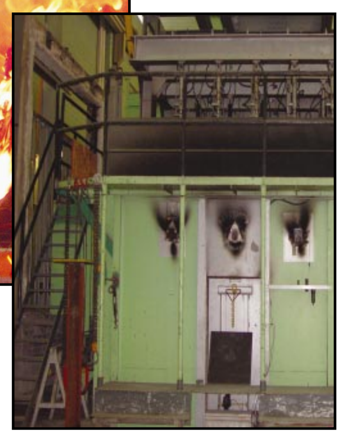
FIRE PERFORMANCE OF WOOD PRODUCTS AWARENESS GUIDE



American Wood Council

American Forest & Paper Association

FIRE PERFORMANCE OF WOOD PRODUCTS

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This publication is one in a series of eight Awareness Guides developed by the American Forest & Paper Association (AF&PA) for the fire service. This series of guides is intended to contribute to the knowledge base of developers of fire service training curriculum and publications. These guides were developed under a cooperative agreement between the Department of Homeland Security's United States Fire Administration and the American Forest & Paper Association.

Fire Performance of Wood Products

There are approximately 1.1 million firefighters in the United States who respond to approximately 2 million fire calls each year. Tragically, in 2001, seventeen fire fighter Line of Duty Deaths (LODD) occurred in residential construction[1]. An essential objective of the United States Fire Administration is to reduce firefighter fatalities[2]. Additionally, the National Fallen Firefighters Foundation's goal is to make sure "Everyone Goes Home."

The National Fire Protection Association (NFPA) has determined that less than 5% of fires originate within concealed spaces where structural wood products are located[3]. Building contents, such as furniture, cabinets, drapes, or electronic equipment, are often the first items ignited and are the primary fuel source in fires. However, when not suppressed, these fires can eventually compromise the structural system of a building and may lead to collapse. If the structure itself becomes involved in fire, the fire service must understand the nature of the structural products used as well as their fire performance characteristics, to reduce risk of death or injury.

Changing Homebuilding Industry

The homebuilding industry is changing in response to resource constraints and market demands. Notably, availability of large-diameter trees is on the decline. At the same time, homeowners are clamoring for homes with open ceilings and larger rooms. To meet this demand, a large number of new products have entered the market.

FIRE PERFORMANCE OF WOOD

Fire professionals all agree that each fire is unique. There is no fool-proof method to predict how a fire will develop in a specific room and what thermal effects will develop on the surrounding structure. However, for purposes of comparison, fire scientists have agreed upon the use of standard fire exposures, developed from data derived from many fires.

Fire intensity and rate of fire growth are influenced by the types, volume, and configuration of contents. Given the infinite possible variations, it is not possible to accurately predict how any particular fire will grow. Hence each fire scenario is unique.

Fire performance characteristics of building products are dependent on fire intensity and rate of fire growth. The following discussion on combustibility, ignition temperatures, flame spread, heat release rate, char rate, smoke, and fire endurance is presented in terms of standardized test methods, allowing comparison between materials, but is not intended to represent any specific fire scenario.

Combustibility and How Wood Burns

Wood will burn when exposed to high enough temperatures and in the presence of oxygen. Thermal degradation of wood occurs in stages. The degradation process and the exact products of thermal degradation depend upon the rate of heating as well as temperatures. This is what happens to wood in a fire:

- as the surface temperature of wood increases due to fire exposure, flammable vapors are produced and a char layer (burnt wood) is formed on the external surfaces;
- in the presence of fire, these flammable vapors ignite and contribute to the fire;
- as the char layer gets thicker, it insulates the remaining unburned wood and slows the rate of vapor production, thereby slowing the charring process.

Ignition Temperature of Materials

In the absence of an open flame, wood typically ignites at temperatures above 550°F[4, 5] depending on species, moisture content, and time of exposure to an elevated temperature. In the presence of a flame, ignition temperatures are lower.

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Flame Spread

The standard fire test used to evaluate flame spread characteristics of building materials in the United States is *ASTM E-84*, *Standard Test Method for Surface Burning Characteristics of Building Materials*[6]. To provide standard conditions for each specimen, the test is conducted in a standard dimension tunnel, calibrated to a benchmark index of zero for noncombustible materials and 100 for nominal one-inch red oak flooring.

Based on the resulting flame spread index, building materials are classified into three classes: Class A = 0 to 25; Class B = 26 to 75; and Class C = 76 to 200. Untreated wood products typically fall into either Class B or C. Fire retardant treatments, typically requiring pressure impregnation, can lower the flame spread rate of wood products to Class A. Table 1 lists the flame spread indices of several wood products. A comprehensive list is available in *Flame Spread Performance of Wood Products*[7].

