
Fire Performance of Log Walls

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FORWARD

Fire Facts

Source: U.S. Fire Administration/National Fire Data Center, *Fire in the United States 1992–2001, Thirteenth Edition, October 2004*

Causes of Fires and Fire Deaths

One- and two-family dwellings, where 73 percent of the population lives, dominate the residential fire picture in 2001: 73 percent of fires, 78 percent of deaths, 67 percent of injuries, and 76 percent of dollar loss.

- ❑ *Cooking is the leading cause of fires and injuries in these structures.. Cooking fires often result from unattended cooking and human error, rather than mechanical failure of stoves or ovens.*
- ❑ *Smoking is the leading cause of fire deaths. Smoke alarms and smolder-resistant bedding and upholstered furniture are significant fire deterrents.*
- ❑ *Heating is the second leading cause of residential fires and the second leading cause of fire deaths. However, heating fires are a larger problem in single-family homes than in apartments. Unlike apartments, the heating systems in single-family homes are often not professionally maintained.*
- ❑ *Arson is the third leading cause of residential fires but is second in residential fire deaths. In commercial properties, arson is the major cause of deaths, injuries and dollar loss.*

What Saves Lives

- ❑ *A working smoke alarm dramatically increases a person's chance of safely evacuating a house fire before the means of escape becomes lethal.*
- ❑ *Over 90 percent of U.S. homes have at least one smoke alarm. However, these alarms are not always properly maintained and as a result might not work in an emergency.*
- ❑ *Residential sprinklers were found in fewer than 3 percent of homes that had reported fires in 2001. Even residential sprinklers are not a guarantee of safety from all fires. Twenty eight percent of the fire deaths are the result of intentionally set fires. Perpetrators of such heinous acts are likely to disable automatic sprinklers prior to setting fires.*

The popularity of log buildings is illustrated by growing numbers of log residences, resorts, and other buildings constructed in rural and suburban environments. This growth is attracting log construction to greater scrutiny as to the performance of log structures. One frequently asked question is “How do log walls perform in a fire?” Building codes and the insurance industry look at this issue to understand the potential hazard that may result in loss of life and property. With life safety and protection of property being the goal, hazard assessment focuses on the type of construction, the availability of firefighting resources, and the proximity of the structure to neighboring structures. The key issue is time... How long will log construction be able to withstand a fire until the manpower, equipment, and water can be deployed to extinguish it? Will the occupants be able to safely leave the burning structure in that time?

Most log structures continue to be built in rural settings and rely on volunteer fire departments that often must bring water to the site. As illustrated in the *Fire Facts* sidebar, life safety has been dramatically improved by the requirement for residences to have smoke detectors installed and operating properly. Yet, despite the short response time of our many volunteer fire departments across the nation, the time it takes firefighters to extinguish a residential fire may be enough to make the structure and contents non-reusable. The good news is that fires per million people have been steadily decreasing. In the 10-year period between 1995 and 2005, fires and fire deaths have decreased 28%. This is primarily from efforts at prevention of accidental fires through education and regulation.

Over the years, the acceptance of solid wood walls as fire-resistive construction by code officials has been elusive. The Log Homes Council (LHC) and its Members have used various resources that relate the performances of solid wood walls to long fire endurance (see [Summary of Fire Tests & Supporting Opinions](#)) at the end of this paper). Some performed in-house tests while others tested their products in certified labs following specific standard procedures. And as the years pass, the number of fire survival stories continues to increase.

The intent of this paper is to explain the nature of fire, the burn characteristics of wood, and the code requirements that apply in the design and construction of log structures.

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ASSESSING FIRE HAZARD

It often appears that building regulations and the officials that enforce them are just another obstacle in the process of building our dream home. Understanding that these regulations are in our mutual best interest is sometimes difficult. Yet, we all agree that a safe, secure residence is our ultimate goal. When it comes to fire protection and life safety, the regulations are based on volumes of research and investigative findings with the goal being to provide an appropriate response to the assessed fire hazard.

What is the assessed fire hazard?

- ❑ **The potential for ignition:** *What types of activities can be expected to be performed within the structure? What types of materials will be present that may constitute fuel? If any of that fuel happens to ignite, to what other surfaces can it spread?*
- ❑ **The potential for smoke:** *When the fuel is burning, how much smoke is produced? Where will it go? Can it be vented away from the occupants? Will the occupants have time to escape the deadly heat, gases, and suffocating fumes associated with smoke?*
- ❑ **The potential for damage:** *Can the fire travel down the hall or go upstairs? Is the fire inside or outside? Can it go through a window? Is there a risk to/from neighboring structures? Is there any method readily available to extinguish the fire? How long will it take for firefighters to arrive and become effective?*

In response to the potential hazards, fire and code experts have created classifications and requirements for new construction. Design professionals are well versed in these requirements and integrate them into their designs as standard practice. They can be grouped as follows:

- ❑ **Occupancy groups** (e.g., residential, institutional, industrial, educational, etc.)
- ❑ **Types of construction** (e.g., non-combustible types, combustible types, and intermediate types such as heavy timber) defining the ability of the structure to endure the damaging effects of flame and heat
- ❑ Minimum requirements for fire resistive **construction to contain fire** to the room in which the fire is ignited
- ❑ **Detection and alarm systems** that alert the occupants of the building to smoke, heat, or flame
- ❑ **Suppression methods** (adding materials to cool, smother, dilute, or chemically react with the fuel source or using turbulence to emulsify the fuel to disrupt combustion) that use extinguishing agents (e.g., water, carbon dioxide, dry chemicals, foaming agents, halogenated agents)
- ❑ **Means of egress** (the means to escape from a burning building, facilitated by access to exits so as to minimize occupant panic), especially properly sized windows in sleeping rooms.

The scope of this paper is primarily limited to one- and two-family residential construction, but log construction has been successfully employed for large hotels, offices, dormitories, and other occupancies. In other than residential occupancies, suppression systems are likely to be a key element in the overall acceptance of the design by building officials. Means of egress and detection systems (primarily smoke) apply to all occupancies are not limited by type of construction. Therefore, the immense subject of fire protection relative to solid wood walls can be focused on restricting the development and spread of a fire.

The Life of the Fire?

The decomposition of combustible materials through the action of heat is the definition of pyrolysis. It begins when a heat source raises the temperature of the material to its ignition point.

