The aim of this project is to develop a virtual handbook of engineering-based resource materials to support fire department WUI property fire risk assessments and recommended mitigation strategies for use in the field.

In 2021, the Society of Fire Protection Engineers (SFPE) received a U.S. Department of Homeland Security Federal Emergency Management Agency Fire Prevention & Safety Grant to create a virtual handbook using engineering-based resources to support firefighters and fire departments operating in the Wildland-Urban Interface (WUI). Many WUI property fire risk assessments are based on simple checklists that don’t provide fire departments with the flexibility they need to make informed recommendations on assessment and mitigation in the field. Moreover, fire departments around the United States vary greatly in their experience of fire hazards in the WUI.

The SFPE & SFPE Foundation WUI Virtual Handbook for Property Fire Risk Assessment & Mitigation is intended to provide guidance to fire departments and fire prevention professionals. However, the recommendations and strategies contained herein should not be considered the only methods of assessing and mitigating fire risks, nor should they be interpreted as necessarily superior to other risk assessment and mitigation strategies. Therefore, SFPE and the SFPE Foundation disclaim all warranties, express and implied, including fitness for a particular purpose, and disclaim any liability arising from the use, application, or reliance on the recommendations, strategies, materials, and information contained herein by fire departments, fire professionals, and others.
About the Handbook

Project Team

About SFPE & the SFPE Foundation

The Society of Fire Protection Engineers (SFPE), located in Gaithersburg, Maryland, was established in 1950 and is the world’s leading professional society representing those practicing fire protection and fire safety engineering. SFPE has over 4,800 members and over 100 chapters worldwide, including more than 20 student chapters.

The SFPE Foundation, established in 1979, is a 501(c)(3) organization that facilitates research and educational initiatives to advance the scientific understanding of fire in the natural and built environments. With the support of external grants and individual, corporate, and SFPE chapter donations, the Foundation funds professional awards, student scholarships, and research grants; leads cross-sectoral research collaborations; conducts research workshops and meetings; develops new initiatives to support the next generation of fire protection engineers and disseminates knowledge to advance the field of fire engineering and fire safety science globally.

Project Personnel

SFPE and the SFPE Foundation led the implementation of this project by leveraging the expertise of the Society of Fire Protection Engineers’ membership— including the fire service, engineering, and insurance industries— alongside the expertise of fire departments with WUI fire property risk assessment and mitigation experience. SFPE and SFPE Foundation staff and a Project Advisory Panel provided oversight throughout the project, which was developed by a Technical Consulting team from Jensen Hughes and adapted for a web-based platform by AS Creative Services. This project was made possible with support from a US DHS FEMA FP&S 2020 grant, held by SFPE.

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- Justin Watson

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Structural Hardening
Roof Systems
Roof Construction & Covering (1.1.1)

Main Concern(s):
The main concerns associated with roof coverings are the large surface area for potentially catching embers or the roof slope (i.e., steeper roofs) for radiant exposure and direct flaming from crown fires leading to ignition. If the structure has a combustible roof covering, is not maintained in good condition, or is littered with vegetative debris, then it is far more vulnerable to ignition from wildfire. The complexity of the roof shape can also play a key role in the risk of ignition.1 Valleys, roof-to-wall intersections at split levels or dormers, joints, and other architectural embellishments on the roof can also support the collection of embers (“ember accumulation”) or vegetative debris that can lead to ignition.

Key Terminology:
+ **Roof Covering**: The exterior roof cover or skin of the roof assembly comprised of a range of materials2 (e.g., shingles, tiles, slate, metal panels, fiberglass asphalt shingles, bitumen membrane).
+ **Roof Assembly**: An assembly of interacting roof components, including the roof deck, underlayment (comprised of a range of components such as vapor retarder, insulation, insulation cover boards, wood battens), and the roof covering.3
+ **Asphalt Fiberglass Composition Shingles**: Shingles composed of a fiberglass mat with asphalt and mineral overlay.

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2 FEMA.
3 FEMA.
Roof Systems 1.1

+ **Polyvinyl Chloride (PVC) Roofing**: Thermoplastic roofing membrane typically used for buildings or structures with flat or low profiles and consisting commonly of 60 mil sheets with reinforced membranes. Seams are either hot-air heat welded, or chemical welded, and the membrane is either fully adhered, ballasted, or mechanically fastened.

+ **Thermoplastic Polyolefin (TPO) roofing**: Thermoplastic roofing membrane also used for buildings or structures with flat or low profiles. Sheets range from 40-100 mil, with reinforced or non-reinforced membranes, and installed fully adhered, mechanically fastened, or loose-laid with ballast. Seams are heat welded with hot air.

+ **Modified Bitumen (MB) Roofing**: An asphalt-based membrane designed for buildings with low-slope or "flat" roof structures. MB roofing systems typically have five layers of protection (i.e., insulation, piles, MB membranes, adhesive or waterproofing material, surfacing).

+ **Fire Retardant Treated Wood (FRTW)**: According to the IBC 2018 Chapter 2 and Section 2303.2, wood products that, when impregnated with chemicals by a pressure process or other means during manufacture, shall have, when tested in accordance with ASTM E108 or UL 790, 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. Additionally, the flame front shall not progress more than 10.5’ (3200 mm) beyond the centerline of the burners at any time during the test. FRTW must typically also be tested per weather protocols such as ASTM D2898.4

**Fire Classification & Ratings:**

The fire resistance of roof assemblies to exterior fire exposures is defined by ASTM E108 or UL 790 Standard Test Methods for Fire Tests of Roof Coverings. The test method includes measurements of the surface spread of flame, the ability of the roof assembly to resist fire penetration from the exterior of the building to the underside of the roof deck, and the potential for the roof covering to develop flying brands of burning material.5

<table>
<thead>
<tr>
<th>Roof Classification</th>
<th>Technical Description</th>
<th>Examples</th>
</tr>
</thead>
</table>
| **Class A**         | This is the highest rating for roof coverings. Roof coverings in this classification are effective against severe fire exposures, provide a high degree of fire protection to the roof deck, do not slip from position, and do not present a flying brand hazard.6 | + Clay and concrete tiles  
+ Metal panels, sheets, tiles, shingles on noncombustible decks/framing  
+ Brick or masonry  
+ Exposed concrete  
+ Most modern asphalt fiberglass composition shingles (Note: Cellulosic fiber asphalt singles, roughly pre-1980s, would not be included)  
+ Other noncombustible materials tested in accordance with ASTM E108 or UL 790  
+ (Special) Fire-retardant wood shingles or shake with an additional fire-resistant underlayment as required to pass ASTM E108/UL 790 |

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6 ASTM International.
### Roof Systems 1.1

#### Fire Test Standards:
- ASTM C1177 Standard Specification for Glass Mat Gypsum Substrate for Use as Sheathing: [https://www.astm.org/c1177_c1177m17.html](https://www.astm.org/c1177_c1177m17.html)

#### Referenced Codes and Standards:
- International Wildland Urban Interface (IWUI) Code: Section 504.2 Roof Assembly
- California Building Code (CBC): Chapter 7A, Section 705A.2 Roof Coverings
- NFPA 1140, Standard for Wildland Fire Protection: Section 25.3 Roof Design and Materials

<table>
<thead>
<tr>
<th>Class B</th>
<th>Roof coverings in this classification are effective against moderate fire test exposure, provide a moderate degree of fire protection to the roof deck, do not slip from position, and do not present a flying brand hazard.⁷</th>
<th>+ Fire-retardant shakes and shingles without the fire-resistant underlayment</th>
</tr>
</thead>
</table>
| Class C | Class C roof coverings, are effective against light fire test exposures. Under such exposures, the roof coverings afford a degree of fire protection to the roof deck, do not slip from position, and are not expected to produce flying brands.⁸ | + Aluminum roof coverings  
+ Recycled plastic/rubber roof covering |
| Non-rated | Roof coverings in this classification failed the fire test, or have not been tested at all. | + Untreated wood shakes |

**Note:** Some roof coverings rely on an underlying material, or special installation techniques, to improve their fire rating.⁹ These types of roofs are considered fire rated roof assemblies. An example of a fire rated roof assembly are fire-retardant treated wood shakes, aluminum and recycled plastic and rubber roof coverings. Examples of underlayment materials include a mineral surfaced cap sheet (formerly referred to as a Type 72 cap sheet) adequate to provide Class A membrane construction, and a fiberglass gypsum panel¹⁰ with a thickness adequate for passing the ASTM E108/UL 790 test.

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⁸ ASTM International.

⁹ University of California, Agriculture and Natural Resources, ‘Roof,’ Fire in California, accessed May 2022. [https://ucanr.edu/sites/fire/Prepare/Building/Roof/](https://ucanr.edu/sites/fire/Prepare/Building/Roof/)

¹⁰ University of California, Agriculture and Natural Resources.
**Roof Systems 1.1**

**Other Codes & Standards:**

Codes and standards will vary depending on location and adoption in individual jurisdictions.

- Check local, county, and state amendments for any additional requirements.
- Check local general plan, multi-hazard mitigation plan or zoning documents for any additional requirements.
- IRC (if applicable – check for wildfire amendments).

