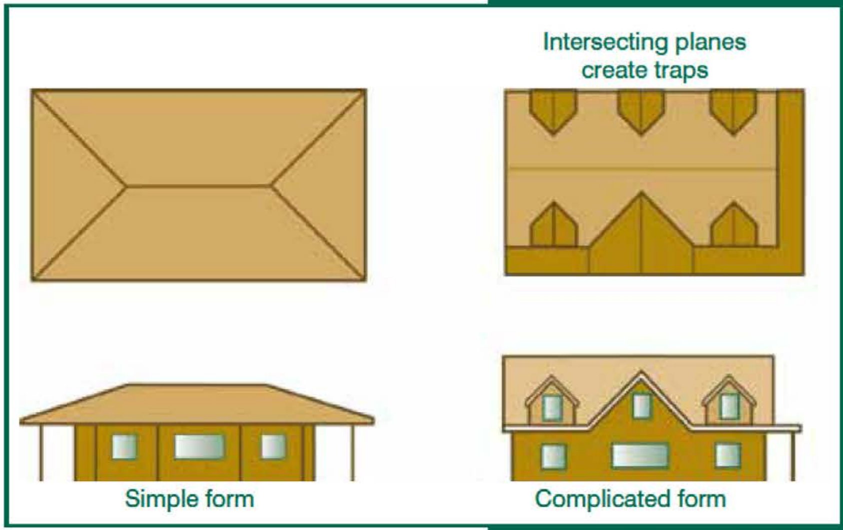

Figure 4-3: Roof forms

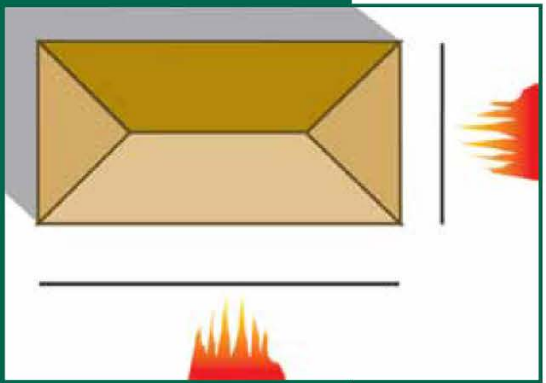

Figure 4-4: Aspect ratio is the ratio between the east-west axis and the north-south axis.

Aspect ratio

Aspect ratio is the ratio between the east-west axis and the north-south axis. In Colorado's climate, it generally is better to build a structure that is longer on the east-west axis than the north-south axis. Such a structure has a more favorable energy relationship with the climate and can benefit from passive solar heat.

With regard to wildfire, if the widest exterior of the structure faces the direction from which a fire is likely to come, it will be more vulnerable. More fire-resistive materials and components are needed on the side that faces oncoming fire. On a flat site, the direction of a fire is somewhat unpredictable, but it generally is determined by predominant winds and fuel.

The probable fire path is more easily predicted on sloping sites. Fire can be expected to approach up the slope. On east- and west-facing slopes, it is best to locate the structure on the longer east-west axis in terms of energy efficiency and fire risk, as the widest side of the structure faces the winter sun and the narrowest side faces the fire path.

When simple forms and optimum aspect ratios cannot be used, the structure will require more ignition-resistant building materials.

Vents, eaves, soffits, gutters, downspouts and decks

Building an ignition-resistant structure can be compared to building a watertight roof. One little hole in the roof allows water to leak in, and it doesn't matter how well the job was done on the rest of the roof, it failed and damage occurred. Small building elements like soffits and vents can be the weak link in a fire. An otherwise ignition-resistant structure can be damaged or destroyed because fire found a way in through these areas.

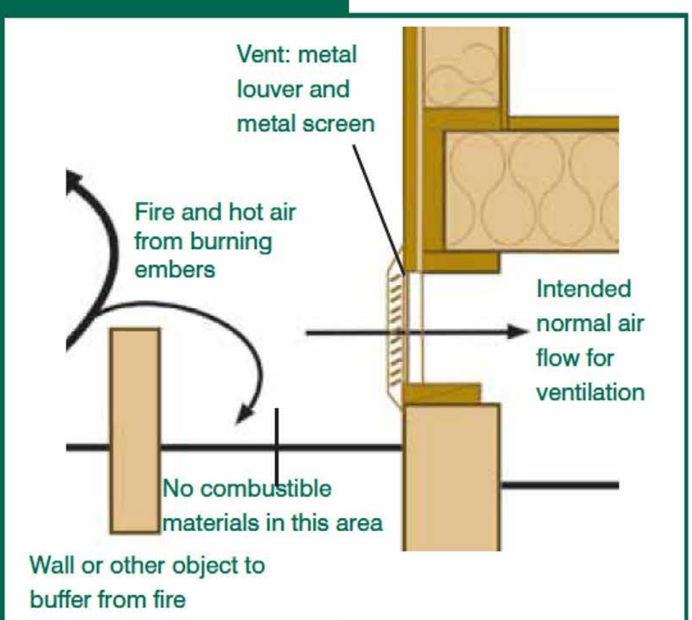

Figure 4-5: Crawl-space ventilation

Vents

The International Building Code (IBC) requires vents to prevent accumulation of water vapor in the structure. All crawl spaces under wood floors are required to have ventilation. One square foot of vent is required for every 150 square feet of floor area. Because these vents typically are located near the ground, combustible vegetation should not be located next to them.

Vents located on the downhill side of the structure should be protected by landscaping elements, such as stone patios or walls, that block the direct path of the fire. Mechanical ventilation with intakes and exhaust located away from the ground also can be used.

All attic spaces and roof cavities are required to have ventilation. One square foot of vent is required for every 300 square feet of horizontal projected roof area (see eaves and soffits). In both cases, the vents should be covered with noncombustible, corrosion-resistant mesh with openings that do not exceed ¼-inch, or be designed and approved to prevent flame or ember penetration into the structure. Roof turbine vents also should be screened to prevent embers from entering attic spaces.

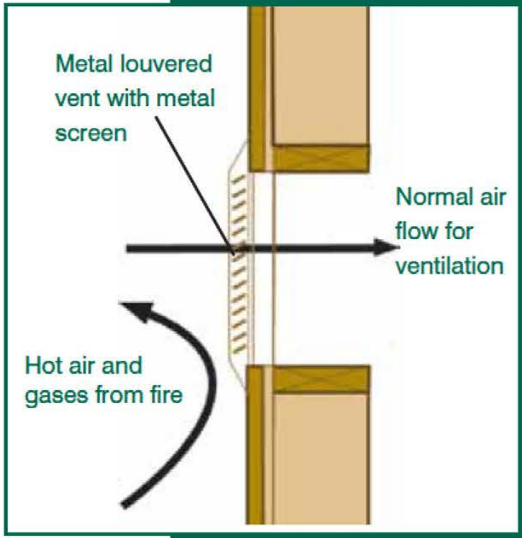

Figure 4-6: Attic vent

Eaves and soffits

The extension of the roof beyond the exterior wall is the eave. This architectural feature is particularly prone to ignition. As fire approaches the structure, the exterior wall deflects the hot air and gasses up into the eave. If the exterior wall isn't ignition resistant, this effect is amplified.