- ❑ **Phase I:** *Over a period of minutes, hours, or days, the early stage of pyrolysis progresses into a smoldering stage where smoke develops, a flame may appear, and ambient temperatures increase.*
- ❑ **Phase II:** *Upon developing a flame, ambient temperatures rapidly (within 5 minutes!) rise to 1000°F.*
- ❑ **Phase III:** *In the next 5 minutes, the confinement of hot, expanding, combustible gases culminates in an explosion known as flashover.*
- ❑ **Phase IV:** *“Fully developed” after only ten minutes of fire, this stage can last for hours.*
- ❑ **Phase V:** *Depending on the extent of fuel and the efforts to suppress the fire, the fire is finally extinguished. At this point, the material enters the cool-down stage that may last for hours or days.*

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The life of a fire through these phases is described in a model known as the Standard Time-Temperature Curve. The importance of this model is to understand how quickly the occupants must evacuate the building (within 5 minutes), how long the structure can withstand extreme temperatures (over 1200°F), and how long the suppression/extinguishing effort is required to cool materials below the ignition point.

Firefighters and scientists recognize that fire is a living, breathing enemy. Feeding on combustible materials in an environment of free oxygen or oxygen released by chemical reaction, the ignition source gives birth to flame. The combustible material is not the only fuel; the chemical reaction caused by the mixture of fuel and oxygen generates hot, toxic, combustible gases. To eliminate the potential for fire, one must remove the source of the fuel, oxygen, or ignition. To extinguish fire, the oxygen to fuel ratio must be diluted or suppressed.

Another factor in the growth of fire is called the fuel array. The quantity of material is described as the fuel load, but the array describes the size of the individual particle and its storage arrangement. Typically, the smaller the particle, the easier it is to ignite. Spontaneous combustion becomes a real possibility when storage of smaller particles is concentrated in a container that is improperly ventilated, or even allowed to reach critical pressure. Which is more combustible, a pile of sawdust and wood chips or a stack of lumber or a log?

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FIRE CONTROL & LIFE SAFETY

The primary focus of design professionals, building departments, insurance underwriters, and firefighters is on four principals: Prevention, detection, evacuation, and containment, in that order. Prevention and containment are the focus of this presentation as they can be attained through proper design and construction. Detection and evacuation requirements are clearly stated in the building codes and apply to log buildings just as they would for any other type of construction.

For the protection of life and property, building codes define limitations on types of construction based on

- ❑ *The intended occupancy or use of the building*
- ❑ *The density and proximity of the building to other buildings*
- ❑ *The availability of fire-fighting services and water sources*
- ❑ *The degree of fire hazard incumbent to the use of the building*
- ❑ *And the combustibility of the materials used in the construction of the building.*

Building Code Requirements

Building departments at the local, county, or state level typically require inspection of new construction to insure compliance with the life safety codes they have adopted. To assist these building departments apply uniform standards, several organizations develop and publish these guidelines into “model” building codes. These model codes are supported with training and certification to building departments that adopt them. For residential construction, the ICC (International Code Council) *International Residential Code for One- & Two-Family Dwellings* (IRC) provides all code requirements in one volume. For commercial construction, the ICC publishes separate model codes that focus on fire (International Fire Code), structure (International Building Code), energy conservation (International Energy Conservation Code), etc. All of these model codes are updated in a rigorous three-year review and approval process. The National Fire Protection Association (NFPA) has also published a set of standards and model codes, the *National Electric Code*, *Life Safety Code*, *Fire Code*, and *Building Construction and Safety Code*, to name a few.

The current version of the IRC at the time of updating this paper is the 2006 edition. The following provisions of the 2006 IRC may or may not be revised during the 2007-2008 code cycle to result in changes in the 2009 edition.

Flame Spread & Smoke Density

Flame spread and smoke density per Section R315: Wall and ceiling finishes shall have a flame-spread classification of not greater than 200 and a smoke-developed index of not greater than 450 according to ASTM E84 testing. This does not apply to trim, doors, windows, or materials that are less than 1/28-inch in thickness cemented to the surface if these materials have a flame-spread characteristic no greater than paper of this thickness cemented to a noncombustible backing. The ratings are grouped in three Classes:

- ❑ *Class A has a flame spread rating of 0 to 25 and is usually specified for escape routes in buildings with large occupancy expectations.*
- ❑ *Class B ratings of 25 to 75 apply to rooms over 1500 square feet in area and escape routes in buildings with moderate size occupancy loads.*
- ❑ *Class C ratings, 75 to 200, apply elsewhere in low to moderate fire hazard conditions.*

In the United States the standard used to evaluate flame-spread characteristics of materials is ASTM E-84, *Standard Test Method for Surface Burning Characteristics of Building Materials*. The test procedure exposes candidate materials in a horizontal, rectangular tunnel typically 17” to 22” wide by 12” in height and 25 feet long. The tunnel is equipped with two gas burners at one end that direct a flame onto the surface of the test material under a controlled air flow. Flame spreads along the surface of the material as the test progresses. The distance of flame travel and the rate at which the flame front advances during a 10-minute exposure determines the calculated flame spread index. To provide standard conditions for each test, the tunnel is calibrated to an index of 0 for noncombustible materials and 100 for 23/32” red oak flooring. Indices for tested materials can range from 0 to over 1000.

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Based on ASTM E-84 testing, flame spread indexes for softwoods range from 60 to over 150. The results typically meet Class C code requirements. A sample of test results follows, as published in Table 17-1 of the Wood Handbook, published by the Forest Products Laboratory, US Forest Service. The most complete and current list for wood products is in AF&PA's Flame Spread Performance of Wood Products - DCA 1 (download a pdf copy at <http://www.awc.org/Codes/dcaindex.html#FirePubs>).

Table 17-1. ASTM E84 flame spread indexes for 19-mm-thick solid lumber of various wood species as reported in the literature

Species ^a	Flame spread index ^b	Smoke developed index ^b	Source ^c
Softwoods			
Yellow-cedar (Pacific Coast yellow cedar)	78	90	CWC
Baldcypress (cypress)	145-150	—	UL
Douglas-fir	70-100	—	UL
Fir, Pacific silver	69	58	CWC
Hemlock, western (West Coast)	60-75	—	UL
Pine, eastern white (eastern white, northern white)	85, 120-215 ^d	122, —	CWC, UL
Pine, lodgepole	93	210	CWC
Pine, ponderosa	105-230 ^d	—	UL
Pine, red	142	229	CWC
Pine, Southern (southern)	130-195	—	UL
Pine, western white	75 ^e	—	UL
Redcedar, western	70	213	HPVA
Redwood	70	—	UL
Spruce, eastern (northern, white)	65	—	UL, CWC
Spruce, Sitka (western, Sitka)	100, 74	—, 74	UL, CWC
Hardwoods			
Birch, yellow	105-110	—	UL
Cottonwood	115	—	UL
Maple (maple flooring)	104	—	CWC
Oak (red, white)	100	100	UL
Sweetgum (gum, red)	140-155	—	UL
Walnut	130-140	—	UL
Yellow-poplar (poplar)	170-185	—	UL

^aIn cases where the name given in the source did not conform to the official nomenclature of the Forest Service, the probable official nomenclature name is given and the name given by the source is given in parentheses.