**Typical Design, Vulnerability & Mitigation Considerations:**

<table>
<thead>
<tr>
<th>Slope of Roof</th>
<th>Design, Vulnerability &amp; Mitigation Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Steep Slope (&gt; 3:12)</strong></td>
<td><strong>Covering</strong></td>
</tr>
<tr>
<td>Clay &amp; Concrete Tile: This material is noncombustible with a relatively high thermal mass which can limit the transfer of heat depending on the thickness, profile and installation method of the tile. Normal weight tiles have a higher thermal mass and are therefore better than lightweight tiles. Barrel shaped tiles perform better than flat or low-profile concrete/clay tiles. Where tiles are installed over wood battens, fire-retardant battens should be used to limit ignition from embers. At the eaves, hips and ridges of tile roofs, birds' nests and other debris can provide fuel hazard for embers to ignite.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-Install &quot;bird stops&quot; at roof edge and ridges.</td>
</tr>
<tr>
<td></td>
<td>As embers can be blown under steep-slope roof coverings, an enhanced underlayment such as a mineral-surface cap sheet rated for use in a Class A rated assembly should be installed. For metal shingles or panels, the metal should not bear directly on the cap sheet due to corrosion concerns.</td>
</tr>
<tr>
<td>Most homes have roof decks comprised of wood (e.g., plywood or oriented strand board). For more protection, a layer of fiberglass gypsum panelized product between the decking and the roof covering should be installed.</td>
<td></td>
</tr>
</tbody>
</table>

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### Roof Systems 1.1

**Design, Vulnerability & Mitigation Considerations**

<table>
<thead>
<tr>
<th>Slope of Roof</th>
<th>Covering</th>
<th>Underlayment</th>
<th>Decking</th>
</tr>
</thead>
</table>
| **Steep Slope (> 3:12) cont.** | **Metal Shingles & Panels:** While these materials are noncombustible, they have relatively high thermal conductivity which means heat from embers or direct flaming can transfer readily to the roof substrate. Thus, where metal shingles/panels are installed over wood battens, fire-retardant battens should be used. When metal shingles or panels are installed over wood decking, minimum 5/8” Type X gypsum roof board per ASTM C 1177 should be installed over the decking (1/2” or 1/4” thickness boards are not type X).  

**Fiberglass-Reinforced Asphalt Shingles:** While asphalt shingles can be rated as Class A roofing, this material still contains asphalt, a combustible material.  

**Wood Shingles & Shakes:** While this material is combustible, some wood shingle or shake roofs can be Class A rated they are fire retardant treated and pressure impregnated, and an approved underlayment that imparts adequate fire resistance to the assembly is installed. Without an underlayment the maximum rating is Class B. |

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## Roof Systems 1.1

### Slope of Roof

<table>
<thead>
<tr>
<th>Slope of Roof</th>
<th>Design, Vulnerability and Mitigation Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Slope (&lt; 3:12)</td>
<td><strong>Covering</strong>&lt;br&gt;Many low-sloped roofs have Class A roof covering options. See table (in Section 1.1.1.3) for various options.&lt;br&gt;As low-sloped roofs may not have attic space providing insulative properties, various roof assemblies and insulative build-ups will likely be encountered. In this case, the construction of the entire roof assembly and not just the rating of the roof covering is essential to ensure resistance to wildfire exposures.</td>
</tr>
</tbody>
</table>

### Mitigation Strategies:

- + Replace any damaged, broken or missing pieces or sections.
- + Remove litter and other vegetation debris on roof annually before core fire season.
- + For tile roofs, bird-stop or mortar open ends of tiles at the roof eaves, roof edge, hips and ridges to reduce vulnerability to ember ignition.
- + Replace roof with Class A rated roofing material. Note: Class A covering alone is not enough, the entire roof system should be considered to include underlayment and any other components that impact wildfire vulnerability.
- + Refer to Typical Design, Vulnerability & Mitigation Considerations for additional mitigation options.
- + For tile roofs, install metal flashing under tiles at roof valleys. For profiled tile, lead or flexible flashing should be installed (as recommended by the manufacturer).
- + Replace roof coverings before significant deterioration due to exposure to weathering.

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Training Programs:
+ NFPA – Assessing Structure Ignition Potential from Wildfire

Gaps in Knowledge:
+ Fire testing does not account for weathering of materials prior to fire exposure.
+ ASTM E108 is an exterior fire exposure based on a piloted ignition scenario. This may not be reflective of anticipated fire exposures for wildfire conditions (e.g., embers, large radiative exposure from wildfire flaming, direct flame impingement, heat release rates characteristic of wildfires).
+ Test conditions are often less severe than actual wildfire exposure.
+ In some cases, it may be challenging to verify in-the-field if a roof covering is rated to Class A, B or C. (Professional judgement required.)

Other References:
+ IBHS Ember Testing: https://ibhs.org/wildfire/building-vulnerability-to-ember-exposure/
+ University of California, Agriculture and Natural Resources: https://ucanr.edu/sites/fire/Prepare/Building/Roof/
Chimneys & Roof Vents (1.1.2)

Main Concern(s):
The intrusion of embers through roof vents and chimneys is a major source of vulnerability that can lead to structure ignition during wildfires. The main concern with roof vents and chimneys is that they can provide several openings where windborne embers, convective heat, and radiant heat from wildfires can be blown in or pulled into the structure leading to ignition of interior building contents and other building components. In addition, chimneys can also be a source of embers from fireplaces leading to ignition of vegetation outside. Both inlet and outlet vents are sources of vulnerability, as fire behavior can create reverse flows due to over-pressures that can drive embers and hot gases into a building interior (e.g., attic, crawl space, basements). Debris can also accumulate at vent openings, chimney openings, and around the chimney chase, providing a source of combustible fuels for ignition.

Key Terminology:

+ **Chimney**: A primarily vertical structure containing one or more flues, for the purpose of carrying gaseous products of combustion and air from a fuel-burning appliance to the outdoor atmosphere.\(^{21}\)
+ **Gas Fireplace Chimney**: A vertical or horizontal vent designed to release hot air from the gas burning fireplace to the outdoor atmosphere.
+ **Ember**: Small burning or glowing pieces of vegetation or other cellulosic-based material.

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Key Terminology cont.: 

+ **Gable-end Vent**: A vent located in the gable-end wall, just below the roof ridge to allow flow into and out of attics. Gable-end vents normally have louver blades. This type of vent is commonly metal and normally has an insect screen.  

+ **Hip Vent and Ridge Vents**: A continuous vent installed along the full length of the hip or ridge of a roof, with the air slots underneath the hip or ridge vents located only at the top portion of the hip or ridge. These vents are typically comprised of metal or plastic and may have internal or external baffle media to minimize the entrance of wind-driven rain or snow.  

+ **Mechanical Exhaust Vents (e.g., Whirly, Wind Turbines)** – Cylindrical dome-shaped vents that sit on the roof of a building and spin in the wind, creating a vacuum that extracts warm air and moisture from the attic. Turbines sit higher above the roof surface, so they stand out more than other exhaust options, but they move air effectively. When there’s no wind, their function is similar to that of a static exhaust vent.  

+ **Powered Exhaust Vent**: These types of vents are powered by electric, solar or a combination of both and are either roof-mounted or gable-mounted. Powered vents typically include thermostat control to provide optimum airflow rating.  

+ **Spark Arrestor Cap**: A metal assembly at the top of the chimney that prevents embers from leaving the chimney while also preventing embers from entering the chimney in the event of a wildfire.  

+ **Through-Roof Vent**: A vent that penetrates the roof to allow exfiltration of attic air or connection to an HVAC system. They can also be known as a dormer or eyebrow vent. These types of vents are typically comprised of metal, plastic or rigid fiberglass.  

+ **Vent**: A device or assembly placed in an exterior opening of a building that allows for aeration.

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Fire Classification & Ratings:
Currently there isn’t an accepted procedure to evaluate ember intrusion and direct flame impingement of ridge vents. The ember and direct flame impingement resistance of gable end and other vent mounted on vertical walls is defined by ASTM E2886 Standard Test Method for Evaluating the Ability of Exterior Vents to Resist the Entry of Embers and Direct Flame Impingement. This test standard prescribes two individual methods to evaluate the ability of the vent opening to resist embers and flame. The ability of such vents to completely exclude entry of flames or embers is not evaluated. Roof ridge and off-ridge (field) vents are excluded from this standard. Acceptance criteria are not provided in this standard. However, performance criteria are specified in the California Building Code (CBC) Section 706A.2 and NFPA 1144 Section 5.3.3.

<table>
<thead>
<tr>
<th>Vent Fire Test</th>
<th>Technical Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ember Penetration Test</td>
<td>This test method provides for a direct ember exposure to vents. The apparatus allows for embers to fall vertically and impinge on the vent mounted horizontally on ledges within the test chamber. An induction fan located at the bottom of the apparatus pulls the air stream through the vent, allowing any embers that pass through the vent to impinge on a combustible target material of cotton. [CBC and NFPA 1144 requirements – No flaming ignition of the cotton material, and maximum temperature of the unexposed side of the vent shall not exceed 662°F or 350°C.]</td>
</tr>
<tr>
<td>Direct Flame Impingement Test</td>
<td>This test method provides for the evaluation of direct flame impingement on a vent mounted in a test assembly as described in Test Method ASTM E2912. The flame source is directed into the test assembly and directly impinges the vent that is mounted in either a vertical or horizontal position. [CBC and NFPA 1144 requirements – No flaming ignition and maximum temperature of the unexposed side of the vent shall not exceed 662°F or 350°C.]</td>
</tr>
</tbody>
</table>

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#### Vent Fire Test

<table>
<thead>
<tr>
<th>Non-Mechanical Fire Dampers Used in Vented Construction</th>
<th>Technical Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>This fire-test-response standard assesses the ability of non-mechanical fire dampers used in vented construction in its open state to limit passage of hot gases, radiation, and flames during a prescribed fire test exposure. The fire exposure condition in this test method is sudden direct flame impingement, which produces these hot gases, radiation, and flames.</td>
<td></td>
</tr>
<tr>
<td>This test method does not circumvent or eliminate the fire-resistance rating requirements for construction.</td>
<td></td>
</tr>
</tbody>
</table>

**Note:** Vents that have been included in a roof covering assembly tested per ASTM E108 to achieve a Class A rating have only been tested for whether they contribute to flame spread, failure/detachment from the roof or production of embers. ASTM E108 does not assess if a vent can resist the penetration of embers or direct flames from wildfires. Factory-built chimneys and fireplaces should be fire-blocked in accordance with UL 103 and UL 127.