Lumber, plywood, and other wood-based materials, including the components of I-joists and trusses, exhibit a relatively narrow range of flame spread. Flame spread rates for LVL, PSL, and LSL are within the same range as solid wood materials. Differences result from factors such as density, thickness, surface characteristics, and coatings or other chemicals applied. Typically, at thicknesses greater than 1/4", flame spread is almost independent of material thickness.

Table 1: Flame Spread Indices of Wood Products

Wood Material	Flame Spread Index	
Yellow Poplar Lumber	185	Class C
Doug Fir Plywood	155	
Walnut Lumber	140	
Oriented Strand Board	138	
Yellow Birch Lumber	110	
Southern Pine Plywood	110	
Maple Lumber	104	
Douglas Fir Lumber	100	
Red or White Oak Lumber	100	
Eastern White Pine Lumber	85	
Western White Pine Lumber	75	Class B
Red Cedar Lumber	73	
Redwood Lumber	70	
White Fir Lumber	65	
Fire Retardant Treated Lumber/Plywood	Less than 25	Class A

Structural glued laminated timber (glulam), laminated veneer lumber (LVL), parallel strand lumber (PSL), and laminated strand lumber (LSL) are wood products made for structural applications in a process similar to that of making plywood (for details on these products, see other Guides available in this series). These wood products react to fire much the same as comparable sizes of solid sawn lumber. Several types of adhesives may be used in the manufacture of these man-made structural products. One commonly used adhesive, phenol-formaldehyde resin, is inert once cured and does not contribute to the fire load. Accordingly, flame spread indices for glulam, LVL, PSL, and LSL are representative of the wood species from which they are manufactured.

Smoke Developed

Smoke developed (sometimes referred to as smoke obscuration) has been measured for some wood products. The index for this criterion also has an established value of 100 for red oak. None of the wood products tested exceeded 450, a limiting value commonly used in building code regulations.

Charring

Wood exposed to fire develops an insulating layer of char that further slows wood degradation (see Figure 1). The char layer contributes no strength to the remaining cross-section, but acts to insulate underlying wood from further charring, thus retarding the char rate. The structural capacity of a wood member exposed to fire depends upon its unburned-wood cross-section. Accordingly, char rate is a major factor in determination of fire endurance of wood products.

In laboratory experiments, the char rate of wood is measured by burning a test specimen for a measured time period. In the test, a wood specimen is exposed to a radiant heat source (example: electric coil heater or gas burners) for a chosen time period, then the remaining uncharred section is measured after extinguishment. Char rate is calculated by dividing the loss of wood due to char by time. A lower char rate indicates a slower burn rate.

Across all species of wood, charring begins at an approximate rate of 1.9 inches/hour for a short period of time, and then slows to about 1.4 inches/hour due to the insulating effect of the initial char layer. For calculations and estimates, the average char rate is assumed to be 1.5 inches/hour. Moisture content in wood significantly affects char rate. Other factors, such as wood density and anatomical features (grain direction, species, etc.), also affect rate of char layer formation[8].

Heat Release Rate

Another measure of how fast or "hot" a material burns is its total heat release (THR) and peak heat release rate (PHR). These measurements are useful to assess relative heat contribution of materials—thick, thin, untreated, or treated—under fire exposure. The cone calorimeter (ASTM E 1354) is the most commonly used bench-scale THR and PHR apparatus. It is an advanced test method which estimates the heat release rate based on how much oxygen is consumed during burning. This method, called the *oxygen depletion method*, provides better accuracy than the traditional method of assessing heat release rate by measuring temperature rise in the exhaust gas stream. This is because the fraction of heat released through radiant emission varies with the type of material being burned, and not all radiant energy contributes to temperature rise.

Table 2 lists THR and PHR data from the cone calorimeter for several wood products. Test specimens were exposed to an external heat flux of 75 kW/m^2, representing post-flashover conditions, for 15 minutes. Total heat released during the 15-minute test and peak heat release rate during this period is shown[9].

Table 2: Heat Release Rates from Cone Calorimeter

Material	THR (MJ/m^2)	PHR (kW/m^2)
Red Oak	139	272
Oriented Strand Board	107	331
Spruce-Pine-Fir (SPF)	109	226
Fire retardant treated plywood	56	155
Fire retardant treated lumber	48	71

Smoke Toxicity

The major chemical elements found in natural wood products are carbon, hydrogen, and oxygen. When thermally decomposed, these elements primarily produce carbon monoxide, carbon dioxide, and water. Where nitrogen or halogens are present in significant quantities, the potential for production of hydrogen cyanide and hydrogen halide exists during the burning process.