^bData are as reported in the literature (dash where data do not exist). Changes in the ASTM E84 test method have occurred over the years. However, data indicate that the changes have not significantly changed earlier data reported in this table. The change in the calculation procedure has usually resulted in slightly lower flame spread results for untreated wood. Smoke developed index is not known to exceed 450, the limiting value often cited in the building codes.

^cCWC, Canadian Wood Council (CWC 1996); HPVA, Hardwood Plywood Manufacturers Association (Tests) (now Hardwood Plywood & Veneer Assoc.); UL, Underwriters Laboratories, Inc. (Wood-fire hazard classification. Card Data Service, Serial No. UL 527, 1971).

^dFootnote of UL: In 18 tests of ponderosa pine, three had values over 200 and the average of all tests is 154.

^eFootnote of UL: Due to wide variations in the different species of the pine family and local connotations of their popular names, exact identification of the types of pine tested was not possible. The effects of differing climatic and soil conditions on the burning characteristics of given species have not been determined.

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Fireblocking

Fireblocking per Section R602.8: “Fireblocking shall be provided to cut off all concealed draft openings (both vertical and horizontal) and to form an effective fire barrier between stories, and between a top story and the roof space.” For example, fireblocking is required in cavities of framed walls (at the ceiling and floor level) and at 10-foot intervals both horizontal and vertical (including floor and roof framing). Also, at openings around vents, pipes, ducts, cables and wires at ceiling and floor level, an approved material is required to seal the opening to resist the free passage of flame and products of combustion.

Fireblocking is not an issue in most log structures. Where logs stack directly on one another, the walls are an assembly of solid wood and do not have cavities through which flames can spread. For log wall technologies that incorporate a space between the logs, it is quite common to provide solid wood bearing blocks on regular intervals (not exceeding 10 feet (3048 mm) to comply with R602.8). Many second floor assemblies are constructed using beam and deck assemblies, again without concealed cavities conducive to flame spread. Similarly, roof systems are often beam and deck construction.

Containment

Dwelling unit separation per Section R317: Dwelling units in two-family dwellings shall be separated from each other by wall and/or floor assemblies of not less than 1-hour fire-resistive rating when tested in accordance with ASTM E119. EXCEPTION: A fire resistance rating of 1/2-hour shall be permitted in buildings equipped throughout with an automatic sprinkler system installed in accordance with NFPA 13R.

Fire resistance ratings are a measure of the capacity of an assembly to withstand the effects of fire while acting as a fire barrier and supporting a load.

ASTM E-119, *Fire Tests of Building Constructions and Materials*, rates by time the ability of an assembly to maintain structural integrity under full design load, prevent flame penetration, and limit temperature increase on the side opposite the burn. Testing a large wall assembly includes applying a design load from above and a direct flame using furnaces. For a one-hour fire rating, the furnace is stopped after a specified amount of time and a 30-pound water stream is applied. If no flame or water penetrates the assembly and the temperature opposite the burn remains at a surface temperature less than 250°F, the assembly is proven to be a one-hour fire-rated wall.

Dwelling unit separation is just one application of the concept of containment. Even within a single structure, differing use may require an assembly to separate one space from another. In dwellings, the wall between the living area and the garage is typically required to be a one-hour fire rated assembly. The conventional response is to apply 5/8" Type "X" gypsum board on common walls/ceilings and to use a 20-minute fire-rated door (wood solid core) with automatic closing device.

Other typical fire code issues reviewed by building officials include

- ❑ *Enclosed accessible spaces under stairs are required to have walls and soffit protected on the enclosed side with 1/2" gypsum board.*
- ❑ *Maintain 6-5/8" minimum distance from inside of flue to combustible materials with a minimum 4" solid masonry.*
- ❑ *Wood stove, chimney, heat shield, and hearth to be installed per appliance manufacturer's specifications and local code. Maintain minimum clearances to wall surfaces.*

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Controlling Fire Hazard

Preventing fire within or outside of the structure is the ultimate key to minimize the risk of damage from fire. The factors below should be considered regardless of your selected source of log building materials.

Suppression Systems

The requirements for fire resistive construction may be relaxed when an approved system of detection, alarm, and suppression is installed. Fire suppression is the application of a smothering, non-combustible substance (e.g., water, foam, dirt) that isolates the fuel from the oxygen required for combustion and/or cools the fuel source below its ignition point. The suppression system is most commonly a method of distributing water over a large area or onto specific areas. In today's high tech world, large rooms full of computer equipment are often protected with chemical or inert gas systems that will not damage the room's valuable contents.

The decision to invest in a suppression system needs to be balanced with the hazard assessment of the building type and the building site. In rural areas where forest fire potential is high, the choice may be to install non-combustible roofing or use a sprinkler system to protect combustible shingle roof coverings. Interior sprinkler systems are more commonly used in buildings that will have higher occupant loads such as hotels, assembly rooms, lodges, etc.

There are many decision points in selecting a fire suppression system, but the critical elements on which to focus are the system's reliability and its response time. The response time of bringing the water to the fire is compounded by the response time of the detection and alarm system. As stated in the Forward sidebar, the presence of an operating smoke detector is the single most important factor in surviving a residential fire.

Careful assessments of the potential hazard as it applies to the type of construction and the intended use of the structure are key to the control of fire and the limitation of potential loss from fire. Minimum standards have been developed for specific situations, but the response to the hazard assessment requires a careful balance in decisions and is not universally applied to all new projects.

Environmental Conditions

The ambiance and character of a log building tend to lead the owner to building it in a more rural setting than more common types of construction. The extent of property loss from wildfires in rural environments since the 1980's spawned the development of ICC's *International Wildland-Urban Interface Code (IWUIC)*.

Building Density

Log home subdivisions probably provide the greatest density of log buildings in a specific parcel of land, but the distance from one building to another reduces the danger from a neighboring structure fire. More often, the danger from a structure fire is from outbuildings and garages located near the log building on the same lot. The distance of the outbuilding to the log home, its intended use, storage of hazardous materials, and type of construction are the primary considerations. The key is to assess the potential hazard and provide an appropriate distance between the log home and the outbuilding.

Defensible Space

Chapter 6 of the IWUIC defines the nature of the surrounding space in terms of the fuel load. This Code is primarily intended for protection "from wildland fire exposures, exposures from adjacent structures and to mitigate structure fires from spreading to wildland fuels."