#### Fire Test Standards:

- **ASTM E2886/E2886M-14 Standard Test Method for Evaluating the ability of Exterior Vents to Resist the Entry of Embers and Direct Flame Impingement:** [https://www.astm.org/2886_e2886m-20.html](https://www.astm.org/2886_e2886m-20.html)
- **ASTM E2912 Standard Test Method for Fire Test of Non-Mechanical Fire Dampers Used in Vented Construction:** [https://www.astm.org/e2912-17.htm](https://www.astm.org/e2912-17.htm)

#### Referenced Building Codes & Standards:

- **International Wildland Urban Interface (IWUI) Code:** 504.10 Vents, 605 Spark Arresters
- **California Building Code (CBC):** 706A Vents, 718.2.5.1 Factory-Built Chimneys
- **NFPA 1144 Standard for Reducing Structure Ignition Hazards from Wildland Fire:** 5.3.3 Vent Assemblies, 5.8 Chimneys and Flues
- **UL 103 Standard for Safety Factory-Built Chimneys**
- **UL 127 Standard for Safety Factory-Built Fireplaces**

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Roof Systems 1.1

Other Codes & Standards:

Codes and standards will vary depending on location and adoption in individual jurisdictions.

+ Check local, county, and state amendments for additional wildfire codes and standards.
+ Check local general plan, multi-hazard mitigation plan, or zoning documents for any additional requirements.
+ IRC (if applicable – check for wildfire amendments).

Typical Design, Vulnerability, & Mitigation Considerations:

<table>
<thead>
<tr>
<th>Component Type</th>
<th>Design, &amp; Construction Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chimney</td>
<td>There are two main types of chimneys: masonry chimneys (stone and mortar, brick or block construction) and prefabricated metal chimneys. Chimneys lining materials include metal, cast cement or clay tiles. Chimneys should be covered and screened using a spark arrestor cap to prevent embers and hot gases from entering the chimney opening. Chimneys should be capped with a solid metal covering if they include gas furnaces with integrated flues. Chimneys that are provided with a spark arrestor cap or covering in conjunction with noncombustible interior construction are a low risk for interior ignition based on wildfire exposure. Chimney chase cladding has the potential to experience vulnerabilities due to debris building up around the chase.</td>
</tr>
<tr>
<td>Gas Fireplace Vent</td>
<td>Gas fireplaces use vertical or horizontal vents to release hot gasses and other products of combustion to the outside atmosphere. Gas fireplaces by their nature do not pose a threat to wildfire ignition as there are no solid burning fuels to emit embers to the outside. These vents also pose little threat to ignition of the structure through ember penetration as the fireplace is constructed of noncombustible materials and designed to withstand high temperatures. 1/8” wire mesh screen can be provided on these vents to provide an additional level of protection.</td>
</tr>
</tbody>
</table>
## Roof Vent Type

### Ridge

Typical ridge vents are not highly fire-resistant. Ridge vents are nominal outlet vents. Most commercially available ridge vents are made of plastic materials. The greatest vulnerability to these vents is ember ignition of vegetative debris that can accumulate at the inlet of the vent, and the exposure to or entry of flames should nearby combustible materials be ignited by embers. Windblown vegetative debris must be removed from the inlet of all ridge vents. Embers can enter the attic through unbaffled ridge vents. Even baffled ridge vents provide limited effectiveness as typical baffle media can melt.29

One option for mitigation for ember intrusion for existing ridge vents is to provide screening with openings no larger than 1/16". The exposure to flames will not be mitigated by the screening. The ends of all roof vents must be closed with solid end pieces. The most effective strategy is the use of noncombustible ridge vents that incorporate an external baffle. When roof coverings have a profile, an off ridge through-roof vent is the best option.

### Through-Roof

Through-roof vents are constructed of metal, plastic, or rigid fiberglass. These vents may include a downturned end (gooseneck) to prevent water infiltration. Through-roof vents can allow passage of embers and hot air/gases. Where used, through-roof vents should be screened where possible or include steel wool infill, which has been shown to be effective at minimizing ember entry into the attic space. Where necessary to penetrate the roof, install a fire damper in the duct at the plane of the roof assembly.30

### Gable-End

Gable-end vents allow air to flow into and out of attics and are often used in conjunction with soffit vents. Under-eave vents are nominal inlet vents. Gable-end vents are nominal outlet vents. Gable-end vents are typically constructed of metal and include insect screening. Insect screening is not typically fine enough to limit the intrusion of embers. Wire metal mesh of a maximum 1/8" (preferably 1/16") may need to be installed in lieu of the insect screening to limit ember intrusion. Alternatively, shutters can be installed over gable-end vents during wildfire threat; they should include a gasket to provide a tight seal between the shutter and vent. Gable-end vents are arguably the most vulnerable vent due to their surface area and their location on a vertical exterior wall for potential entry of embers.

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## Roof Systems 1.1

### Roof Vent Type

<table>
<thead>
<tr>
<th>Roof Vent Type</th>
<th>Design &amp; Construction Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whirlybird or Wind Turbines</td>
<td>These vent types are typically constructed of metal and can oftentimes present an avenue for embers to enter the attic space unless protected with a woven mesh guard (i.e., max 1/8&quot; mesh metal screening, stapled to the underside of the roof sheathing in the vent opening area). Turbine vents are very effective at minimizing the entry of embers when they are in good condition and the wind is blowing to better keep the vent spinning while keeping embers out of the attic. At low wind speeds, embers can pass through one side of the vent and drop into the attic because there is not enough momentum to pass through to the opposite side of the vent.</td>
</tr>
<tr>
<td>Unventilated Attics</td>
<td>Unventilated attics are the most conservative approach to preventing embers and hot gases from entering the attic. Unventilated attics are controversial and may not comply with local building codes. When unventilated attics are allowed by the building code or code compliance is not an issue, and when climatic and interior humidity conditions are conducive to an unventilated design, an unventilated attic is a reliable way to prevent embers and hot gases from entering the attic.</td>
</tr>
</tbody>
</table>

### Mitigation Strategies:

+ Debris should be removed from around vents and chimney chases periodically.
  - Wind-blown vegetative debris must be removed from the inlet of all ridge and off-ridge vents, paying particular attention to vents with plastic components. Plastic components are commonly used in ridge vents.²
+ Provide ember resistant vents protected with wire mesh with openings no larger than 1/8", preferably 1/16".
  - Common ¼" screens are ineffective and should be replaced.³³
  - Do not use fiberglass or plastic mesh because they can melt and burn.³⁴

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³³ Fire Safe Marin.
³⁴ Fire Safe Marin.
Roof Systems 1.1

+ Provide spark arrester cap on all chimneys
  - Chimneys serving fireplaces, barbecues, incinerators, or decorative heating appliances in which solid or liquid fuel is used, should be provided with a spark arrester.  
  - Spark arrestors are required to be constructed of woven or welded wire screening of 12 USA standard gauge wire having openings not exceeding 1/2".
+ Avoid using non-wildfire-resistant off-ridge and ridge vents. Of the ridge and off-ridge outlet vent options, the following performed well:
  - Miami-Dade wind-driven-rain-compliant ridge vent
  - Wildfire-resistant off-ridge vent
  - Turbine (off-ridge) vent with screening attached to the roof sheathing
+ Replace non-metal roof vents with corrosion-resistant, metal vents and vent flashing.
+ Ensure turbines are capable of spinning freely to prevent ember intrusion.
+ Specify and install vent openings with a maximum net free area of 144 sq. in.
+ Place all vent openings at least 10' from other buildings or property lines to avoid ignition from embers and hot gases from an adjacent building that has ignited.
+ Refer to Typical Design, Vulnerability, & Mitigation Considerations for additional mitigation options.
+ Ember and flame-resistant vents have been developed. Vents that comply with the provisions of the California Building Code can be found on the California Office of the State Fire Marshal, Building Materials Listing Program website.

Training Programs:

+ NFPA – Assessing Structure Ignition Potential from Wildfire

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36 International Code Council, Inc.
39 FEMA.
Gaps in Knowledge:

- Fire testing does not account for weathering of materials prior to fire exposure or the impact of general wildfire environmental conditions (e.g., high winds, flying debris, impact from objects).
- ASTM E2886 does not evaluate the ability of vents to completely exclude entry of flames or embers.
- ASTM E2886 does not include roof ridge and off-ridge (field) vents, however, the functional parts of some approved vents have been installed in dormer-style off-ridge vents, and should perform as well in this location as others.
- Most ASTM standards do not provide acceptance criteria. Where information is needed for the Authority Having Jurisdiction (AHJ), review the report section of the standard where the authors of the standard typically provide key information. Also, review information in the Appendix as this can provide information helpful for determining “acceptance criteria.”
- In most instances, it’s challenging to verify in-the-field if a vent has been fire-tested. (Professional judgement and discussion with the homeowner are required.)
- Air flow calculations may need to be reconsidered or redesigned where fire rated vents are installed in existing structures, to ensure sufficient airflow is still satisfied for non-fire purposes.
- There is no accepted procedure to evaluate ember intrusion and direct flame impingement of ridge vents.

Other References:

- IBHS Ember Testing:
  - https://ibhs.org/wildfire/building-vulnerability-to-ember-exposure/
  - https://www.facebook.com/watch/?v=389602881106017
- University of California: https://ucanr.edu/sites/fire/Prepare/Building/Vents
Joints (Chimney-Roof, Ridges & Valleys, Skylights, etc.) (1.1.3)

Main Concern(s):
In general, joints create gaps in the continuity of a fire rated or fire resistive roof assembly and present a potential avenue for embers, hot gases, or flame to breach the exterior envelope of a rated roof. Joints can also create places for the accumulation of combustible debris that can be easily ignited by embers, hot gases, or direct flaming. Embers can oftentimes accumulate at roof joints, creating a concentrated source of heat. In addition, there is currently no fire test for roof joints to wildfire exposure – embers, direct flaming, or hot gases. This can create a short-circuit of a Class A rated roof assembly. Some joints may not be visible (e.g., between panel joints on the roof deck), therefore making it difficult to verify if appropriate joint protection is provided. However, where joints are visible, it is important to verify that flashing and joint protection are in good condition.
Key Terminology:

+ **Joint**: The opening in or between adjacent assemblies that is created due to building tolerances or is designed to allow independent movement of the building in any plane caused by thermal, seismic, wind, or any other loading.  