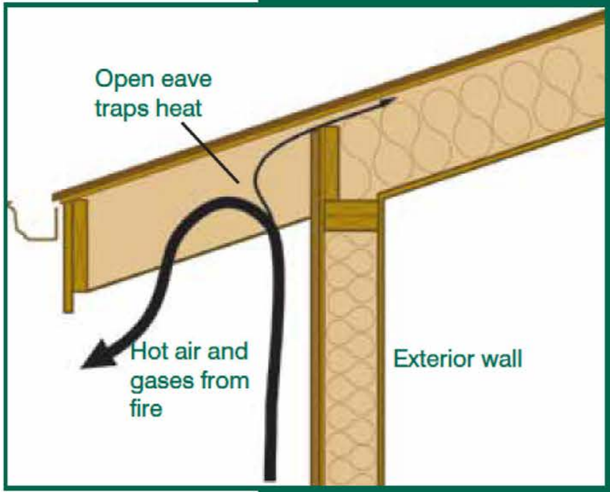

Figure 4-7: Open eave with no soffit

The eave should be covered with a soffit. If the soffit is applied directly to the rafter eave, it forms a sloping soffit, which creates a pocket that can trap fire.

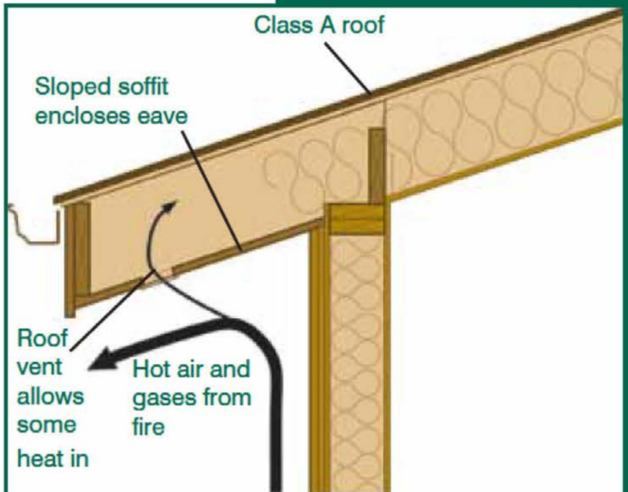

Figure 4-8: Open eave with soffit

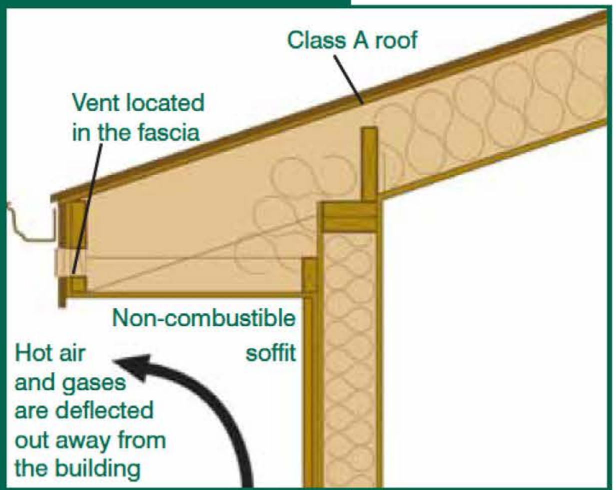

Figure 4-9: Fully enclosed soffit with isolated vent

A flat soffit allows the structure to more readily deflect fire outward.

Vents for roof ventilation often are found in the soffit. Placing vents in these locations creates a path for fire to enter the roof structure. If the vent must be placed in this location, it is better to place it farther from the wall and closer to the fascia. The vent also can be placed in the fascia or near the lower edge of the roof.

Gutters and downspouts

Gutters and downspouts collect leaves and pine needles. Gutters and eave troughs made from combustible materials (e.g., wood, vinyl) are as vulnerable to ember collection as the roof and other parts of the structure. If leaf litter is allowed to gather in gutters, embers can ignite the leaf litter, which in turn could ignite combustible eave materials or overhangs. If gutters are attached to combustible fascia boards, the fascia board should be considered a possible fuel that can be ignited by fine fuels burning in the gutters.

Figure 4-10: Conventional deck in a fire

Decks

Decks are a popular and well-used feature of the structure, especially in the mountains. Because they are elevated above the terrain and surrounding vegetation, they offer a better view and provide flat areas for walking on otherwise sloping terrain.

Most decks are highly combustible structures. Their shape traps hot gasses, making them the ultimate heat traps. And because they often face downhill – they allow easy access to an approaching fire, which most likely is moving up a slope.

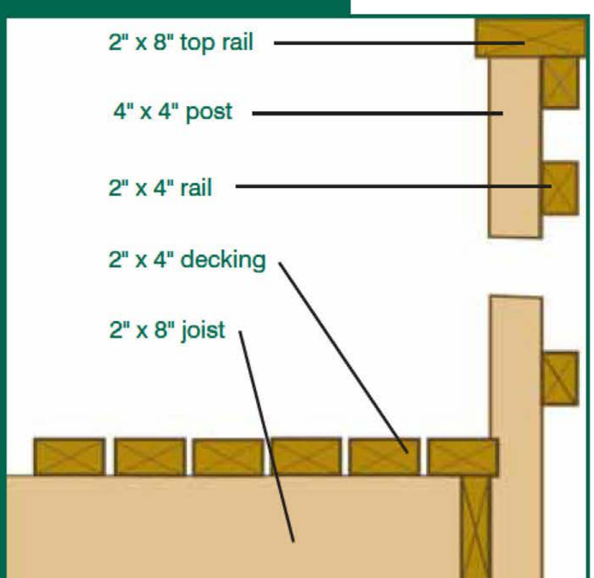

Figure 4-11: Conventional deck construction detail

Decks are built to burn almost as easily as wood stacked in a fireplace. All the components of a deck – joists, decking and railings – generally are made of wood, plastic or wood-plastic composites generally no more than 2 inches thick with high surface-to-volume ratios.

When fire approaches, deck material quickly heats up. Ignition can easily occur when the radiant energy from the fire gets hot enough or a burning ember lands on it.

Ignition of decks

Conventional decks are so combustible that when a wildfire approaches, the deck often ignites before the fire gets to the structure.

Normally, decks ignite in one of two ways. A burning brand landing on the surface of the deck is all that's required, particularly if the decking is dry or has wide gaps between the boards, which allows airflow and harbors embers. Similarly, space between the first deck board and the structure can provide airflow and catch embers, increasing the risk that the siding will ignite.

The other common cause of deck fires is direct flame from unmaintained vegetation igniting the deck from below, or a burning brand igniting debris under the deck. Again, dry or widely spaced deck boards speeds the spread of fire.