Controlling the available fuel source around the building can decrease the hazard of fire. The Code defines three fuel modification distances that are measured along the grade from the outermost projection of the building (eave overhang, exterior deck, etc.). In a moderate hazard, defensible space means that combustible materials and vegetation must be modified or removed for a distance of 30 feet from the projected perimeter

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of the building (50 feet for high hazard, 100 feet for extreme hazard). The requirement for modification is measured horizontally between crowns of the trees to any other combustible fuel or potential ignition source.

- ❑ *A minimum distance of 10 feet to overhead electrical wires, chimney outlets, etc.*
- ❑ *Keep limbs pruned to a height 6-feet above grade*
- ❑ *Regularly remove dead limbs and litter*
- ❑ *Limit storage of firewood or other combustible material to 20-feet from the projected building perimeter and 15-feet from trees (measured horizontally to the crown of the tree).*
- ❑ *Use spark arresters for any fuel-burning appliance to minimize the risk of fire spread.*

Ready Response

There are several possible responses to the detection of a fire. The most common method of extinguishing burning solids is to use water. This is because of its available supply, ease of application, low cost, and effectiveness in the cooling, smothering, and dilution of a fire. Thus, an available water supply with proximity to the structure becomes a worthy consideration.

Chapter 4 of the IWUIC describes appropriate man-made or natural water supply. The critical elements are the replenishment of the water supply and access to it. For one-and two-family dwellings, the minimum duration of supply is 30 minutes when pumped at a rate of 1,000 gallons per minute (less than 3600 sq. ft.) to 1,500 gallons per minute (over 3600 sq. ft.). Other occupancy types are to have an available water supply of 1,500 gallons per minute for up to two hours.

When the source of the fire is occupancy-related, it may involve other than solid fuels as the source of the problem. Electrical fires, for example, are best extinguished directly by carbon dioxide, dry chemical or halogenated agents or controlled after the power is shut off using water. Hazardous/flammable liquids and gases can also be extinguished directly with appropriate fire extinguishers. Automatic shutoff valves tied to detection systems are recommended.

It is generally recommended by firefighters that evacuation be the absolute first response to fire because smoke and rapid heat development can overwhelm the best intentions of an occupant who chooses to fight.

Building Design and Material Selection

As previously mentioned, building codes call for early detection (smoke, heat rise and flame) and the presence of clear exit routes. Code-writing agencies have responded to the life-saving success of smoke detectors by requiring residences to have at least one direct-wired and one battery-powered smoke detector supplied per dwelling, located near the entrance to each bedroom or group of bedrooms.

Beyond the specific code requirements, there are important preventive steps that can be taken to reduce the risk of fire damage. Many of these recommendations were developed following the study of widespread fire damage in residential areas. Possibly the most significant of these studies was following the damaging fires in the hills surrounding Oakland, California in the fall of 1991.

Windows & Wall Openings

It is not practical to limit the amount or number of glazed openings in buildings, especially when there isn't any apparent danger from neighboring structures. Yet, open windows allow structure fires to spread.

When internal gases explode during flashover, windows are commonly blown out allowing flame and combustible gases to exit the building and damage the exterior of the building. The size, number, and location of the windows can determine the extent of spread or damage. In fact, the window geometry can determine the nature of the flame plume that projects from the window as outside oxygen combines with the escaping gases. The flame plume tends to extend out horizontally when the window is tall and narrow but becomes vertical from short, wide windows.

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The effective fire block can provide the moments needed for evacuation. Fire spread to upper floor windows can be limited by fire resistive construction above the lower window. This construction may be

- ❑ *A balcony or eyebrow*
- ❑ *A 36" high wall below the upper floor window*

An interesting finding of residential fires shows that the thermal performance of the glazing in windows combined with the type of interior window treatments has a critical impact on the passage of fire through an opening. This is due to two factors: 1. The higher thermal performance of the glazing allows the opening to resist transfer of heat to the other side. 2. These windows usually have more than one layer of glazing, thus the glass exposed to the fire may be sacrificed while the opposite panel remains intact. Since the ability of the glass to resist breakage is significant for protection, tempered glass is also a good option.

The longest resistance to the high temperature of a fire is a closed window with high-performance (energy efficient) glazing and non-combustible window treatments. As the temperature on the non-fire side of the glazing increases, the distance of combustible material from the window becomes more critical. For better protection of openings, it is recommended that tempered or multiple glazing layers be used for exterior windows and skylights.

Overhangs & Gutters

The edge of the roof produces interesting issues in the study of fire behavior. First, the overhang is a focal point for fire resistive construction because it can trap flames, heat and smoke. Where fire hazard is moderate or higher, the IWUIC requires noncombustible materials for the construction of gutters and downspouts.

- ❑ *For a Class A roof, two-inch thick (nominal) fascia boards are required to protect the edge of the roof assembly for 1-1/2 hour rated assembly, with a one-hour rated soffit construction.*
- ❑ *In Class B roof assemblies, the eave must be protected with a minimum of 3/4" thick material, and rafter tails (except for heavy timbers) cannot be exposed.*
- ❑ *"For roof coverings where the profile allows a space between the roof covering and the roof decking, the space at the eave ends shall be fire stopped to preclude entry of flames or embers."*

Roof Coverings

Roof coverings are rated for fire resistive construction as Class A, B, or C. Materials are tested according to ASTM standard test methods (primarily E108) to measure how long they resist ignition, stay in position, and whether or not burning pieces can be broken off and blown away. In the National Roofing Contractors Association overview of the International Building Code, requirements for roof coverings are as follows:

"Brick, masonry, slate, clay or concrete tile, exposed concrete deck, ferrous or copper shingle, and panel roof coverings are considered to have Class A fire-resistance classifications without being tested. Similarly, metal sheet or shingle roof systems are considered to have Class B fire-resistance classifications without testing."

Examples of typical Class C roofing are asphalt composition shingles, treated wood shingles, or cold-applied built-up roofing.

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HOW SOLID WOOD WALLS RESPOND

What is the fire rating for a solid wood wall? Fire ratings are determined by either an actual test applied to a specific construction or by calculations derived from such tests. Because of the diverse nature of the log building industry, it is difficult to physically test every specific construction especially if one considers that each test cost tens of thousands of dollars to prepare, perform, and analyze. Therefore, the Log Homes Council holds the position that evidence from existing research provides an acceptable basis for determining the fire rating of the wall.