+ **Fire-Resistant Joint System**: An assemblage of specific materials or products that are designed, tested, and fire-resistance rated in accordance with a standard fire test to resist for a prescribed period of time the passage of fire through joints made in or between fire-resistance-rated assemblies.  

(Note: There are currently no fire-resistant joint system tests for wildfire exposures.)

+ **Roof Ridge**: The roof ridge, or ridge of a roof, is the horizontal line running the length of the roof where the two roof planes meet. This intersection creates the highest point on a roof, sometimes referred to as the peak.

+ **Flashing**: A thin metal that is installed at joints to protect against intrusion of unwanted elements such as water and embers.

+ **Roof Valley**: A roof valley is formed where two roof slopes or planes meet. A valley occurs where two roof planes intersect. Valleys are places where leaves and needles often accumulate and where embers can land.

+ **Expansion Joint**: A physical discontinuity that spans the entire breadth of an element in a building, creating two separate sections of the element instead of one bigger one. They are designed and configured to allow the different building sections to move independently of each other, so the structures don’t become overstressed and crack or break under various loads (e.g., thermal expansion/contraction, moisture-related dimensional change, seismic movement).

Fire Classification & Ratings:

Currently, there is no fire test standard to evaluate ember intrusion, direct flame impingement or thermal transmission of heat via convection, or radiation from wildfires for joint systems (roof joints or otherwise). Fire rated joints are necessary in order to maintain a roof system’s fire rating, integrity, and continuity to wildfire exposure. While a variety of fire tests exist for joints in interior building fire exposures (e.g., ASTM E1966 or UL 2079), none are applicable to the fire conditions presented by wildfires. A range of joint systems (e.g., static joints, movement joints) and joint conditions (e.g., chimney-to-roof, vent-to-roof, skylight-to-roof, roof panel-to-roof panel, edge-of-roof joint, roof expansion joints) for exterior wildfire exposures are still needed.

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41 International Firestop Council.


43 University of California, Agriculture and Natural Resources, “Roof,” Fire in California, accessed May 2022, [https://ucanr.edu/sites/fire/Prepare/Building/Roof](https://ucanr.edu/sites/fire/Prepare/Building/Roof)

Roof Systems 1.1

Fire Test Standards:
Currently, there is no fire test standard to evaluate ember intrusion, direct flame impingement or thermal transmission of heat via convection, or radiation from wildfires for joint systems (roof joints or otherwise).

Referenced Codes & Standards:
+ International Wildland Urban Interface (IWUI) Code: No explicit requirements
+ California Building Code (CBC): No explicit requirements
+ NFPA 1144 Standard for Reducing Structure Ignition Hazards from Wildland Fire: No explicit requirements

Flashing detail at chimney-to-roof joint.

Headwall flashing details. Image courtesy of InterNACHI.
Other Codes & Standards:

Codes and standards will vary depending on location and adoption in individual jurisdictions.
+ Check local, county, and state amendments for additional wildfire codes and standards.
+ Check local general plan, multi-hazard mitigation plan, or zoning documents for any additional requirements.
+ IRC (if applicable – check for wildfire amendments).

Typical Design, Vulnerability, & Mitigation Considerations:

<table>
<thead>
<tr>
<th>Joint Types at Roof</th>
<th>Design, Vulnerability, &amp; Mitigation Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roof Expansion Joint</td>
<td>An expansion joint at the roof is typically provided with a cover. The joint allows the roof membrane to expand and contract in sync with the roof deck, without compromising the roof system. Roof expansion joint covers are specifically designed to prevent air or water from entering the building through the roof; they usually extend all the way from one side of the roof to the other. Expansion joints accommodate the thermal expansion and contraction of building materials due to changes in the ambient temperature (think about a potential 50-degree change in temperature between night and day and how much thermal expansion that would cause). There are numerous types of details and systems to accommodate this movement (whether vertical or horizontal). The materials used at the expansion joint can consist of a range of combustible and noncombustible materials (e.g., foam, neoprene, sealant). If the materials are combustible or have metal flashing without sufficient, noncombustible thermal insulation, they can present a vulnerability in the roof for embers, hot gases, or flaming to enter. Note: Some expansion joints may not be visible, therefore making it difficult to verify if appropriate joint protection is provided. However, where joints are visible, it is important to verify that flashing and joint protection are in good condition.</td>
</tr>
</tbody>
</table>

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44 Roof Online Staff.
## Valley Joints

To increase the resistance of the valley to heat and flames there are a few important installation considerations. If metal valley flashing is used, an underlying mineral surfaced cap sheet must be incorporated into the assembly. With Class A asphalt composition shingles, use of metal flashing can be avoided by interweaving the shingles. A cut valley could also be used. 47

## Roof-to-Wall Joint

The more intersections and shapes included in the roof design, the more opportunity there will be for leaf, needle and other vegetative debris to accumulate. Flame exposure to siding at roof-to-wall intersections can occur if vegetative debris is ignited by embers. If the siding is installed close to the roof, the siding could be ignited directly by embers (i.e., without initial ignition of vegetative debris). 48

## Dormers & Chimney-to-Roof Joints

Dormers and other exposed siding can be reinforced with an underlayment of a fire rated gypsum product to increase the resistance of the siding to the penetration of flames. Referred to as Type X, many of the gypsum board manufacturers produce a product that can be used in this application. When a combustible siding product is used, a corrosion resistant metal flashing can be used at roof-to-wall intersections to improve the resistance of siding to ignition from embers that can accumulate at these locations. Installation details are important to avoid moisture related degradation that could occur should water get behind the flashing. 49

## Vent-to-Roof Joint

Debris accumulation can occur at the vent-to-roof interface and needs to be cleaned to minimize potential for ignition. Where existing vents are of combustible construction, metal flashing should be used to protect the vent-to-roof interface. Seal gaps and penetrations around vents with fire-resistant caulks, noncombustible mortar, or fire rated expanding foam.

## Skylight-to-Roof Joint

Debris can also accumulate at the edge of skylights. If that debris were to ignite, then the materials and connections at the roof-to-skylight intersection could be vulnerable. If metal valley flashing is used, an underlying mineral surfaced cap sheet must be incorporated into the assembly. 50

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47 University of California, Agriculture and Natural Resources, “Roof,” Fire in California, accessed May 2022, [https://ucanr.edu/sites/fire/Prepare/Building/Roof/](https://ucanr.edu/sites/fire/Prepare/Building/Roof/)

48 University of California, Agriculture and Natural Resources.

49 University of California, Agriculture and Natural Resources.

50 Division of Agriculture and Natural Resources, University of California, “Skylights,” Homeowner’s Wildfire Mitigation Guide, accessed April 2022, [https://ucanr.edu/sites/Wildfire/Roof/Skylights/](https://ucanr.edu/sites/Wildfire/Roof/Skylights/)
Mitigation Strategies:
+ Debris should be removed from around all joints created at the roof (e.g., expansion joints, vents/chimney-to-roof joints).
+ Noncombustible materials (e.g., mineral) in lieu of combustible materials should be provided to fill expansion joints.
+ Fire-resistant sealants should be provided in lieu of non-fire rated caulking.
+ Metal flashing should be installed at vent-, chimney-, and skylight-roof joints to limit ember penetration or direct flame infiltrating the roof substrate. Where the roof underlayment is combustible, refer to appropriate protection measures in the roof construction/covering section for detailing.
+ Refer to Typical Design, Vulnerability & Mitigation Considerations for additional mitigation options.

Training:
+ NFPA – Assessing Structure Ignition Potential from Wildfire

Gaps in Knowledge:
+ Currently, there is no fire test standard to evaluate ember intrusion, direct flame impingement or thermal transmission of heat via convection, or radiation from wildfires for joint systems (roof joints or otherwise).
+ It is unclear how susceptible various roof joints are to wildfire exposures.

Other References:
+ University of California, Agriculture and Natural Resources: [https://ucanr.edu/sites/fire/Prepare/Building/Roof/](https://ucanr.edu/sites/fire/Prepare/Building/Roof/)
+ General Roof Expansion Joint References
  + National Research Council Canada (NRC) – Built-Up Roof Joints: [https://nrc-publications.canada.ca/eng/view/fr/?id=ccde0331-086c-41a9-8fff-7b82e29f8144](https://nrc-publications.canada.ca/eng/view/fr/?id=ccde0331-086c-41a9-8fff-7b82e29f8144)
  + Copper Development Association – Roof-to-Wall: [https://www.copper.org/applications/architecture/arch_dtb/archdetails/building_expansion/roof_edges.html](https://www.copper.org/applications/architecture/arch_dtb/archdetails/building_expansion/roof_edges.html)
Roof Edge (1.1.4)

Main Concern(s):
The roof edge is a portion of a structure that is highly vulnerable to wildfires and other sources of ignition. As gutters are typically located at the roof edge, a debris filled rain gutter can present a fuel source where embers can collect during a wildfire, creating an ignition source near the roof edge. Gaps between the roof covering and underlayment at the roof edge can create a source of weakness for embers to enter the structure. Roof edges can also be exposed to direct flame impingement and high temperatures where surrounding vegetation is in proximity or directly touching the roof edge.

Key Terminology:
+ **Metal Drip Edge**: Metal flashing installed at the edge of the roof designed to keep water or embers away from the fascia board.
+ **Fascia or Gutter Boards**: Vertical roof trim located along the perimeter of a building, usually below the roof level, to cover the rafter tails at the eaves and to seal off the top of the siding along the rake.\(^1\)

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Roof Systems 1.1

Fire Rated Assemblies:
Currently, there are no fire rated assemblies for roof edge detailing.

Fire Test Standards:
Currently, there is no fire test standard to evaluate ember intrusion, direct flame impingement or thermal transmission of heat via convection or radiation from wildfires to roof joints such as the roof edge.