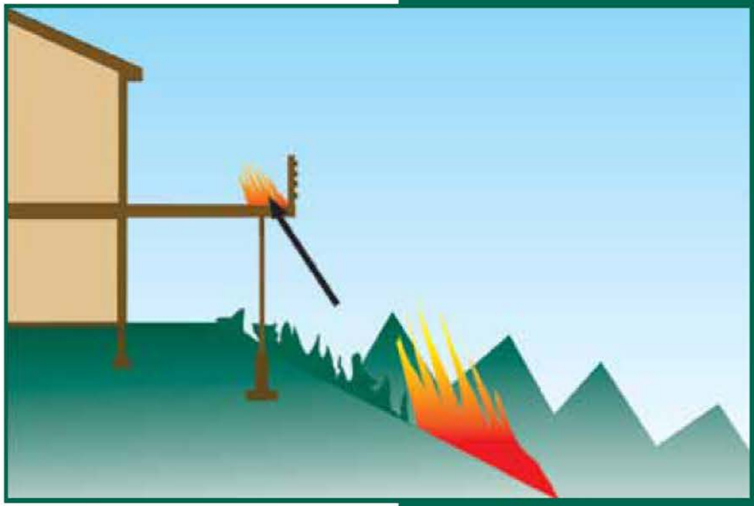

Figure 4-12: Conventional decks can easily ignite during a wildfire

Once the deck ignites, it may set the structure on fire. Heat from the deck fire, for example, may cause the glass in a sliding door to break, permitting flames to enter the interior of the structure. Or, combustible siding or soffits can ignite, carrying fire to the structure. The end result is the same. Even if the structure itself doesn't ignite, the structural integrity of the deck can be compromised and can become too hazardous to use.

Isolate the deck from wildfire with a patio and a wall

In low and moderate fire areas, it may be sufficient to isolate the deck from the fuels and fire by building a noncombustible patio and wall below it. The patio will ensure that no combustible materials are below the deck. The wall will act as a shield, deflecting both the radiant and convective energy of the fire.

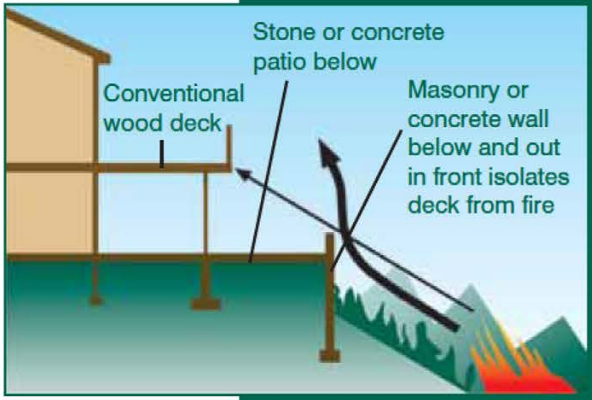

Figure 4-13: Deck with a patio and a wall below

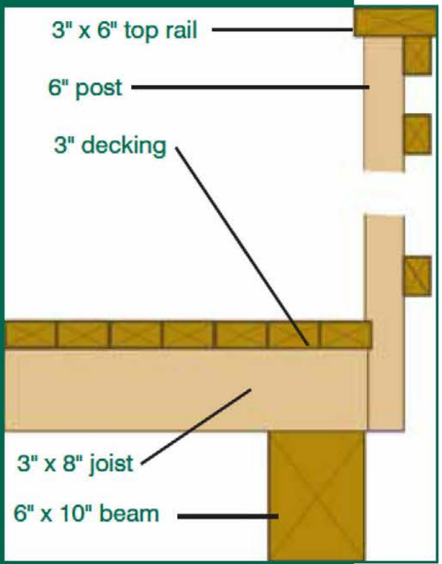

Figure 4-14: Heavy timber deck

Heavy timber construction

Like log construction, heavy timber is combustible but so thick that it burns very slowly.

Minimum thickness for a heavy timber deck is 6 inches for the posts and structural members and 3 inches for the decking and rails. This type of construction can be used with a patio below for additional protection.

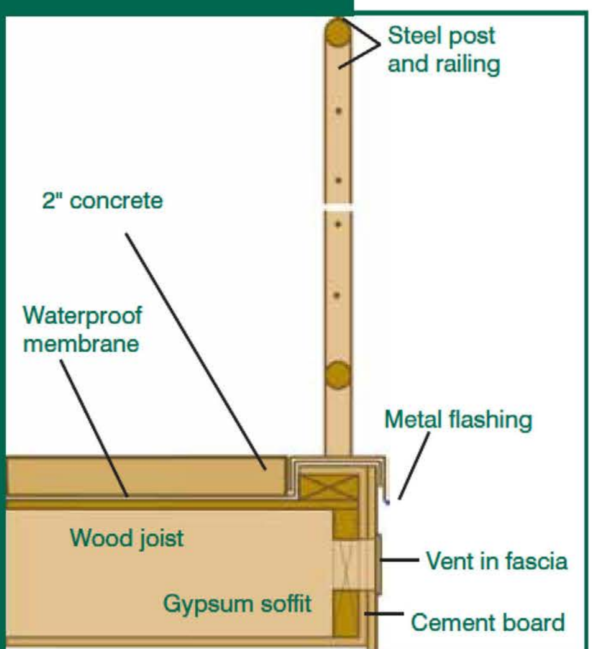

Figure 4-15: Fire-resistive deck construction detail

Fire-resistive deck construction

In the highest fire hazard areas, consider noncombustible surfaces, fire-retardant-treated wood and fire-resistive building materials for a deck. Wood frame construction is permitted, but the surface should be composed of noncombustible, fire-retardant-treated or one-hour fire-resistive materials.

To build this type of surface, place a waterproof membrane over the top of the deck. This allows the use of fire-resistive soffit materials, which cannot tolerate moisture. The most common materials are cement fiber or metal panels (noncombustible), fire-retardant-treated plywood (ignition resistant) and gypsum sheathing (noncombustible).

Cover the membrane with fire-retardant-treated lumber decking, or use 1 to 2 inches of concrete or stone. This surface is ignition resistant and protects the deck from air-borne embers, but will require that the structure be strengthened to support the additional weight.

Posts and railings can be economically built from steel. Wood posts near the ground can have stone, brick or noncombustible coverings, or be of fire-retardant-treated wood. A popular, but expensive, baluster design is steel wire. Steel pipe, usually 1 to 2 inches in diameter, is economical and easy to work with. Square steel shapes can look like traditional wood railings.

Fully enclosed decks

The best design is to convert the deck to a solid form by fully enclosing it, completely eliminating the heat trap. This form also complies with the *2009 International Wildland-Urban Interface Code*.