Until 2007, when the ICC published ICC 400, *Standard on the Design & Construction of Log Structures*, one of the biggest problems for the log home industry was the lack of recognition of log construction in building codes. To identify the potential performance of a log home in a fire, one had to reference the ICC International Building Code (IBC) for the definition of heavy timber construction. The most similar type of construction in the codes continues to be heavy timber, using massive beams, posts, rafters, and other structural members. The IBC lists requirements for Type IV construction in section 602.4:

- Beams & Girders: Not less than nominal 6x10 (inches, width x depth; 152x254 mm)
- Columns: Not less than 8 inches (203 mm) nominal when supporting floor loads; nominal 6x8 (inches, width x depth) or greater for roof and ceiling loads only.
- Rafters, purlins, timber trusses: Not less than nominal 4x6 (inches, width x depth; 102x152 mm)
- Decking: Floors and roofs 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 (76 mm) nominal in thickness covered with 1-inch (25 mm) nominal dimension tongue-and-groove flooring, laid crosswise or diagonally...” For wood roof decks, the dimension changes to 2 inch nominal (51mm).

An interesting component of the IBC Type IV Construction is the allowance for exterior structural members in section 602.4.7: “Where a horizontal separation of 20 feet (6096 mm) or more is provided, wood columns and arches conforming to heavy timber sizes shall be permitted to be used externally.” This is a relevant note because the typical exterior wall of Type IV construction is masonry or other material that provides a 2-hour fire-resistance-rated construction. Further in 602.4.7, “Partitions shall be of solid wood construction formed by not less than two layers of 1-inch (25 mm) matched boards or laminated construction 4 inches (102 mm) thick, or of 1-hour fire-resistance-rated construction.” It would appear that most log walls would satisfy the partition component of Type IV construction.

The importance of being recognized as Type IV construction goes beyond just the size of the structural elements. The expected use, or occupancy group, of the building will impact the required fire-resistance rating for the exterior walls as determined by the fire separation distance between structures and the height of the wall. For residential construction where neighboring structures are 30-feet or more apart, the exterior wall is not required to be fire-resistance rated, but within 5 feet of another structure a 1-hour rating from both sides is required.

The comparison of log buildings to Type IV construction is relevant because many log structures likewise employ structural timbers as joists, rafters, beams, and posts. The deviation is that the timbers also act as the structural component of the walls. As wall-logs, the wall members have structural capacity and are fully supported along their length. However, the stacking of logs to form a solid wall produces a different dynamic in fire, more like that of a glued laminated beam.

The key section in the code is really IBC 704.6: “The wall shall extend to the height required by Section 704.11 and shall have sufficient structural stability such that it will remain in place for the duration of time indicated by the required fire-resistance rating.” So, what is required to satisfy that requirement when the exterior wall is solid wood construction?

Fire Performance of Log Walls

What Happens to Wood in a Fire?

The only elements we can have some influence over are the presence of **heat, oxygen**, and the availability of the fuel source: **the wood itself**. Wood is a cellular material that makes up the bulk of the tree. Water, tannins, waxes, gums, starches, alkaloids and oils occupy the cell cavities, contributing to the color, odor, taste, decay resistance, and flammability of the wood. It is like a honeycomb composed mainly of dead, hollow, tubular cells. This cellular structure is what gives wood its amazing strength, insulating value and allows it to hold water, oxygen, and nutrients.

Insulating Effect of Char

As an organic material, wood is combustible. Yet its insulating and charring characteristics produce an astounding response to fire. While wood begins to char at 300°F, commonly exceeded in the first five minutes of an accidental fire, the wood beneath the char remains structurally sound. Compare this unique response to that of structural steel which loses 50% of its strength at 1000°F. The charring effect of wood results in a protective coating over the surface of the uncharred material. This protective char coat is very similar to the effect created by some intumescent chemicals used to protect materials and assemblies.

Chapter 17 of the Wood Handbook (*Wood Handbook: Wood as an Engineering Material*, FPL-GTR-113) includes a discussion on charring, explaining that the “The temperature profile within the remaining wood cross-section can be used with other data to estimate the remaining load-carrying capacity of the uncharred wood during a fire and the residual capacity after a fire.” This is essentially what the American Forest & Paper Association (AF&PA) demonstrates in their Technical Report 10, *Calculating the Fire Resistance of Exposed Wood Members* and summarized in their Design for Code Acceptance Series, DCA 2 – *Design of Fire-Resistive Exposed Wood Members*. These documents are relevant to the discussion as they are the original research that effectively became Chapter 16 of ANSI/AF&PA NDS-2005, the *National Design Specification® for Wood Construction (NDS®)*. The NDS is referenced in the model building codes for wood design and in the ICC400 Log Standard specifically for calculating fire-resistance of log walls.

The NDS notes that a nominal char rate of 1.5 inches per hour in the direction perpendicular to the surfaces of exposure to fire is commonly demonstrated and thus assumed for solid sawn and glued laminated timbers. This assumption is supported by information in the Wood Handbook that notes that the studies and tests performed contained many variables that could not be controlled in a manner sufficient to derive a distinct char rate per wood species.

The wood that remains within the estimated charring is analyzed in accordance with the NDS to determine its remaining strength after a fire. Essentially, the initial size of the timber is specified to provide the required section properties plus the estimated char layer per surface that is exposed. For beams (3-sided exposure) and columns (4-sided exposure), this is illustrated below from AF&PA’s Technical Report 10.

Fire Performance of Log Walls

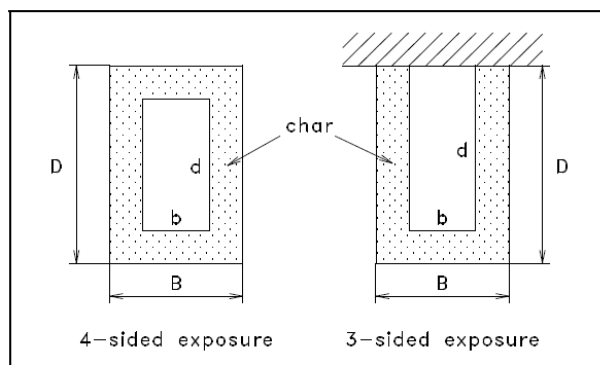


Figure 2 Symbols for cross-sectional dimensions
Courtesy, American Forest & Paper Association, Inc., Washington, DC

While the effect of charring is to protect the structural wood fiber beneath it, charring does remove the structural capabilities of the affected area. This is critical to the connection of timbers to each other. When timber connections are made with hangers and/or fasteners, the connection must take fire-resistance into consideration. For example, if the connection is intended to survive a one-hour fire event, it is likely that the fastener length will need to be a longer length so that it is connected to structurally sound wood. Its diameter may also be a factor to resist the heat flux of the fire. APA-The Engineered Wood Association Technical Note #Y245 also presents the approach taken by AF&PA, but this paper goes further to describe and illustrate how connections can be protected for fire-resistive construction. Concealed by 5/8" Type "X" gypsum or 1-1/2" of wood, the fasteners are less likely to conduct heat through the connection.