Referenced Codes & Standards:
+ International Wildland Urban Interface (IWUI) Code: No explicit requirements
+ California Building Code (CBC): No explicit requirements
+ NFPA 1144 Standard for Reducing Structure Ignition Hazards from Wildland Fire: 5.3.7 Roof Design and Materials

Other Codes & Standards:
Codes and standards will vary depending on location and adoption in individual jurisdictions.
+ Check local, county, and state amendments for additional wildfire codes and standards.
+ Check local general plan, multi-hazard mitigation plan, or zoning documents for any additional requirements.
+ IRC (if applicable – check for wildfire amendments).

Typical Design, Vulnerability, & Mitigation Considerations:

<table>
<thead>
<tr>
<th>Types of Roof Edges</th>
<th>Design, Vulnerability, &amp; Construction Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Profile Filed</td>
<td>Provide bird-stop or mortar at open ends of tiles at roof edges. Refer to the roof construction section (1.1.1) for additional considerations.</td>
</tr>
<tr>
<td>Flat Tiled</td>
<td>Metal flashing at the roof edge provides additional protection. Refer to the roof construction section (1.1.1) for additional considerations.</td>
</tr>
<tr>
<td>Pressure Impregnated, FRT</td>
<td>Metal flashing at the roof edge provides additional protection. Specific underlayment should be installed to maximize fire-resistance, which should be continuous to the roof edge. Refer to the roof construction section (1.1.1) for additional considerations.</td>
</tr>
<tr>
<td>Wood Shake or Shingled</td>
<td></td>
</tr>
</tbody>
</table>
Roof Systems 1.1

<table>
<thead>
<tr>
<th>Metal Panel or Shingle</th>
<th>Specific underlayment should be installed to maximize fire-resistance, which should be continuous to the roof edge. Refer to the roof construction section (1.1.1) for additional considerations.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fiberglass Asphalt</td>
<td>Asphalt is a combustible material. Metal flashing at the roof edge provides additional protection. Where 5/8&quot; gypsum roof board has been provided for the roof, this layer should be continuous to the roof edge. Refer to the roof construction section (1.1.1) for additional considerations.</td>
</tr>
</tbody>
</table>

Mitigation Strategies:
+ Install a metal drip edge or flashing to seal off the roof edge to minimize ember entry to the attic via materials burning in a rain gutter or wind-blown embers impinging on the area at the edge of the roof.52
+ Replace any damaged, broken or missing pieces or sections of roof at the roof edge.
+ Remove litter and other vegetation debris at the roof edge and in gutters annually before core fire season.
+ For profiled tile roofs, bird-stop or mortar open ends of tiles at the roof edges to reduce vulnerability to ember ignition.
+ For tile roofs, install metal flashing under tiles at roof edge. For profiled tile, lead or flexible flashing can be installed (as recommended by the manufacturer).53 Where underlayment is combustible provide an additional fire-resistant underlayment between the roof covering and underlayment.
+ Replace roof coverings and underlayment at roof edge before significant deterioration with age and exposure to weathering.
+ Trim back vegetation touching, overhanging or in close proximity to the roof edge.
+ Refer to Typical Design, Vulnerability, & Mitigation Considerations for additional mitigation options.

Training:
+ NFPA – Assessing Structure Ignition Potential from Wildfire

52 University of California, Agriculture and Natural Resources, “Roof,” Fire in California, accessed May 2022, https://ucanr.edu/sites/fire/Prepare/Building/Roof/
Roof Systems 1.1

Gaps in Knowledge:
+ Currently, there is no fire test standard to evaluate ember intrusion, direct flame impingement or thermal transmission of heat via convection or radiation from wildfires at the roof edge. The roof edge includes the underlayment, sheathing, fascia, and gutter and how these systems interact.

+ As there are no fire testing standards for roof edges, it is unclear how weathering of materials prior to fire exposure or the impact of general wildfire environmental conditions (e.g., high winds, flying debris, impact from objects) will impact performance over time.

Other References:
+ University of California, Agriculture and Natural Resources: [https://ucanr.edu/sites/fire/Prepare/Building/Roof/](https://ucanr.edu/sites/fire/Prepare/Building/Roof/)
Gutters (1.1.5)

Main Concern(s):
Combustible debris such as leaves and pine needles can accumulate in gutters, especially from nearby or overhanging trees. Due to difficulty in accessing upper stories of a home, gutters two and three floors high are even more problematic since they will be difficult to clean out on a regular basis. If ignited, combustible debris in the gutter will expose the edge of the roof covering, typically the fascia and or roof sheathing. Depending on the condition of the wood and presence (or absence) of metal flashing at the edge of the roof, debris in the gutter may make it easier for fire to enter the attic. In addition, the material of the gutter is a concern. Many gutters are constructed of plastic. Plastic gutters are typically composed of polyvinyl chloride (PVC) and can melt and fall to the ground. While PVC will self-extinguish once the debris around and in it burns out (the chlorine acts as a fire retardant), the fact that the gutter may contain burning debris as it collapses creates another mechanism for spread fire along the façade of the building or to combustible fuel beds below.

Debris in gutters can ignite and lead to ignition of the roof or fascia board.


Roof Systems 1.1

Key Terminology:

+ **Gutters**: A shallow trough fixed beneath the edge of a roof to catch and direct rainwater.
+ **Fascia or Gutter Boards**: Vertical roof trim located along the perimeter of a building, usually below the roof level, to cover the rafter tails at the eaves and to seal off the top of the siding along the rake. 
+ **Gutter Guard**: Gutter guard is a generic term used to describe anything that goes over gutters to limit the accumulation of vegetative debris [e.g., leaves, needles, twigs] in the gutter. There are a range of gutter guards including brush inserts, foam inserts, DIY screen, micro-mesh, hood, etc. Gutter guards can be combustible or noncombustible. Noncombustible options should be used.

Fire Rated Assemblies:

Currently, there isn’t an accepted procedure to evaluate the fire performance of gutters to ember exposure, radiant heat, convective heat, or direct flame impingement due to wildfires. Therefore, there are no fire rated assemblies.

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Roof Systems 1.1

Fire Test Standards:
Currently, there is no fire test standard to evaluate ember exposure, direct flame impingement, or thermal transmission of heat via convection or radiation from wildfires to evaluate the effectiveness of gutter covers and gutter cover devices.

Referenced Codes and Standards:
+ 2021 International Wildland Urban Interface (IWUI) Code: Section 505.4 Gutters and Downspouts
+ 2021 International Building Code: Section 1502.4 Gutters
+ 2019 California Building Code (CBC): Section 1502.4 Gutters, Chapter 7A: Materials and Construction Methods for Exterior Wildfire Exposure
+ 2018 NFPA 1144 Standard for Reducing Structure Ignition Hazards from Wildland Fire: Section 5.3.2

Other Codes & Standards:
Codes and standards will vary depending on location and adoption in individual jurisdictions.
+ Check local, county, and state amendments for additional wildfire codes and standards.
+ Check local general plan, multi-hazard mitigation plan, or zoning documents for any additional requirements.
+ IRC (if applicable – check for wildfire amendments).

Typical Design, Vulnerability, & Mitigation Considerations:

<table>
<thead>
<tr>
<th>Types of Gutters</th>
<th>Design, Vulnerability, &amp; Mitigation Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metal (Noncombustible) Gutters</td>
<td>Metal gutters are noncombustible and will stay in place during a wildfire. The resulting fire will remain at the roof edge.</td>
</tr>
<tr>
<td>Plastic or Vinyl Gutters</td>
<td>Plastic or vinyl gutters can melt when exposed to the high temperatures that occur from a wildfire (this can be from direct flame front or by ignition of debris by embers), which can result in the gutter and its contents falling to the ground. If the gutter falls to the ground, it and its contents can ignite nearby combustibles (i.e., mulch, vegetation, siding, etc.).</td>
</tr>
</tbody>
</table>
Mitigation Strategies:
+ Clean out debris from gutters, regularly, especially during fire season.
+ Install metal flashing at the roof edge to provide additional protection to the roof edge.56
+ Install noncombustible gutters over plastic gutters in fire hazard areas.
+ Install noncombustible gutter guards or covers to minimize the amount of debris that may enter.
+ Inspect gutter guards regularly to assure that they have not become dislodged.
+ Refer to Typical Design, Vulnerability & Mitigation Considerations for additional mitigation options

Training:
+ NFPA – Assessing Structure Ignition Potential from Wildfire

Gaps in Knowledge:
+ Observations have been made that metal drip edge is effective against ignition of the structure if there is debris in the gutter, but further testing is needed to evaluate its performance.
+ There are no fire test standards to evaluate the performance of gutters when exposed to wildfire conditions.
+ Little to no fire testing has been conducted to obtain the rate of fire spread from the gutter to the structure if vinyl or plastic gutters are installed
+ Little to no fire testing has been conducted to find if plastic or vinyl gutters will propagate from embers if there is no combustible debris in the gutter.

Other References:
+ Fire Safe Marin, Gutters: https://firesafemarin.org/harden-your-home/fire-resistant-gutters/
+ Ready For Wildfire, Gutters: https://www.readyforwildfire.org/cf-action/home-hardening-gutter/

Solar panels (1.1.6)

Main Concern(s):
Residential panel installations are a relatively new technology and building component/feature that has evolved significantly since 2014. While there have been significant strides in understanding fire hazards and risks from these systems and how to effectively design to mitigate those risks, little research and design standards have been undertaken to specifically address wildfire exposures and the associated risks that contribute to home ignition, fire load or firefighter safety during wildfire operations.