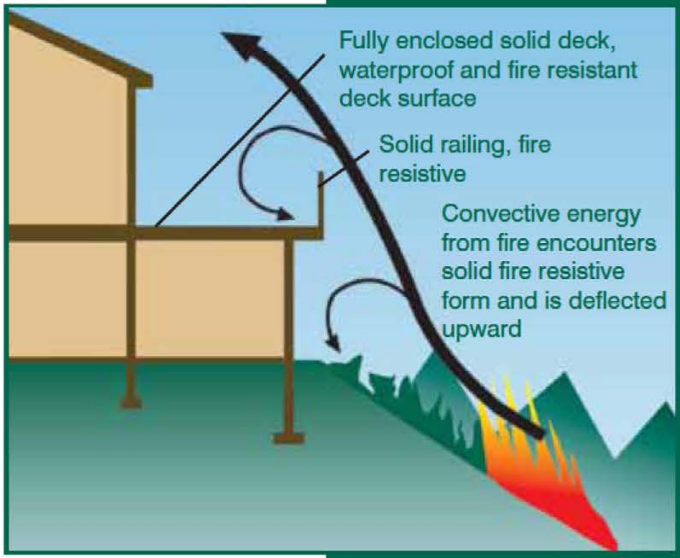

Figure 4-16: Fully enclosed solid deck

Ignition-resistant construction class

The IWUIC requires that structures constructed, modified or relocated into or within WUI areas meet the requirements of Class 1, Class 2 or Class 3 ignition-resistant construction. The requirements of these ignition-resistant construction classes are based on the fire hazard severity of the site. The greater the fire severity, the greater the fire protection provided by the class. Class 1 provides the most protection in areas of extreme fire hazard; Class 2 provides protection in areas of high fire hazard; and, Class 3 provides additional protection over the traditional construction requirement in areas of moderate fire hazard. The following table is an extract of IWUIC Sections 504, 505 and 506, which define the Class 1, Class 2 and Class 3 requirement, respectively.

Allowable Construction and Architectural Features for Various Ignition-Resistant Construction Classes

Architectural Feature	Class 1 (Extreme Severity)	Class 2 (High Severity)	Class 3 (Moderate Severity)
Roof covering	Class A Roof Assembly	Class B or noncombustible	Class C or noncombustible
Eaves and soffits	Ignition-resistant material, or 1-hour fire-resistance-rated construction, or 2-inch dimensional lumber, or 1-inch exterior fire-retardant-treated lumber, or ¾-inch exterior fire-retardant-treated plywood	Combustible eaves, facias and soffits shall be enclosed with solid materials with a minimum thickness of ¾ of an inch. No exposed rafter tails are permitted unless constructed of heavy timber.	No special requirement
Gutters and downspouts	Constructed of noncombustible materials and provided with approved means to prevent the accumulation of leaves and debris in the gutter.	Constructed of noncombustible materials and provided with approved means to prevent the accumulation of leaves and debris in the gutter.	No special requirement
Exterior walls	1-hour fire resistance from the exterior side, or Approved noncombustible materials, or Heavy timber or log wall construction, or Exterior of fire-retardant treated wood , or Exterior of ignition-resistant material	1-hour fire resistance from the exterior side, or Approved noncombustible materials, or Heavy timber or log wall construction, or Exterior of fire-retardant-treated wood , or Exterior of ignition-resistant material	No special requirement
Unenclosed underfloor protection	1-hour fire-resistance-rated construction, or Heavy timber construction, or Exterior fire-retardant-treated wood	1-hour fire resistance-rated construction, or Heavy timber construction, or Exterior fire-retardant-treated wood	1-hour fire resistance-rated construction, or Heavy timber construction
Appendages and projections, such as decks	1-hour fire resistance from the exterior side, or Heavy timber construction, or Approved noncombustible materials, or Exterior fire-retardant-treated wood, or Ignition-resistant building materials	1-hour fire resistance from the exterior side, or Heavy timber construction, or Approved noncombustible materials, or Exterior fire-retardant-treated wood, or Ignition-resistant building materials	No special requirement
Exterior glazing	Tempered glass, or Multilayered glazed panels, or Glass block, or Fire protection rating of not less than 20 minutes	Tempered glass, or Multilayered glazed panels, or Glass block, or Fire protection rating of not less than 20 minutes	No special requirement
Exterior doors	Approved noncombustible construction, or Solid core wood not less than 1¾-inch thick, or Fire protection rating of not less than 20 minutes	Approved noncombustible construction, or Solid core wood not less than 1¾-inch thick, or Fire protection rating of not less than 20 minutes	No special requirement
Vent location	Not allowed in soffits, eave overhangs, between rafters at eaves or in other overhang areas.	Not allowed in soffits, eave overhangs, between rafters at eaves or in other overhang areas.	No special requirement

Figure 4-17 * *Not all jurisdictions follow these fire-severity classifications. Consult your local building department, fire department or county planning department for local fire hazard classifications.*

** *For statewide fire hazard ratings, see the Colorado Statewide Forest Resource Assessment & Strategy (Action Plan).*

5. Building Materials and Components

When discussing building materials and components, we make frequent references to types of construction, noncombustible materials and various classes and ratings. Flame-spread classes, roofing classes and hourly ratings are confusing terms and sometimes are misused. The first is based on the Society for Testing and Materials' ASTM E-84/UL 723 "Test for Surface Burning Characteristics of Building Materials," the second is based on ASTM E-108/UL 790, "Test for Fire Performance of Roofing Materials," and the third is based on ASTM E-119, "Fire Tests of Building Materials."

Noncombustible

As applied to building materials, noncombustible means a material that, in the form in which it is used, is one of the following:

1. Material of which no part will ignite and burn when subjected to fire. Any material conforming to ASTM E-136 "Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C" is considered noncombustible. Materials such as concrete, steel and brick masonry generally are considered noncombustible.
2. Material that has a structural base of noncombustible material, as defined in Item 1 above, with a surfacing material not over 1/8-inch (3.2 mm) thick, and a flame spread index of 50 or less. The paper face on most gypsum wallboard has a flame-spread index of 15 and is considered noncombustible.

If a building material does not fall into either of the above categories, it is assumed to be combustible.

Flame-spread classification of building materials

The Uniform Building Code UBC uses the I-II-III designation, and the International Building Code (IBC) uses A-B-C. The flame-spread categories are as follows, per ASTM E-84/UL 723:

Class A or I:	Flame-spread index of 25 or less (Fire-Retardant-Treated Wood or FRTW)
Class B or II:	Flame spread index of 26 to 75 (some untreated lumber)
Class C or III:	Flame spread index of 76 to 200 (most untreated lumber and plywood)

Class A-B-C roof coverings

Class A, B or C roofing systems sometimes are confused with the Class A-B-C/I-II-III flame-spread categories as referenced above. The tendency is to assume that Class A roof systems have a Class A flame spread, and so on, but there is no correlation.

The ASTM E-108/UL 790 roof-coverings test does not produce a flame-spread rating. It is a pass-fail test under which a product either passes the criteria as a Class A, B or C roof covering system or it doesn't. It is an entirely different test from ASTM E-84/UL 723, and it includes weathering per the ASTM D-2898 "Standard Rain Test." The highest fire classification is Class A. Note that a Class C roof system is considered fire resistant, while a Class C (or III) building material (as above) is not. Non-classified roof systems have no fire rating.

Hourly fire-resistance ratings

Hourly ratings are a function of the assembly being used (wall, floor, door, ceiling, roof, etc.) and generally require use of a noncombustible membrane (e.g. gypsum, masonry). ASTM E-119 "Fire Tests of Building Construction Materials," is the test used to determine the hourly rating of an assembly. It exposes an assembly to heat and flame on one side and tests for heat transmission, burn-through, structural integrity and ability to withstand a hose stream from a fire hose.