Code Comparison: Solid Wood Walls vs. Heavy Timber Construction Type

Heavy timber construction is considered fire-resistive if the structure can maintain its integrity for a specific amount of time during a fire. The structure can consist of timber framing to provide the entire support; curtain walls or load bearing walls must be fire-resistive construction. The intent of the codes is to provide a barrier to movement of fire through containment with minimal impact on structural integrity. Containment is measured by temperature rise on the wall surface opposite of the fire exposure while the construction continues to support the design loads.

Load Transfer Comparison

In heavy timber construction, the structural loads placed on the assembly are transferred from spanning members (beams, rafters, joists) to specific bearing areas (post, column, mullion, bearing wall). In log buildings, the exterior bearing wall is a continuously supported solid wood member supporting the same heavy timber structural frame members.

- ❑ *Rather than substantial concentrated loads on a few vertical members supporting the entire framework, log wall construction spreads the loads throughout the entire structure.*
- ❑ *Secondly, the log wall assembly is likely to be only exposed to fire on one side while the timber column will have three or all four surfaces exposed.*

These are important considerations since the log building is likely to be less prone to collapse in any one area under a fire condition.

Fire Exposure Comparison

Since log walls are a solid assembly extending from subfloor to roof, there is only opportunity for exposure on two sides of the assembly. The concept that the unobstructed height of the log wall is to be used in determining fire resistance is supported by Rule 1 from T.Z. Harmathy's *Ten Rules of Fire Endurance Rating* (published in 1965 in *Fire Technology*). This rule states:

Fire Performance of Log Walls

The “thermal” fire endurance of a construction consisting of a number of parallel layers is greater than the sum of the “thermal” fire endurance characteristics of the individual layers when exposed separately to fire.

This rule, as substantiated by testing on glu-lam beams, supports the fact that the fire rating of a log wall would be based on the total height of the assembly as defined by contiguous courses (layers) and protected openings. The effective height would be determined to the bottom of an adjoining horizontal interface (floor or roof assembly). This philosophy was adopted by the committee that developed the IWUIC, resulting in the definition below:

LOG WALL CONSTRUCTION. A type of construction in which exterior walls are constructed of solid wood members and where the smallest horizontal dimension of each solid wood member is at least 6 inches (152 mm). This definition is directly correlated to the requirement for Heavy Timber Construction that calls for a minimum 6” dimension to structural members. In the absence of supporting research and/or testing, it is impractical to include log wall technologies that have narrower dimensions. It is also important to note that ICC400 does not consider sealants or other materials between logs, so that the fire-resistance is considered only on the basis of the width of the log wall. However, sealants (e.g., chinking systems) can have a dramatic effect on the wall’s performance, but ASTM E-119 testing of the specific materials and assembly would be required to acknowledge a rating.

Paths for Code Compliance

By the time the ICC IS-LOG Committee was developing the ICC400 *Standard on the Design & Construction of Log Structures*, AF&PA had fine-tuned its research and modified the analysis to a mechanics-based design method. With the precedent established in the UWUIC that defined log wall construction and acknowledged a minimum 6” width (at the narrowest point) as a one-hour fire-resistive construction, Section 303 of ICC400 was able to establish three distinct paths for establishing the fire resistance ratings of log walls.

1. **Prescriptive Path:** This path adopted the IWUIC precedent. If the criteria in this path is satisfied, the code is satisfied.
2. **Calculated Path:** The path adopted NDS Chapter 16 as the method for calculating fire resistance. The principle applied is that, “The induced stress shall not exceed the resisting strength which has been adjusted for fire exposure”. The adjustment is the removal of wood due to char rate and thickness of the char layer. It is important to note that this provision sets a maximum of a 2-hour rating on any analysis.
3. **Tested Path:** It is critical to understand that if neither the Prescriptive or Calculated Paths can be applied, that the reported results of full scale testing of a specific wall assembly in accordance with ASTM E119 by an accredited fire testing laboratory can be used to establish the fire resistance rating.

Calculating Fire Resistance Rating

The desire to establish a reasonable fire rating for solid wood walls included a search for existing methodology that could be logically applied. Initial research for this paper uncovered formulas for determining fire resistance for beams and columns published by the American Institute of Timber Construction, American Forest & Paper Association, and adopted into each of the model building codes (BOCA, ICBO, SBCCI). Additional research on glued laminated timbers demonstrated that layered wood members perform in a similar fashion, This has been considered in ICC400 and, as noted in the previous discussion of the Insulating Effect of Char, these calculations have been updated and incorporated into the building codes through the NDS.

In DCA 2 - Design of Fire-Resistive Exposed Wood Members, guidelines are given for calculating the effect of fire on columns (exposed on four sides) and beams (exposed on three sides). This simplified approach based on empirical testing provides the calculation of fire resistance rating for a given timber beam size, in minutes, equal to

$$\text{Minutes of Fire Resistance Rating} = 2.54 Z_b [4-(b/d)].$$

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Where:

b = the breadth (width) of a beam or larger side of a column before exposure to fire, inches. By definition of this section, the minimum breadth is 6-in. nominal (5.5-in. actual per the NDS).

d = the depth of a beam or smaller side of a column before exposure to fire, inches. It is assumed that each horizontally laid wall-log (as defined by ASTM D-3957) acts as a beam to support roof/floor loading.

Z = the load factor is typically established at 1.3 for a beam

Using these criteria, the ratings for a nominal 4", 6" and 8" thick log wall were calculated as follows. The first three calculations maintain the premise assumed above. The last provides a more conservative approach that coincides with the definition of heavy timber construction.

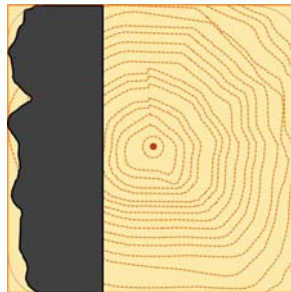
- a) If $b \geq 3.5"$, $d = 3.5"$, and $Z = 1.3$; $(2.54 * 1.3 * 3.5 * [4 - (3.5/3.5)]) = 34.67$ minutes
- b) If $b \geq 5.5"$, $d = 5.5"$, and $Z = 1.3$; $(2.54 * 1.3 * 5.5 * [4 - (5.5/5.5)]) = 54.48$ minutes
- c) If $b \geq 7.25"$, $d = 7.25"$, and $Z = 1.3$; $(2.54 * 1.3 * 7.25 * [4 - (7.25/7.25)]) = 71.82$ minutes
- d) If rating = 60 minutes, $b = d$, and $Z = 1.3$; $(60 / (2.54 * 1.3 * [4 - (4/4)])) = 6.057$ inches.