General concerns include:
+ Rooftop placement is isolated from routine occupant awareness, fixed fire protection systems, and detection features. These factors result in potential accumulation of debris, delayed fire detection, and no fire protection.
+ Combustible portions of the module and other components provide fuel to support a fire and can reflect heat from a fire towards the roof, contributing to combustion and burn-rate.
+ Defensive fire service actions have been found to have reduced impact as PV panels conceal and shield fire below. Fire service personnel must take additional precautions when approaching a structure that includes rooftop solar installation, as power generated by the panels cannot be turned off. Fire service may not identify presence of PV panels if not visible from ground-level.
+ In general, there is limited data on how PV systems behave under wildfire exposure. There is potential for these systems to contribute to a wildfire event during substantial exposure, based on the materials used and their constant energization when exposed to light. Rooftop PV systems may include penetrations for building service which may compromise the continuity and integrity of the building envelope, potentially leading to early failure during wildfire exposure.
Roof Systems 1.1

Key Terminology:

+ **Photovoltaic (PV) Module**: An environmentally protected planar assembly of solar cells, optics, and ancillary parts, such as interconnections, terminals, (and protective devices such as diodes) intended to generate direct current power under un-concentrated sunlight. The structural (load carrying) member of a module can either be the top layer (superstrate) or the back layer (substrate).\(^\text{57}\)

+ **PV Panel**: This is the technical term for a solar panel, often used interchangeably with PV module (especially in one-module systems), but more accurately used to refer to a physically connected collection of modules (i.e., a laminate string of modules used to achieve a required voltage and current). A collection of photo-voltaic modules mechanically fastened together, wired, and designed to provide a field-installable unit.\(^\text{58}\)

+ **PV System**: A complete set of components for converting sunlight into electricity by the photovoltaic process, including the array, rack support system, and balance of system components.\(^\text{59}\)

+ **Photovoltaic-Thermal (PV/T) System**: A photovoltaic system that, in addition to converting sunlight into electricity, collects residual heat energy and delivers both heat and electricity in usable form. Also called a total energy system or solar thermal system.

+ **Solar Panel**: Synonymous with PV Panel.

Fire Rating & Classification:

PV systems (PV modules with mounting systems) are available with Class A, B, and C ratings. Classification of roof mounted PV systems is based on UL 1703 (PV Modules) and UL 2703 (PV Mounting Systems). The combination of roof mounted solar modules and racking components is required to be considered as a system. The system is required to meet or exceed the fire classification of the roof assembly on which they are mounted. PV modules are also categorized by roof slopes they are tested for.

UL 1703 also assigns module types that are based on panel construction and fire performance; there are 33 total module types used by UL 1703, defined based on panel material/thickness, encapsulation method, substrate material/thickness, frame and fire test performance for external fire exposure. Under the current standard, the use of module types is optional.

Fire Test Standards:


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\(^{58}\) National Fire Protection Association.

\(^{59}\) National Fire Protection Association.
Rooftop, Pre-2014 PV Systems
Mounting and support systems and attachments were not well-regulated or assessed for compatibility. Installations prior to 2014 can vary broadly in their installation and mounting systems. Further testing/information is needed, more information to be determined in future editions of this Handbook.

Typical Design, Vulnerability, & Mitigation Considerations:

<table>
<thead>
<tr>
<th>Types of Solar Panel Systems</th>
<th>Vulnerability, &amp; Mitigation Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>In-Roof (Building Integrated)</td>
<td>Solar panel systems integrated into the roof assembly can result in complicated geometry and joints that can be challenging to protect and clear of vegetative debris. In-roof system geometry should be kept simple to minimize debris collection. Further testing/information is needed, more information to be determined in future editions of this Handbook.</td>
</tr>
<tr>
<td>Rooftop, Pre-2014 PV Systems</td>
<td>Mounting and support systems and attachments were not well-regulated or assessed for compatibility. Installations prior to 2014 can vary broadly in their installation and mounting systems. Further testing/information is needed, more information to be determined in future editions of this Handbook.</td>
</tr>
</tbody>
</table>
Rooftop, Post-2014 PV System Installation
For flat installations, solar panels should be installed with sufficient clearance from the roof for clearing of vegetative debris. For sloped installations with potential for debris accumulation, provide means to prevent accumulation (that don’t reduce PV performance) or physical means to clear debris (such as removal tools or under panel water spray).

Mitigation Strategies:
+ Install Class A rated panels for the greatest protection.
+ Maintain the panels free of debris and damage. This includes providing sufficient clearance between the panels and roof for clearing debris and inspecting the underside for damage.
+ Install inverter and energy storage components within the building to minimize ignition hazards. These elements should not be installed outside within 5’ of exterior walls.
+ Refer to Typical Design, Vulnerability, & Mitigation Considerations for additional mitigation options.

Training:
+ NFPA – Assessing Structure Ignition Potential from Wildfire

Gaps in Knowledge:
+ There is limited information available on how solar panels behave in a wildfire event, as this is dependent on the module, mounting hardware, and roof as a system. Actual performance of a rack-mounted PV system exposed to fire or flame is strongly dependent on the mounting geometry of the PV array and properties of the components that make up the specific PV module type.  
+ Fire classification requirements were updated in 2014 (UL 1703) with substantial focus on fire performance considerations. Since the PV systems field continues to be an innovative field, technology and requirements will continue to evolve.
+ Improper design, installation or components can cause hot spots and/or electrical failures that can lead to ignition of the system and adjacent materials during high load. Self-installed systems can significantly increase the risk of fire. PV system installation must be appropriately designed and installed using classified and listed products; compliant PV systems have a very low incident rate of ignition.
+ Roof attachments and methods must be compatible with the roof system and use appropriate precautions. Incorrect attachment methods can compromise fire performance, waterproofing ability, and in extreme cases, structural performance.
+ Battery and inverter equipment locations do not typically consider exterior exposure risks and may be located on the building exterior.

Other References:

+ Solar ABCs / UL:
  - http://www.solarabcs.org/about/publications/reports/flammability-testing/pdfs/Flammability_Interimreport.pdf
Skylights (1.1.7)

Main Concern(s):

Skylights can compromise a home’s ability to survive a wildfire when precautions are not taken to minimize the potential for them being an entry point for embers and/or flames. During a wildfire, a skylight can be compromised due to extended radiant heat exposure or to flames when embers have ignited vegetative debris on top or next to the skylight. Most guidance recommends using a flat glass skylight rather than a plastic dome style because the plastic is combustible. However, there are situations based on the slope of the roof where flat glass could become more vulnerable.61

+ Vegetative debris can more easily land and stay on a low slope roof leading to increased risks.
+ Typical flame temperatures from wind-blown ember ignition of debris would be high enough to break even tempered glass.62

Roof Systems 1.1

Key Terminology:
+ Skylight, Unit: A factory-assembled, glazed, fenestration unit, containing one panel of glazing material that allows for natural lighting through an opening in the roof assembly while preserving the weather-resistant barrier of the roof.63
+ Skylights & Sloped Glazing: Glass or other transparent or translucent glazing material installed at a slope of 15 degrees or more from vertical. Unit skylights, tubular daylighting devices, glazing materials, solariums, sunrooms, roofs, and sloped walls are included in this definition.64

Fire Rated Assemblies:
Skylights can comply with several different requirements in order to resist the effects of fire. Applicable options are as follows:
+ Be constructed of multi-pane glazing with a tempered pane.65
+ Be constructed of glass block units.66
+ Be comprised of fire rated glazing per ASTM E119.
+ Have a fire-resistance rating of not less than 20 minutes when tested in accordance with NFPA 257.

Fire Test Standards:
+ NFPA 257 Standard on Fire Test for Window and Glass Block Assemblies

Referenced Building Codes & Standards:
+ International Wildland Urban Interface (IWUI) Code: Sections 504.8, 505.8 Exterior Glazing
+ California Building Code (CBC): 708A Exterior Windows, Skylights, and Doors. 202 Definitions
+ NFPA 1144, Standard for Reducing Structure Ignition Hazards from Wildland Fire: 5.7 Exterior Openings
+ ASCE 7-05 American Society of Civil Engineers Standard: Windborne debris criteria

64 International Code Council, Inc.
Roof Systems 1.1

Other Codes & Standards:
Codes and standards will vary depending on location and adoption in individual jurisdictions.
+ Check local, county, and state amendments for additional wildfire codes and standards.
+ Check local general plan, multi-hazard mitigation plan, or zoning documents for any additional requirements.
+ IRC (if applicable – check for wildfire amendments).

Typical Design, Vulnerability, & Mitigation Considerations:

<table>
<thead>
<tr>
<th>Types of Skylights</th>
<th>Design, Vulnerability, &amp; Mitigation Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flat Skylights</td>
<td>Less likely to experience ember intrusion on a steep-slope roof because vegetative debris is less likely to accumulate. The steeper the slope, the more likely that the flat skylight will respond like an exterior wall. In such cases, consider the potential for radiant heat or flame contact exposure from combustibles outboard of the skylight.</td>
</tr>
<tr>
<td>Dual-Pane Glass</td>
<td>Newer skylights feature dual-pane systems similar to multi-pane windows in an exterior wall. It is common to see that the outer pane uses tempered glass, and the inner pane uses laminated safety glass. Double-paned glass is also more energy efficient than single-paned glass.</td>
</tr>
<tr>
<td>Laminated Glass</td>
<td>Provides 3 to 4 times more resistance to windborne firebrands than tempered glass. Laminated glass is two panes of annealed glass with a plastic sealer holding the two panes together. The two panes will behave like a thicker pane of annealed glass during a fire event. If a firebrand strikes with enough momentum to break the glass, the plastic film in the core of the glass will keep the glazing in the frame, allowing the broken glass to continue to resist firebrand impacts, embers, and hot gases. If the plastic film in the core gets sufficiently hot, the pane will delaminate whether or not the glass has been broken. If laminated glass is specified, it should either be protected by shutters, or combined with tempered glass in an IGU. When laminated glass breaks, it will break into shards.</td>
</tr>
</tbody>
</table>