Because of the potential for radiant heat exposure from one structure to another, either on adjoining sites or on the same site, the IBC regulates the construction of exterior walls for fire resistance. Where exterior walls have a fire-separation distance of more than 5 feet, IBC Section 705.5 allows the fire-resistance rating to be determined based only on interior fire exposure. This recognizes the reduced risk that is due to the setback from the lot line. For fire separation distances greater than 5 feet, the hazard is considered to be predominately from inside the structure. Thus, fire-resistance-rated construction whose tests are limited to interior fire exposure is considered sufficient evidence of fire resistance under these circumstances. However, at a distance of 5 feet or less, there is additional hazard of direct fire exposure from a structure on the adjacent lot and the possibility that it may lead to self-ignition at the exterior face of the exposed structure. Therefore, exterior walls located very close to any lot line must be rated for exposure to fire from both sides. The listings of various fire-resistance-rated exterior walls will indicate if they were only tested for exposure from the inside, usually by a designation of "FIRE SIDE" or similar terminology. Where so listed, their use is limited to those applications where the wall need only be rated from the interior side. For application in the WUI, the "FIRE SIDE" of the wall system must be the exterior wall surface.

The difference between a non-combustible material and a rated material or assembly is the surface resistance to ignition versus the protection afforded the structure behind it. A good example of a non-combustible material is metal roofing and siding. Metal is non-combustible, but an excellent conductor of heat. If the fire remains present long enough, the heat will be conducted through the metal and ignite the material behind it. An example of a fire-rated assembly is wood siding applied over 5/8 inch gypsum sheathing. This assembly is rated as one hour. The surface can ignite, but the structure is protected from the fire for one hour. **The importance is the difference between intensity of fire and duration of fire, as described in the fire behavior section (Section 2).**

Most ratings are for commercial structures in urban settings. That is why the IWUIC references the IBC, which is used to build both commercial and residential structures, rather than the IRC, which is used for single family and multi-family homes with up to four units.

The IBC allows both prescriptive and performance-based fire-resistant designs, although its current emphasis is clearly on the former. Section 720 of the code explicitly lists several detailed, prescriptive fire-resistant designs. However, Section 703.3 also allows the designer to choose from other alternative methods for design as long as they meet the fire exposure and criteria specified in the American Society for Testing and Materials (ASTM) fire test standard ASTM E-119.

IBC 703.3 Alternative methods for determining fire resistance:

1. Fire-resistant designs documented in recognized sources.
2. Prescriptive designs of fire resistance-rated building elements, components or assemblies, as prescribed in Section 720.
3. Calculations in accordance with Section 721.
4. Engineering analysis based on a comparison of building element, component or assemblies designs having fire-resistance ratings, as determined by the test procedures set forth in ASTM E119 or UL 263.
5. Alternative protection methods, as allowed by Section 104.11.

Fire-resistant construction assemblies (walls, floors, roofs) and elements (beams, columns), that perform satisfactorily in standard fire-resistance tests, are documented in building codes, standards, test reports and special directories of testing laboratories. Over the years, a considerable amount of accumulated test data allowed the standardization of many fire-resistant designs involving generic (non-proprietary) materials, such as wood, steel, concrete, masonry, clay tile, "Type X" gypsum wallboard and various plasters. These generalized designs and methods are documented in IBC sections 720 and 721, with detailed explanatory figures, tables, formulas and charts. Fire-resistant designs that incorporate proprietary (pertaining to specific manufacturers and/or patented) materials are documented by test laboratories in reports and special directories of both test laboratories and trade associations. The major sources of documented construction designs rated for fire resistance are described below.

Underwriters Laboratories Inc. (UL) conducts tests of various building components and fire protection materials. The assemblies are tested under recognized testing procedures, including ASTM E119 and ANSI/UL 263, all of which are essentially the same. When the assembly complies with the acceptance criteria of the fire-test standard, a detailed report is provided, including its description and performance in the test, pertinent details and specifications of materials used. A summary of the important features is produced and given a UL designation, which is then added to the UL directory.

To facilitate the design process, numerous associations publish wall-design configurations that meet various fire criteria. Examples of these publications are Fire Rated Wood Floor and Wall Assemblies (DCA-3), published by the American Wood Council; Fire Rated Systems Design/Construction Guide (W305), published by APA-The Engineered Wood Association; and Fire Resistance Design Manual (GA-600), published by the Gypsum Association.

Heavy timber and log wall construction

Heavy timber is another type of wood construction. Experience and fire tests have shown that the tendency of a wood member to ignite in a fire is affected by its cross-sectional dimensions. During a fire, large-size wood members form a protective coating of char that insulates the inner portion of the member from the fire. This type of wood construction often is referred to as slow burning.

Different minimum dimensions apply to different types of wood members, and the minimum cross-sectional dimension required in order to qualify for the heavy-timber fire rating is set forth in IBC Section 602.4. The following is a condensed version of building code sections, which is provided as a guide. Consult the IBC or your local building or fire departments to determine complete requirements.

602.4.1 Columns. Wood columns shall be not be less than 8 inches nominal in any dimension where supporting floor loads and not less than 6 inches nominal in width and not less than 8 inches nominal in depth where supporting roof and ceiling loads only.

602.4.2 Floor framing. Wood beams and girders shall be not less than 6 inches nominal in width and not less than 10 inches nominal in depth.

602.4.3 Roof framing. Framed or glued-laminated arches for roof construction, framed timber trusses and other roof framing, which do not support floor loads, shall have members not less than 4 inches nominal in width and not less than 6 inches nominal in depth.

602.4.4 Floors. Floors shall be without concealed spaces. Wood floors shall be of sawn or glued-laminated planks, splined or tongue-and-groove, of not less than 3 inches nominal in thickness. Floors shall not extend closer than 0.5 inch to walls. This space shall be covered by a molding fastened to the wall and so arranged that it will not obstruct the swelling or shrinkage movements of the floor.

602.4.5 Roofs. Roofs shall be without concealed spaces and wood roof decks shall be of sawn or glued-laminated, splined or tongue-and-groove plank, not less than 2 inches nominal in thickness, 1 1/8 inch thick plywood, or of planks not less than 3 inches nominal in width, set on edge close together and laid as required for floors. Other types of decking shall be permitted to be used if providing equivalent fire resistance and structural properties.

Fire-retardant-treated wood

Certain ingredients, when added to the wood, can insulate its surfaces so that its temperature remains below the kindling temperature for an extended period of time, no matter how hot the heat source might become. Among the ingredients used for this purpose are the acid salts of sulfates and phosphates, borates and boric acid.

All fire-retardant treatments are water-soluble, so water is used as the vehicle for carrying the treatments into the wood. The only effective method of application is the pressure treatment process. After pressure impregnation, most of the moisture is removed until the treated wood has a moisture content of no more than 19 percent for lumber and 15 percent for plywood.

Fire-retardant treatments do not necessarily prevent wood from being destroyed by fire, but they are the necessary ingredient that, when added to wood, slow decomposition to such an extent that the wood structurally outperforms most other building materials during actual fire conditions.

When temperatures reach a point slightly below the kindling point, the chemicals react with each other. Nonflammable gases and water vapor are formed and released at a slow, persistent rate that envelops the wood fibers, insulating them from temperatures that cause the wood to decompose. The inflammable gases and tars are reduced and an insulating char forms on the surface of the wood, further slowing the process of decomposition. Structural integrity of the wood is preserved for a longer time with the reduced rate of decomposition, and smoke and toxic fumes are greatly reduced. When the heat source is removed, the treated wood ceases to decompose and fire spread is eliminated.