Applying NDS Principles to a Log Wall

While it has been established that the log wall is capable of acting as a beam (a structural member that is designed to resist bending), the nature of the wall assembly is similar to that of decking when exposed to fire. In the discussion of fire design in Chapter 16 of the NDS, there is a provision for Timber Decks (section 16.2.5) that can be applied to log walls. This section can be applied in that the log wall should be "designed as an assembly of wood beams fully exposed on one face" if a tongue and groove exists between logs.

Section 16.2.5 also makes a distinction between tongue-and-groove (T&G) decking as opposed to pieces that are butted to one-another. In a log wall, like in a plank floor or roof, these butted joints can be at the ends of the piece and/or along the sides. A conservative approach to designing a log wall with butt joints to resist a 1-hour fire event would be to include the required effective char layer to the exposed face and to be sure that the edges at the butt joints are reduced by 33% of the effective char rate. For 1-hour fire endurance, the horizontal dimension of the log section would be reduced by a 1.8" char layer, and the vertical dimension would be reduced by 0.6" along the top and bottom edges.

Whether horizontal or vertical, it is clear that the design of the joint between logs and the sealants used to protect them have as much of an effect on fire performance as they do on air infiltration. The reported performance of planks, tongue and groove decking, and glued laminated beams substantiates this concept.



Charring on the exposed face of a 6x6 after 1-hour

When designing the fastening schedule for the log wall, the fire-resistance rating of the wall should be considered in addition to edge and end distance or the need for lead holes. For a one-hour rated assembly, the fasteners should be placed a minimum of 1.8" from either edge of the log profile, referencing the narrowest width of the log wall. When sealants or coatings approved for the required endurance time are used, this distance to the edge of the log can be reduced (e.g., when covered by a rated chinking product).

The following table from AF&PA TR10 demonstrates the design load ratios for exposed butt-joint timber decks. It is relevant to log walls in that the tabulated values (resulting from principles of engineering mechanics presented in the report and included in NDS Chapter 16) show that a wall assembly consisting of nominal 6x6's would remain at 100% of the structural capacity of the original cross-section after a one-hour fire event. This would support an argument that the prescriptive code be changed from an actual 6" minimum dimension to 5-1/2".

Fire Performance of Log Walls

Table 10. Butt-Joint Timber Decking

Rating	1-HOUR				1.5-HOUR			2-HOUR	
Beam Width	1.5	2.5	3.5	5.5	2.5	3.5	5.5	2.5	5.5
Beam Depth	Design Load Ratio, R _s								
2.5	0.05	0.12	0.15	0.18	-	-	-	-	-
3	0.09	0.24	0.30	0.36	0.03	0.04	0.05	-	-
3.5	0.14	0.35	0.44	0.53	0.08	0.12	0.16	-	-
4	0.18	0.45	0.57	0.68	0.14	0.21	0.28	0.02	0.08
4.5	0.21	0.54	0.68	0.80	0.19	0.30	0.39	0.04	0.16
5	0.24	0.61	0.77	0.92	0.24	0.38	0.50	0.06	0.24
5.5	0.27	0.68	0.85	1.00	0.29	0.45	0.59	0.09	0.32

Courtesy, American Forest & Paper Association, Inc., Washington, DC

At openings in the log wall, the common practice of installing a wood frame (buck) in which to install windows or doors is beneficial to the fire performance of the opening. When the buck is largely self-supporting and consists of nominal 2x lumber or larger pieces, the buck protects the ends of the logs and the bottom of the header because it will be sacrificed to the fire rather than the log. Therefore, the header log(s) can be assumed to experience the same charring as the remainder of the log wall.

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FINAL NOTES

Over the years, there have been many reports of fires that have burned inside and outside of log buildings without destroying the building's structural integrity, illustrating the fire resistive nature of solid wood walls. It is a combination of the insulating response of the charred wood at the surface with the slow rate at which flame will spread along the wood surface, and the fact that there are no concealed cavities in a log wall through which the fire may travel (ultimate fireblocking!). Combined with the selection of beam and deck second floor and roof options often incorporated into log buildings, log structures are a top choice for endurance and integrity in a fire.

This paper has attempted to provide a greater understanding of wood, the implications of your building site and building design, and their impact on your decisions toward developing an understanding of the fire resistive nature of solid wood walls. The unique aspect of most log homes is that the logs themselves are what make up the structural soundness of the building. Because of this, most solid wood walls can be expected to satisfy one-hour fire-resistant ratings while greater wall thickness can result in even longer ratings. The Log Homes Council contends that the performance of solid wood walls, while composed of combustible materials, is sufficient to perform satisfactorily as the bearing wall portion of the *Heavy Timber* type of construction recognized by building codes.

For more information, refer to

PUBLICATIONS

- ❑ *Wood Handbook: Wood as an Engineering Material (FPL-GTR-113)*, Forest Products Laboratory, Madison, WI
- ❑ *Structural Fire Design: Wood (FPL 450)*, E.L. Schaffer, Forest Products Laboratory, Oct. 1984
- ❑ *Charring Rate of Wood for ASTM E119 Exposure*, Robert H. White and Erik V. Nordheim, *Fire Technology* Vol. 28, No. 1, Feb. 1992
- ❑ *1997 Urban-Wildland Interface Code*, International Fire Code Institute, 5360 Workman Mill Road, Whittier, CA 90601-2298
- ❑ *The Supplement to the National Building Code of Canada*, National Research Council of Canada, Ottawa, NRCC#17724
- ❑ *Fire Resistance of Log Walls*, Dalibor Houdek, Ph.D., LOG BUILDING NEWS, International Log Builders Association, Number 35, September, 2001 (http://logassociation.org/resources/fire_resistance.pdf)
- ❑ AF&PA American Wood Council, 1111 Nineteenth St., NW, Suite 800, Washington, D.C. 20036, www.afandpa.org and www.awc.org. Publications include ANSI/AF&PA NDS-2005 National Design Specification® for Wood Construction, Design for Code Acceptance (DCA) #1 Flame Spread Performance of Wood Products, DCA #2 Design of Fire-Resistive Exposed Wood Members, DCA #3 Fire Rated Wood Floor and Wall Assemblies, and Technical Report #10 Calculating the Fire Resistance of Exposed Wood Members.