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### Roof Systems 1.1

<table>
<thead>
<tr>
<th>Tempered Glass</th>
<th>The resistance of tempered glass can be enhanced with a low-e coating or proprietary reflective coating. Firebrands with sufficient momentum can break tempered glass. Tempered glass breaks into many small, not sharp pieces. To avoid breakage, the glass can be protected by shutters. Another alternative is to specify and install an IGU with a laminated glass inner pane. (^{70})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domed Skylights</td>
<td>Skylight in the shape of a dome. Less vulnerable to the accumulation of debris.</td>
</tr>
<tr>
<td>Plastic Skylights</td>
<td>Vulnerable to melting during wildfire conditions.</td>
</tr>
<tr>
<td>Low-e Type Coating</td>
<td>Proprietary reflective coating available for application to annealed and tempered glass. The coating is primarily used for energy saving benefits. The coating acts like a low-e coating in that it reflects radiant heat, but the proprietary reflective coating may be more effective. Provides a higher level of resistance to radiant heat than other types of glazing because the coating reflects radiant heat, reducing the probability that the heat will be able to enter the building. (^{71})</td>
</tr>
<tr>
<td>Proprietary Fiberglass-Reinforced Translucent Glazing</td>
<td>Skylight glass with proprietary fiberglass-reinforced translucent glazing. This skylight material has a Class A rating.</td>
</tr>
<tr>
<td>Insulated Glazing Unit (IGU)</td>
<td>An IGU consists of two or three panes of glass that are separated by a sealed air space. Double-paned annealed units last about 10 minutes in a wildfire, which is about twice as long as single-paned windows. In many cases, 10 minutes is long enough to provide protection from the fire. If the first pane fails, the second pane still exists to resist penetration. Laminated glass, tempered glass, and glass with a low-e coating can be combined in various ways into an IGU. (^{72})</td>
</tr>
<tr>
<td>Skylight Frames</td>
<td>To avoid window failure, frames for skylights should only be constructed of metal or metal-clad wood. Wooden and plastic frames should not be used. Maintenance is critical. Both domed and flat skylights have similar framing systems (bases). Each uses a metal flashing to protect the wood framing members from ember related damage. This flashing helps the skylight survive when threatened but should be maintained to avoid risks. (^{73})</td>
</tr>
</tbody>
</table>


\(^{71}\) FEMA.

\(^{72}\) FEMA.

\(^{73}\) FEMA.
Mitigation Strategies:
+ Opt for flat / tempered glass skylights. Debris can accumulate at roof-to-skylight intersections. If ignited by embers, flames can potentially wrap around and impinge upon the top surface of the skylight.
+ Regularly inspect your roof for debris accumulation on and around skylights. Debris is more likely to accumulate on top of a skylight installed on a flat roof.
+ A variety of products are available for glazing in skylights. Glazing can be in a single- or multi-paned configuration. If plastic skylights are installed, it is recommended that they are replaced with laminated glass, tempered glass, glass with a low-emissivity, fiberglass-reinforced translucent glazing, and/or insulated glazing units. Glazing products that are not recommended are annealed glass, ceramic glass, and plastic glazing.
+ Refer to Typical Design, Vulnerability, & Mitigation Considerations for additional mitigation options.

Training:
+ NFPA – Assessing Structure Ignition Potential from Wildfire

Other References:
+ University of California, Homeowner’s Wildfire Mitigation Guide, Skylights: [https://ucanr.edu/sites/Wildfire/Roof/Skylights](https://ucanr.edu/sites/Wildfire/Roof/Skylights)
Structural Hardening

Roof to Exterior Wall
Soffits & Eaves Construction (1.2.1)

Main Concern(s):
Soffit and eave construction is a critical component of home exterior fire resistance. Soffits are located at the down-slope edge of a sloped roof and function as the transition between the roof and fascia/wall. Eaves are vulnerable to damage from wildfires. Once an eave or soffit has ignited, fire can spread from the under-eave area onto the roof, into the attic, or onto and through the exterior wall. Metal soffit panels can conduct heat and allow the passage of embers and hot gases. Untreated wood soffit panels can ignite, and vinyl panels can melt and fail away.

Structure showing the location of the fascia, eaves, and under-eave areas. Under-eave areas can be soffited or open.

An example of open-eave construction. The roof rafter rails are exposed. The circular frieze-block vents shown here are typically located in the blocking. Note the gaps between the blocking and adjacent framing which would allow ember entry. These gaps could be caulked. Backer rod may be needed for wider gaps. The caulked joints should be inspected annually and failed joints repaired.

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+ Windborne embers, convective heat and radiant heat can be trapped under overhangs and in the upper portion of exterior walls. 78
+ Typical construction materials for eaves, overhangs, and soffits are not fire-resistant, and therefore, are susceptible to ignition by embers and hot gases. 79
+ Soffits normally have vents as part of the attic ventilation system. Unprotected vents can allow embers and hot gases to enter the attic. 80
+ Depending on how the under-eave area is constructed (i.e., “soffitless” or “open-eave”) there will be different vulnerabilities from flame contact exposures, ember accumulation, as well as different weaknesses for vents.

Key Terminology:
+ **Boxed-in Eave:** An overhang with a sofit that closes and finishes the underside of the eaves.
+ **Fascia or gutter boards:** Vertical roof trim located along the perimeter of a building, usually below the roof level, to cover the rafter tails at the eaves and to seal off the top of the siding along the rake. 81
+ **Open Eave:** Design where the roof rafters extend beyond the exterior wall and visible. Blocking is used to fill the space between the top of the exterior wall and the roof sheathing. 82
+ **Soffit:** Encloses the underside of roof overhangs.

Fire Classification & Ratings:
Currently there isn’t an accepted procedure to evaluate ember intrusion of eaves, soffits, or overhangs that results in the designation of a fire rating. Fire test standards that detail tests to evaluate resistance of fire penetration and direct flame impingement of eaves, overhangs, and other projections, as well as tests to evaluate ember/flame resistance of vents, exist and are listed below. Soffits may be included in assemblies that receive fire resistance ratings, but the soffit itself does not.

80 FEMA, “Technical Fact Sheet No. 6: Eaves, Overhangs, and Soffits.”
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Example of a boxed-in or closed-eave.


Fire Test Standards:
+ ASTM E2886 Standard Test Method for Evaluating the Ability of Exterior Vents to Resist the Entry of Embers and Direct Flame Impingement: [https://www.astm.org/e2886_e2886m-20.htm](https://www.astm.org/e2886_e2886m-20.htm)
+ ASTM E2957 Standard Test Method for Resistance to Wildfire Penetration of Eaves, Soffits, and Other Projections: [https://www.astm.org/e2957-17.html](https://www.astm.org/e2957-17.html)

Referenced Codes & Standards:
+ International Wildland Urban Interface (WUI) Code: Sections 504.3, 505.3 Protection of Eaves; Sections 504.10.1, 505.10.1: Vent locations
+ International Building Code (IBC), 2021: Section 705: Exterior Walls
+ California Building Code (CBC), 2019: 707A.5 Enclosed Roof Eaves and Roof Eave Soffits
+ NFPA 1144 Standard for Reducing Structure Ignition Hazards from Wildland Fire, 2018: 5.3 Roof Design and Materials
Other Codes and Standards:
Codes and standards will vary depending on location and adoption in individual jurisdictions.
+ Check local, county, and state amendments for additional wildfire codes and standards.
+ Check local general plan, multi-hazard mitigation plan, or zoning documents for any additional requirements.
+ IRC (if applicable – check for wildfire amendments).

Typical Design, Vulnerability, & Mitigation Considerations:

<table>
<thead>
<tr>
<th>Types of Eaves, Overhangs and Soffits</th>
<th>Design, Vulnerability, &amp; Construction Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boxed-in, Closed or Soffited Eave &amp; Overhang</td>
<td>A soffited eave must be able to communicate with the attic space via vents. If soffit vents are unprotected embers and hot gases can enter the attic space. The vulnerability of a soffited eave can also be due to the material of the eave and joints. Joints in combustible eave construction are particularly susceptible to fire and ember intrusion, particularly as eaves and other overhangs are where embers, fire and hot gases accumulated during a wildfire. It's also where flame can easily travel up a combustible wall siding and into the joint or soffit vents, if not well protected. Joints will also be the most likely failure location in noncombustible construction. Refer to “soffit vents” and “joints” section for more details.</td>
</tr>
<tr>
<td>Open Eave and overhang</td>
<td>Structures with open eaves have inlet vents on the top of the wall-to-roof interface, and typically have exposed structural framing. Exposed structural framing is highly susceptible to ignition. The same vulnerabilities of these inlet vents and the joints, as in the closed eaves, applies. However, open eaves tend to have more gaps/joints as part of the construction and therefore present more opportunities for ember, flame and hot gas intrusion. Open eave construction is overall more vulnerable to embers and flames compared to soffited eave construction.</td>
</tr>
<tr>
<td>Noncombustible Soffits</td>
<td>Soffits can be constructed of a range of noncombustible materials including fiber-cement panels, metal panels, stucco, and vinyl panels. Several of these materials are susceptible to damage from wildfires, including metal panels and vinyl panels. Metal panels may distort, and vinyl panels can melt and fall away. This could potentially allow passage of embers and hot gases. Note: With a long enough exposure, all potential soffit materials can be vulnerable.</td>
</tr>
<tr>
<td>Combustible Soffits</td>
<td>Soffits can be constructed of a range of combustible materials including wood sheathing. As windborne embers, convective heat, and radiant heat can be trapped under overhangs, eaves and soffits due to unique fire induced flows during wildfire incidents, untreated wood panels or other exposed combustible surfaces for eave soffits can be highly vulnerable to ignition. Where timber is desired, it should be comprised of fire retardant treated wood. All combustible fuel loads (e.g., combustible furniture, unattended vegetation, non-fire adapted plants, BBQs, etc.) below the soffit should be removed to minimize any fire hazards directly below.</td>
</tr>
</tbody>
</table>
Mitigation Strategies:

+ Enclose open overhangs with soffits that have a minimum one-hour fire-resistance rating to prevent embers and hot gases from contacting the joists, rafters or trusses, or the underside of the roof decking.  
+ Where possible, replace open eaves with soffited eaves.
+ Use flat, horizontal soffits instead of attaching the soffits to the sloped joists, which creates sloped soffits. A flat soffit reduces the potential for entrapment of embers and hot gases.  
+ For the fascia, use noncombustible or fire-resistant materials (e.g., fire-retardant-treated lumber, fiber-cement board, etc.).  
+ Evaluate the fire-resistance of existing soffits and replace soffits that are not fire-resistant according to the guidance provided in FEMA Technical Fact Sheet No.8 located within The Home Builder’s Guide to Construction in Wildfire Zones.  
+ In very high Fire Severity Zones, install exterior 5/8” fire-resistant gypsum board between the existing and new soffit materials for enhanced fire resistance.  
+ If the fascia is combustible, cover the fascia board with a noncombustible or fire-resistant material like fire-retardant-treated lumber, fiber-cement board, etc.  
+ Fill joints and gaps with fire rated caulking and other appropriate firestopping materials.  
+ Do not store firewood, construction materials or other combustible materials under any overhang.  
+ Avoid planting combustible vegetation under eaves and overhangs.  
+ Refer to Typical Design, Vulnerability and Mitigation Considerations for additional mitigation options.