In Section 2303.2, the IBC defines fire-retardant-treated wood as

> *"any wood product that, when impregnated with chemicals by a pressure process or other means during manufacture, shall have, when tested in accordance with ASTM E 84 or UL 723, a listed flame spread index of 25 or less and show no evidence of significant*

progressive combustion when the test is continued for an additional 20-minute period. In addition, the flame front shall not progress more than 10.5 feet (3200 mm) beyond the centerline of the burners at any time during the test."

This is far more severe than the 10-minute ASTM E-84 test used for the flame-spread classification of building materials.

Flame-spread classification per ASTM E-84, 30-minute duration, has no relation to a 30-minute rating or any other hourly rating (which must be determined by ASTM E-119). ASTM E-119 is not a required test for FRTW, therefore FRTW has no different hourly rating than untreated wood. The advantage of FRTW over untreated wood and other combustible materials is the fact that it doesn't ignite or contribute to flame spread.

The IWUIC and IBC require FRTW to be properly labeled. Code-compliant stamps must contain the information in Figure 5-1. Product coloration is not a substitute for a building-code approved, third-party inspection agency label.

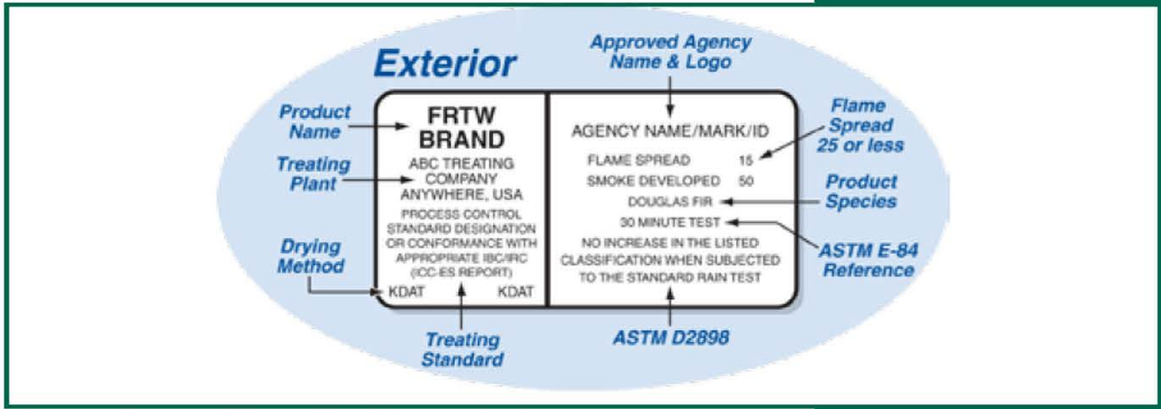

Figure 5-1: Courtesy of Western Wood Preservers Institute

Ignition-resistant building material

Ignition-resistant building materials are those that sufficiently resist ignition or sustained flaming combustion under worst-case weather and fuel conditions and with exposure to burning embers and small flames. Ignition-resistant building materials shall comply with any one of the following:

1. Extended ASTM E 84 testing. Materials that, when tested in accordance with the procedures set forth in ASTM E 84 or UL 723, for a test period of 30 minutes, comply with the following:

    1.1 Flame spread. Material shall exhibit a flame-spread index not exceeding 25 and shall show no evidence of progressive combustion following the extended 30-minute test.

    1.2 Flame front. Material shall exhibit a flame front that does not progress more than 10 1/2 feet (3200 mm) beyond the centerline of the burner at any time during the extended 30-minute test.

    1.3 Weathering. Ignition-resistant building materials shall maintain their performance in accordance with this section under conditions of use. Materials shall meet the performance requirements for weathering (including exposure to temperature, moisture and ultraviolet radiation) contained in the following standards, as applicable to the materials and conditions of use:

1.3.1 Method A "Test Method for Accelerated Weathering of Fire-Retardant-Treated Wood for Fire Testing" in ASTM D 2898, for fire-retardant-treated wood, wood-plastic composite and plastic lumber materials.

1.3.2 ASTM D 7032 for wood-plastic composite materials.

1.3.3 ASTM D 6662 for plastic lumber materials.

Identification. All materials shall bear identification showing the fire-test results.

2. Noncombustible material.
3. Fire-retardant-treated wood identified for exterior use.
4. Fire-retardant-treated wood roof coverings. Roof assemblies containing fire-retardant-treated wood shingles and shakes that comply with the requirements of Section 1505.6 of the *International Building Code* and classified as Class A roof assemblies, as required in Section 1505.2 of the *International Building Code*.

Roofing

Noncombustible roof coverings

The following are noncombustible roof coverings:

- cement shingles or sheets
- exposed concrete slab roof
- ferrous or copper shingles or sheets
- slate shingles
- clay or concrete roofing tile
- approved roof covering of noncombustible material

Roofing is one of the most important ways to protect a structure from wildfire. As shown earlier, when wildfires become more intense, the lofted embers become a significant cause of the fire spread. Because most roofing has a rough surface and numerous cracks, it can trap wind-blown embers. In many major WUI fires, burning roofs have been observed on structures thousands of feet from the fire.

Figure 5-2: Wood shakes

Wood shakes and shingles

Simply put, untreated wood shakes and shingles are almost like kindling. They are thin, 1/2- to 1-inch thick, with a very rough surface and many cracks. When an untreated wood roof burns, it also lofts burning embers, contributing to fire spread.

Cedar shakes and shingles can be modified by pressure impregnation with fire-retardants, which changes their classification to either B or C. Fire-retardant-treated cedar shakes and shingles installed over a gypsum underlayment have a Class A assembly rating.

Figure 5-2: Reinforced asphalt shingles

Asphalt shingles

Conventional mineral reinforced asphalt shingles usually have a Class C rating.

Mineral-reinforced shingles gradually have been replaced by fiberglass-reinforced asphalt shingles. These have a Class A rating. They are available in many colors and textures and can even imitate wood or slate shingles.

Metal

Metal roofing in many colors is available in sheet form, and usually has standing seams or ribs. The most common metal roof is galvanized steel with factory-applied paint.

Metal roofing also is available in patterns that imitate wood and slate shingles. This product is made by stamping a texture and shape on the metal and then applying the appropriate color. This imitation is so good that at a distance of 100 feet or more it is difficult to tell the difference between it and the material it is imitating.

Figure 5-4: Metal roofing

While metal roofing is noncombustible, it requires a gypsum underlayment in order to have a Class A assembly rating.

In addition to galvanized steel with paint, metal roofing also is available in aluminum with paint, stainless steel and copper. These tend to be more expensive, but may last longer.

Fiber–cement shingles

These shingles are made of cement and fiberglass, or cement and wood. Like the metal shingle, they are made to imitate a wood shingle's texture, shape and color. The cement in these products is altered with polymers to make it less brittle. These products may be noncombustible and may require an underlayment for a Class A assembly rating.

Membrane roofs

These materials include both rubber and hot-applied, bituminous-saturated mineral felt for flat roofs. They are marginally combustible, but most often are used with other covering systems such as concrete. They can be applied over a gypsum underlayment for a Class A assembly rating.