WEB SITES

American Forest & Paper Association	http://www.afandpa.org/
American Wood Council	http://www.awc.org/
American Plywood Association	http://www.apawood.org/
University of California Forest Products Laboratory	http://www.ucfpl.ucop.edu/Prefire/map.htm
Forest Products Laboratory, USDA	http://www.fpl.fs.fed.us/
The Forest Products Society	http://www.forestprod.org/
National Fire Protection Agency	http://www.nfpa.org/
National Institute of Standards, Fire Research Information Services	http://www.bfrl.nist.gov/bfrlris/
FEMA/United States Fire Administration	http://www.usfa.dhs.gov/
fireSafety.gov	www.firesafety.gov

Fire Performance of Log Walls

Summary of Fire Tests & Supporting Opinions

- In a 1981 letter from E.L. Schaffer, Project Leader in Fire Design Engineering at Forest Product Laboratory, the Log Homes Council received Schaffer's opinion that a 4" tongue & groove joint wall will last one hour. He based this on char rate data (table 2 of Res. Note FPL-0145). He also noted a test conducted by the National Bureau of Standards on load bearing and non-load bearing tests of 8-foot high walls made by stacking 2x4 lumber (3-5/8" thick) and 2x6 lumber (5-5/8" thick). In the load bearing walls, buckling occurred in 68 minutes for the 2x6 wall. Burn through occurred in 85 minutes for the 2x4 non-load bearing wall.
- In the 1980's, a Log Homes Council Member Company, Authentic Log Homes, performed and documented their own test. A fire was ignited in a small "dog house size" log building. Fire temperatures reached 1,800°F after 90 minutes, but cotton waste material applied to the outside of the wall did not ignite, illustrating the thermal barrier capacity of the wall. At the 2-hour mark, the test was halted and the load bearing capacity was measured. At 2-1/2 hours into the test, less than 1/3 of the log thickness had burned, and the remaining wall presented sufficient surfaces to withstand the design load. It was noted that there was not a tendency of the wall to burn faster at seams or corners.
- In 1987, a log construction burn-through test was conducted at the University of Wyoming in accordance with ASTM E-119 Standard Method for Fire Testing of Building Construction. The construction, built to the specifications of Authentic Log Homes (6x8 nominal Lodgepole pine), withstood a 2-hour burn without failure. Four deviations were employed that were believed to create a more severe test situation:
 - 1) A 4-sided log wall structure (9-ft x 3-ft x 12-ft long) provided the furnace and test specimen to simulate what would take place in an oven with consumable walls.
 - 2) The test was run exposing the bearing log wall to ambient weather conditions with wind being the major concern (wind velocity was measured a 5-minute intervals and effects noted).
 - 3) A 7,000-pound load was supported by the wall prior and throughout the test.
 - 4) The hose stream test had to be altered because the structure was a closed cubicle. To compensate for this, the water pressure was increased from 30 psi to 175 psi.
- Lincoln Logs, Ltd. tested a 12-ft x 9-ft high assembly using nominal 6x8 red cedar logs with moisture content of 7%. Warnock Hersey International conducted the test (WHI 495-0925) in accordance with ASTM E119 test methods. With an equivalent of 2,000 pounds per lineal foot of load placed on the log wall, the wall passed a one-hour fire endurance test and hose stream test.
- In 1995, Honkarakenne Oy (Honka Homes USA, Inc.) complied with Finish requirements by performing fire resistance testing "on a loadbearing separating wall construction" according to standard DIN 4102 (Test Report NRO RTE11134/95:E by VTT Building Technology). This test is significantly similar to ASTM Standard E-119. The tested assembly was comprised of 14 courses of nominal 6" thick logs (137mm wide x 215mm tall). The test summary is as follows:

"The tested wall construction with a width of 3000 mm and a height of 3010 mm subjected to a centric line load with an intensity of 6,1 kN/m and supported freely at the top and bottom edges met in

one test during 90-minutes the requirements of loadbearing and separating wall constructions presented in the standard DIN 4102 Part 2 Edition 1977."

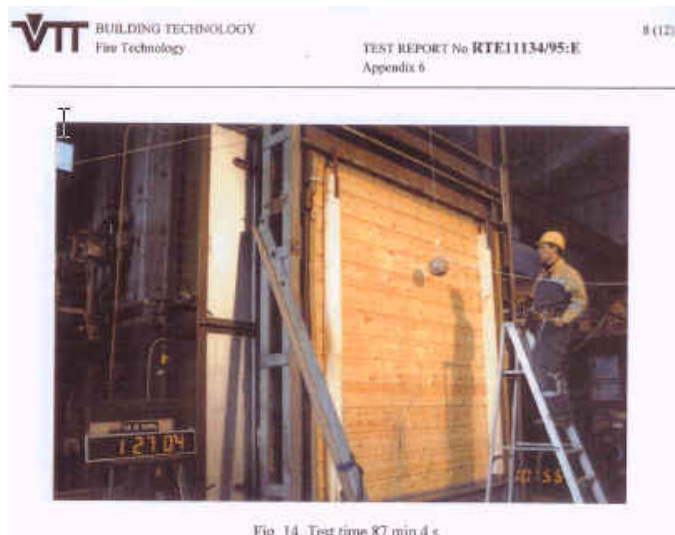
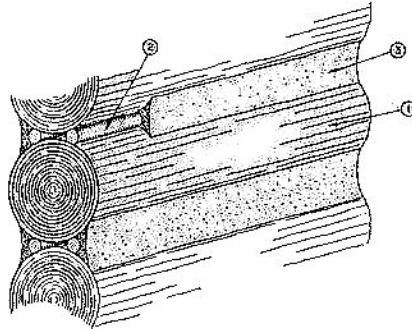


Fig. 14. Test time 87 min 4 s.

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- Sashco Sealants, Inc. performed E119 testing to establish the fire resistive rating of their backer rod and chinking system on a round log wall. The UL listing for the test is shown below.

Design No. U519
Assembly Rating—1 Hr.
Nonbearing Wall



1. **Wood Logs**—Soft wood timbers with a minimum diameter of 7.0 in. The gap between the logs shall not be greater than 2-1/2 in.
2. **Backer Rod**—Foamed polyethylene backer rod used to fill the gap between wood logs and to provide support to the chinking material. The diameter of the backing rod varies with the width of the gap between logs. The backer rod may be mechanically secured to the wood logs.
3. **Joint Treatment Material**—The chinking material is applied with a caulking gun over the backing rod and to the surface of each log adjacent to the backer rod. The minimum thickness shall be 0.5 in. The maximum width shall not exceed 4 in. The chinking material may be troweled to achieve a smooth finish and/or feather the edges.

Sashco Sealants, Inc.