Performance of Metal Fasteners and Connectors

Steel fasteners and connectors share the following common attributes:

- they have 50% of yield strength at 1100°F[10];
- they initially reflect radiant heat under fire conditions; and,
- much of their structural capacity comes from the portions of connectors embedded in wood and somewhat insulated from the fire.

Fire Endurance

Questions often arise related to fire endurance characteristics of metal truss plates, protected fire assemblies, and heavy timber construction. It is commonly alleged that metal connector plates in trusses fail by curling away from wood due to heat in a fire. In fact, the curling occurs due to tension forces pulling on the metal connector plates. This mode of failure can be seen in tension tests on unheated, uncharred wood and in connections that have been burned (Figure 1).

Figure 1: Metal Connector Plates After Fire Test

Metal connector plates curled away from wood due to tension forces induced in the bottom chord of a truss when the butt-ends of the lumber separated as the floor sagged during a fire test.

Fire endurance is typically determined in accordance with ASTM E 119, *Standard Test Methods for Fire Tests of Building Construction Materials*, according to a standardized time-temperature curve. The test protocol requires the furnace temperature to reach 1000°F in the first five minutes and increase to 1700°F at one-hour. For structural assemblies, this test has traditionally been conducted on protected assemblies, and forms the basis of fire endurance ratings. Figures 2 and 3 show a typical floor assembly fire endurance furnace and its loading system. Figures 4 through 6 show a wood floor specimen subject to fire endurance testing. Figure 7 shows the time-temperature curve for a standard fire endurance test.

Protected assemblies are common in buildings that are required to have a fire endurance rating, such as a one or two-hour rating. Most one- and two-family residential structures do not require rated assemblies; however, there are instances when rated construction is required, such as between dwelling units, dwellings in close proximity to the property line, and between attached dwellings.

Figure 2 ASTM E 119 Test Furnace

Full-scale floor-ceiling test furnace for performing fire tests in accordance with ASTM E 119.

Figure 3 ASTM E 119 Hydraulic Cylinders

Hydraulic cylinders apply load to a floor-ceiling assembly in an ASTM E 119 test. Many furnaces use tanks of water to apply design load to an assembly.

Figure 4 Gypsum Wallboard During Fire Test

Red-hot gypsum wallboard ceiling during ASTM E 119 fire test of a wood-based floor-ceiling assembly.

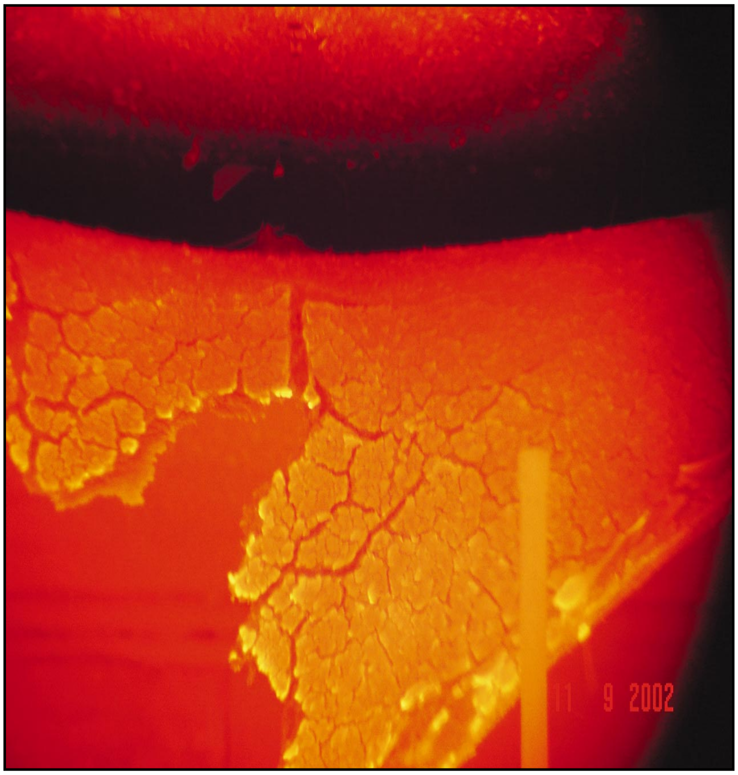


Figure 5 System Failure at End of Fire Test

System failure at the end of an ASTM E 119 test of a floor-ceiling assembly.

Figure 6: Floor-Ceiling Assembly Removal After Fire Test

Floor-ceiling assembly being removed from furnace at completion of an ASTM E 119 fire test.