Concrete shingles and tile, slate shingles and clay tile

These products are noncombustible. They are 1-inch thick, heavy (10 pounds per square foot or more) and Class A rated. Concrete shingles often are manufactured to look like wood shingles.

Figure 5-5: Concrete tiles

Exterior walls: siding

The exterior walls of a structure are most affected by radiant energy from the fire and, if defensible space is not adequate, by direct impingement of the fire.

Wood panels and boards

Wood panels and boards are the most common and economical forms of siding, but they are readily combustible. This siding usually is not very thick (1/2-inch to 3/4-inch) and will burn through to the structure behind it in less than 10 minutes. A one-hour fire-resistance rating can be achieved by adding 5/8-inch Type X gypsum sheathing behind the siding.

Figure 5-6: Wood siding

Fire-retardant-treated lumber and plywood siding is another option. These products are traditional wood-siding materials that have been pressure impregnated with fire retardants and meet the definition of ignition-resistant materials. They can be used in all fire hazard severity zones.

Fiber cement panels, boards and shingles

While these products may be noncombustible, they may not have a fire-resistance rating and may need gypsum sheathing to achieve a one-hour rating. These materials are virtually permanent on a vertical surface and may need to be painted; stain can even be used on some with satisfactory results. These products are available with textures molded to imitate wood grain.

Metal

Like their counterparts in roofing, metal siding is available in either flat sheets with seams or in stamped patterns intended to imitate wood boards or shingles. They are noncombustible, but like other metal products, they need gypsum sheathing to achieve a one-hour rating.

Stucco

Real stucco, as base material, is ¾-inch to 1-inch thick cement and gypsum. The stucco is applied in two or three coats with metal mesh reinforcement. It is both a non-combustible and one-hour rated material, which makes it a very good material for high-hazard areas.

Synthetic stucco

Synthetic stucco also is referred to as EIFS (exterior insulating finish system). It consists of a 1/8-inch thick acrylic cement finish on fiberglass mesh. This is applied to the top 1 to 2 inches of expanded polystyrene insulation. The surface may be noncombustible and has no rating by itself. During a fire, it can delay ignition of the structure because it melts and falls away. It can, like other products, obtain a one-hour rating with gypsum sheathing.

Figure 5-7: Log wall construction

Log wall construction

Log wall construction has exterior walls constructed of solid wood members where the smallest horizontal dimension of each member is at least 6 inches. Although the logs are combustible, the low surface-to-volume ratio of the logs causes them to burn very slowly.

Log siding is not an acceptable substitute for log wall construction, as it is not as thick as actual log wall construction. However, log siding can achieve a one-hour fire resistance rating by adding 5/8-inch Type X gypsum sheathing behind the siding.

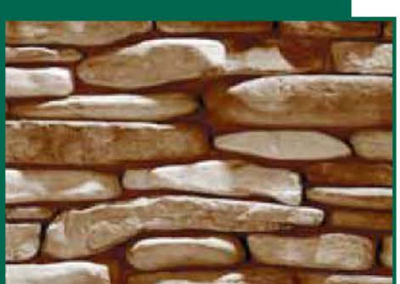

Figure 5-8: Concrete synthetic stone

Concrete synthetic stone

Concrete synthetic stone is cast concrete with integral color forming the texture and shape of the stone being imitated. The stones are modular in shape with consistent dimensions and flat backs. This synthetic stone is noncombustible and can have a fire resistance rating.

Brick, stone and block

These materials are inherently noncombustible and can have a fire-resistance rating.

Figure 5-9: Brick wall

Windows and Glass

Windows are one of the weakest parts of a structure with regard to fire. They usually fail before the structure ignites, providing a direct path for the fire to reach the structure interior.

Glass failure

Glass provides only a partial barrier to fire and only for a short time as it fractures in the presence of heat. In the case of a wildfire, this will happen in about five minutes. Glass deflects most of the convective energy, but not the radiant energy of the fire.

Convective energy contains hot air and gasses. Approximately 70 percent of the heat is deflected by window glass; roughly 20 percent is absorbed; and 10 percent is transmitted to the interior of the structure.

Radiant energy from a fire is infrared light energy, like the energy we experience from the sun. Sixty percent of the radiant energy from a fire is transmitted through the glass to the interior of the structure; approximately 20 percent is reflected; and the other 20 percent is absorbed by the window glass.

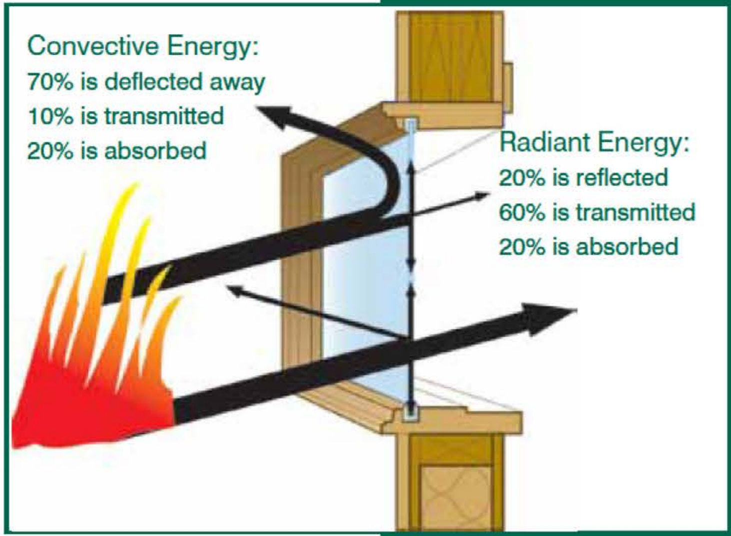

Figure 5-10: Energy transmission, conventional glass

Both radiant and convective energy heats the glass, but the perimeter of the glass is covered and protected by a sash. As a result, differential heating and stressing of the glass occurs, which causes it to crack.

Large and small windows

Even if the glass does fracture, the hot gasses (convective energy) from the fire and the fire itself cannot enter the structure if the glass stays in place. Only the radiant energy heat can pass through the glass. Eventually, even with the glass in place, combustible materials behind the window may ignite. (See Low E glass).

Small windows, less than 2 feet wide or tall on a side, will keep fractured glass in place. The size of glass held in place by the sash is relatively small and light weight.

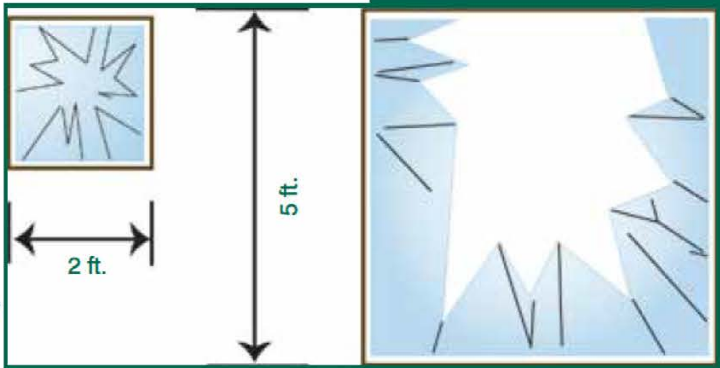

Figure 5-11: Small and large windows

Large windows (more than 2 feet wide or tall on a side) cannot keep the fractured glass in place. The size and weight of glass in relationship to the length of sash is too great.