Calculation Methods

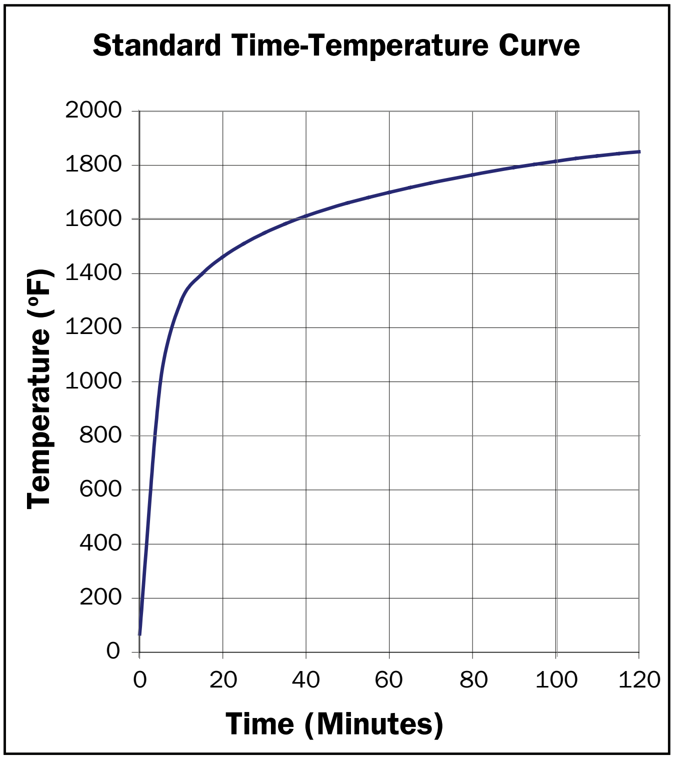
The char rate of wood is very predictable. A method has been developed that allows heavy timber trusses to be designed to achieve a calculated fire rating. The technique requires web and chord members to be oversized to allow for charring, while the underlying fiber supports the design load. Fasteners are either concealed within the timbers or protected with gypsum wallboard. More information on this technique is available in the *National Design Specification® for Wood Construction (NDS®)*[11].

Fire Movement Within Concealed Spaces

Fire can originate or extend into concealed spaces through holes in the protective membrane from recessed lights, electrical boxes, ventilation openings, and other penetrations. Protective membranes include gypsum wallboard, paneling, and dropped ceilings. Fire growth within the concealed space will vary, based on the volume of the space, air supply, and presence of firestopping. Unlike balloon-frame construction, commonly used in the past, platform construction provides inherent barriers to the spread of fire. A comparison of balloon-frame and platform-frame construction methods can be found in *Solid Sawn Lumber*, a separate guide in this series of resource guides for the fire service.

With truss construction, building codes limit the area of concealed space. Since trusses do not provide an inherent barrier, like solid lumber or I-joist webs, building codes require installation of draftstopping to limit the concealed area within floor or roof assemblies.

Figure 7 ASTM E 119 Standard Time-Temperature Curve



Example of an ASTM E 119 standardized time-temperature curve, showing fire endurance in a test of building construction materials.

Firestopping and Draftstopping

Building codes typically require firestopping in stud spaces at ceiling and floor levels to prevent the vertical spread of fire in concealed spaces. Horizontal fire-stopping is provided by requiring solid blocking of floor joists over points of support and in some cases, at partitions. Firestopping in platform construction is inherent with the way walls are framed. Continuity between the vertical stud space and horizontal truss space must be avoided. Trusses that bear directly on the top plate require no additional firestopping. If the truss is top chord bearing or a soffit is constructed, firestopping must be provided in the wall cavity.

The need for draftstopping in large concealed spaces has been recognized for many years. In residential construction, draftstopping is required at 1,000 square foot intervals when there is usable space above and below the assembly. This requirement is based on the rationale that the integrity of a floor is more critical than that of a roof. Therefore, allowable open areas should be smaller within floor spaces than in attics.

SUMMARY

In summary, firefighters must understand the dangers of any structural component exposed to direct fire, regardless of component material, especially when there are large amounts of stored items such as furniture or other items within the area. It is important to consider that all building components must be designed, installed and maintained properly in order to perform properly. In many cases, homeowners are asking for much larger spans without intermediary support of structural components.

In the residential setting, most codes do not require protection on the basement side of a structural floor. Over the years, there have been collapses involving basement fires that have led to firefighter entrapment. They have involved many different types of construction. On all incidents, it is necessary to examine the conditions present and determine if the risk of saving lives outweighs the danger in putting out the fire with an interior attack. It is recommended that tools such as a thermal imaging camera be used to examine for hidden fires or those affecting a focused area of the structural components. It is necessary for all firefighters to review buildings during construction and become familiar with different products installed in buildings today.

END NOTES

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