Figure 5-12: Thermopane window

Thermopane or double-glazed windows

Most of today's energy codes require glass to be double-glazed or Thermopane. During a fire event, double-glazed windows last approximately twice as long as a single pane, or about 10 minutes.

The same processes of convective and radiant energy affect the front pane of glass. As long as the front pane is in place, the second pane is partially protected. When the front pane fails and falls away, the process continues until the second pane fails and falls away.

As shown earlier in the fire behavior section (Section 2), the duration of a fire in an area is dependent on slope and fuels; which, in the case of a grass fire, can be as short as 5 minutes.

If the duration of the fire is any longer than 10 minutes due to preheating or significant fuel around the structure, additional protection is necessary to prevent glass failure and fire from entering the structure.

Tempered glass

Tempered glass is resistant to high impact and high heat, which means it will remain in place and intact throughout a wildfire event. Building codes require tempered glass to be used in patio doors and all areas subject to human impact. Tempered glass also is used in front of fireplaces.

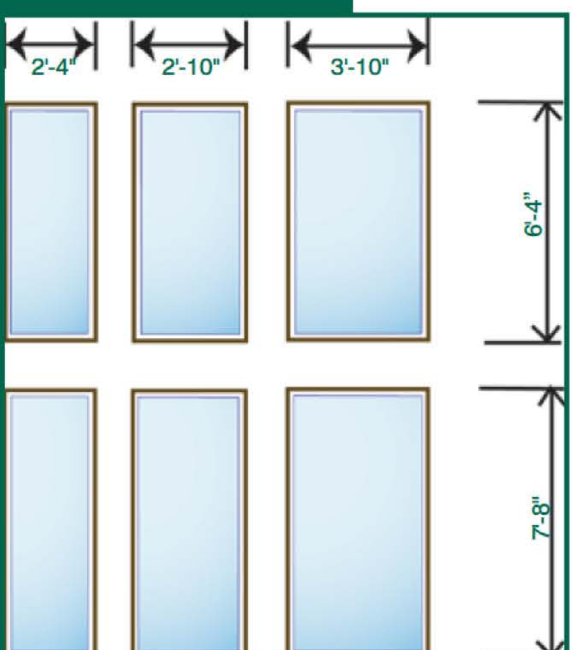

Figure 5-12: Patio door replacement unit sizes

Tempered glass typically costs 50-percent more than regular glass. However, patio door replacement units are mass-produced and stocked by virtually every glass business. As a result, they are economical and less expensive than conventional glass. They come in six sizes, as shown in Figure 5-12, and typically can be used as a picture window unit, or combined to make a window wall or solar structure.

Using patio door replacement units provides tempered glass at a very economical price.

A few brands of windows are marketed as replacement windows in existing mid-rise urban structures where the use of tempered glass is required. As a result, the additional cost for these brands of tempered glass is only 25 percent more than standard glass. Your local window supplier can suggest appropriate manufacturers.

Glass block

Glass block is the most fire-resistive glass available. It has the highest available rating of 90 minutes.

Glass block may be a good choice when only daytime lighting is needed, a view is not a factor and the window is oriented toward a very high fire hazard.

Figure 5-14: Glass block

Doors

Wood doors

Residential structures typically use wood doors with glass inserts. The same fire issues related to window glass apply to glass in doors. An unrated wood door typically is 1 1/2 to 2 inches thick, and can readily ignite and burn through in only 10 minutes, which is much faster than the rest of the structure.

Wood doors are available with a 20-minute rating. Solid-core wood doors a minimum of 1 1/2-inches thick also are acceptable.

Metal doors, steel and aluminum

Metal doors are non-combustible and available with 20-minute, 45-minute and 90-minute ratings. Glass sizes are restricted in these doors. The surfaces are available with embossing to simulate wood grain and raised panel designs.

Just as with energy conservation, a good fire-resistant door requires adequate weather stripping to prevent hot gasses or burning embers from entering the structure.

6. Summary

A major wildfire can be an overwhelming event to experience. It can be huge, blotting out the sun and creating its own winds. It can throw flames and burning embers everywhere. Wildfire is a natural part of our environment that we can either respect or fear. When we modify our homes and the surrounding environment, we can adapt to living in fire-prone areas. Every WUI resident must understand the basic characteristics of wildfire and the risks it presents to their lives and property. The actions we take by building appropriate structures and properly caring for the surrounding environment can significantly reduce wildfire hazards.

A comparison often is made between fire and water. Fire, like water, tries to find a way into our homes. It does not matter how fire-resistant some parts of a structure are if weak points allow a fire to enter. An awareness of how each building component is affected by fire will allow the owner, architect or builder to eliminate those weak points.

References and Additional Resources

2009 International Wildland-Urban Interface Code
International Code Council, Inc.
www.iccsafe.org/Store/Pages/Product.aspx?id=3850X09

NFPA 1144 Standard for Reducing Structure Ignition Hazards from Wildfire
National Fire Protection Association, (NFPA)
www.nfpa.org/catalog/product.asp?pid=114413

2009 International Building Code
International Code Council, Inc.
www.iccsafe.org/Pages/default.aspx

Fire-Retardant-Treated Lumber and Plywood
Hoover Treated Wood Products
www.FRTW.com

The following is a partial list of organizations that can provide more information on the subjects covered in this document.

Colorado State Forest Service
http://csfs.colostate.edu/
http://csfs.colostate.edu/pages/wildfire.html
http://csfs.colostate.edu/pages/wf-publications.html

Fire Adapted Communities
http://fireadapted.org/

Firewise Communities USA (National Fire Protection Association)
http://www.firewise.org/

eXtension Wildfire Information Network (eWIN)
http://www.extension.org/surviving_wildfire

Southern Rockies Fire Science Network
http://www.frames.gov/partner-sites/srfsn/home/

Federal Emergency Management Agency-Wildfire
http://www.ready.gov/wildfires

Insurance Institute for Business and Home Safety
http://www.disastersafety.org/Wildfire

USDA Forest Service, Southern Research Station, Centers for Urban and Interface Forestry
http://www.humanandnaturalsystems.org/technology/cuif

University of Nevada Cooperative Extension, Living with Fire
http://www.livingwithfire.info/who-we-are

Acronyms

APA	American Plywood Association (now APA-The Engineered Wood Association)
ANSI	American National Standards Institute
ASTM	American Society for Testing and Materials
BOCA	Building Officials and Code Administrators International, Inc
FEMA	Federal Emergency Management Agency
FRTW	Fire-retardant-treated wood
ICBO	International Conference of Building Officials
ICC	International Code Council
IRC	International Residential Code
IWUIC	International Wildland-Urban Interface Code
NFPA	National Fire Protection Association
SBCCI	Southern Building Code Congress International
UBC	Uniform Building Code
UL	Underwriter's Laboratory
WHIMS	Wildfire Hazard Identification and Mitigation System
WUI	Wildland-Urban Interface

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