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85 FEMA.

86 FEMA.

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88 FEMA.
Roof to Exterior Wall 1.2

Training:
+ NFPA – Assessing Structure Ignition Potential from Wildfire

Gaps in Knowledge:
+ Fire testing does not account for weathering of materials prior to fire exposure or the impact of general wildfire environmental conditions (e.g., high winds, flying debris, impact from objects).
+ “Ignition-resistant” eaves and soffits that have been tested against criteria from SFM Standard 12-7A-3 may be difficult to verify in-field.
+ “Ignition-resistant” is not a widely used term when referencing fire resistance of eaves, overhangs, and soffits. The term is only used in some local jurisdictions and does not exist in ICC or NFPA codes.
+ Incorrect language is often used when referencing fire-resistance of soffits. The soffit itself does not receive a rating. It must be part of an approved assembly.

Other References:
+ IBHS Wildfire Home Assessment and Checklist: https://www.iafc.org/docs/default-source/pdf/wildfire-checklist_ibhse1e8b15c78366c709642ff00005e0421.pdf?sfvrsn=5bdedd0d_0
Soffit Vents (1.2.2)

Main Concern(s):
Windborne embers, convective heat, and radiant heat can be trapped under overhangs, eaves, and soffits due to unique fire induced flows during wildfire incidents. Eaves, overhangs, and soffits typically have vents as part of the attic ventilation system. If soffit vents are unprotected embers and hot gases can enter the attic or other parts of the structure leading to ignition of interior building contents. Often times, fires that initiate via embers into attics or other concealed spaces can go undetected for long periods of time.

Key Terminology:
+ **Soffit Vent**: A continuous or intermittent vent installed along a soffit as part of the attic ventilation system of a building.99
+ **Eaves**: Eaves are located at the down-slope edge of a sloped roof and serve as the transition between the roof and fascia/wall.90

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90 FEMA.
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+ **Overhangs**: Overhangs are extensions of the roof beyond the exterior wall (i.e., the joists, rafters, or trusses and the decking they support cantilever past the wall).91

**Fire Rated Assemblies:**

The ember and direct flame impingement resistance vents in the under-eave area is defined by ASTM E2886 Standard Test Method for Evaluating the Ability of Exterior Vents to Resist the Entry of Embers and Direct Flame Impingement. This test standard prescribes two individual methods to evaluate the ability of the vent opening to resist embers and flame. The ability of such vents to completely exclude entry of flames or embers is not evaluated. Acceptance criteria are not provided in this standard.92

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Exemplar of individual type soffit vents. Exemplar of a continuous soffit vent.

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**Fire Test Standards:**

+ ASTM E2886/E2886M-14 Standard Test Method for Evaluating the ability of Exterior Vents to Resist the Entry of Embers and Direct Flame Impingement:
  
  [https://www.astm.org/e2886_e2886m-20.html](https://www.astm.org/e2886_e2886m-20.html)

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### Vent Fire Test

**Technical Description**

This test method provides for a direct ember exposure to vents. The apparatus allows for embers to fall vertically and impinge on the vent mounted horizontally on ledges within the test chamber.

An induction fan located at the bottom of the apparatus pulls the air stream through the vent, allowing any embers that pass through the vent to impinge on a combustible target material (e.g., cotton).

[CBC and NFPA 1144 requirements – No flaming ignition of the cotton material, and maximum temperature of the unexposed side of the vent shall not exceed 662°F or 350°C.]

### Ember Penetration Test

**Technical Description**

This test method provides for the evaluation of direct flame impingement on a vent mounted in a test assembly as described in Test Method E912.

The flame source is directed into the test assembly and directly impinges the vent that is mounted in either a vertical or horizontal position.

[CBC and NFPA 1144 requirements – No flaming ignition and maximum temperature of the unexposed side of the vent shall not exceed 662°F or 350°C.]

### Direct Flame Impingement Test

**Technical Description**

This test method provides for the evaluation of direct flame impingement on a vent mounted in a test assembly as described in Test Method E912.

The flame source is directed into the test assembly and directly impinges the vent that is mounted in either a vertical or horizontal position.

[CBC and NFPA 1144 requirements – No flaming ignition and maximum temperature of the unexposed side of the vent shall not exceed 662°F or 350°C.]

### Non-Mechanical Fire Dampers Used in Vented Construction

**Technical Description**

This fire-test-response standard assesses the ability of non-mechanical fire dampers used in vented construction in its open state to limit passage of hot gases, radiation, and flames during a prescribed fire test exposure. The fire exposure condition in this test method is sudden direct flame impingement, which produces these hot gases, radiation, and flames.

This test method does not circumvent or eliminate the fire-resistance rating requirements for construction.

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**Note**: In most cases, fire rated walls are typically rated as “assemblies”. This means that the entire wall assembly creates the containment, including the covering, underlayment, studs or interior structural support, interior-side underlayment, screw types and spaces, etc. Thus, assessing the fire resistance rating of an exterior wall in the field will likely not be possible.

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94 ASTM International.
Typical Design, Vulnerability, & Mitigation Considerations:

<table>
<thead>
<tr>
<th>Soffit Vent Type</th>
<th>Design, Vulnerability, &amp; Mitigation Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous</td>
<td>Continuous soffit vents have recently become popular because they allow the most amount of fresh air to enter the attic space. These devices come in a variety of shapes and sizes. However, the most common is generally long and narrow. Soffit vents typically have a screen attached to them to prevent rodents from working their way into your attic. These screens may not be small enough to limit the passage of embers. The noncombustible mesh should be no more than 1/8&quot;, preferably 1/16&quot;. Research has shown that 1/8&quot; mesh screening can still lead to embers with sufficient energy to ignite fine fuels in the attics. With finer mesh screening additional vents may be needed to satisfy building officials.</td>
</tr>
<tr>
<td>Individual</td>
<td>Individual soffit vents are the most widely used soffit vent type and are useful for problematic areas of a house (e.g., bedrooms, kitchens and partitioned attics). Soffit vents typically have a screen attached to them to prevent rodents from working their way into your attic. These screens may not be small enough to limit the passage of embers. The noncombustible mesh should be no more than 1/8&quot;, preferably 1/16&quot;. Research has shown that 1/8&quot; mesh screening can still lead to embers with sufficient energy to ignite fine fuels in the attics. With finer mesh screening additional vents may be needed to satisfy building officials.</td>
</tr>
</tbody>
</table>

Referenced Codes & Standards:

+ International Wildland Urban Interface (IWUI) Code: Section 504.10, Vents
+ California Building Code (CBC): 706A, Vents
+ NFPA 1144 Standard for Reducing Structure Ignition Hazards from Wildland Fire: Section 5.7.4, Exterior Openings and 5.3.3 for Vents

Other Codes and Standards:

Codes and standards will vary depending on location and adoption in individual jurisdictions.

+ Check local, county, and state amendments for additional wildfire codes and standards.
+ Check local general plan, multi-hazard mitigation plan, or zoning documents for any additional requirements.
+ IRC (if applicable – check for wildfire amendments).
Mitigation Strategies:
+ Cover existing vents with wire mesh screen having openings with a maximum of 1/8". Preferably 1/16". Research has shown that 1/8" mesh screening can still lead to embers with sufficient energy to ignite fine fuels in the attics.
+ Install ember resistant vents manufactured with wire mesh screening with a maximum of 1/8". Preferably 1/16". Research has shown that 1/8" mesh screening can still lead to embers with sufficient energy to ignite fine fuels in the attics.
+ Common 1/4" screens are ineffective and should be replaced.
+ Replace screens that have painted over or detached from the substrate.
+ Do not use fiberglass or plastic mesh because they can melt and/or burn.
+ Use fire rated caulking around penetrations to seal openings.
+ Protect vents in eaves or cornices with baffles to block embers, backed by 1/16" wire mesh (mesh alone is not enough).\(^5\)
+ If possible, move soffit vents away from the exterior wall.
+ Refer to Typical Design, Vulnerability, & Mitigation Considerations for additional mitigation options.

Training:
+ NFPA – Assessing Structure Ignition Potential from Wildfire

Gaps in Knowledge:
+ Fire testing does not account for weathering of materials prior to fire exposure or the impact of general wildfire environmental conditions (e.g., high winds, flying debris, impact from objects).
+ ASTM E2886 does not evaluate the ability of vents to completely exclude entry of flames or embers.
+ ASTM E2886 does not provide acceptance criteria.
+ Air flow calculations may need to be reconsidered or redesign where fire rated vents are installed in existing structures, to ensure sufficient airflow is still satisfied for non-fire purposes.
+ In most instances, it’s challenging to verify in-the-field if a vent has been fire-tested. (Professional judgement and discussion with the homeowner are required).

\(^5\) Fire Safe Marin, “Fire-Resistant Vents,” Fire Safe Marin, accessed April 2022, [https://firesafemarin.org/harden-your-home/fire-resistant-vents](https://firesafemarin.org/harden-your-home/fire-resistant-vents)
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Other References:
+ IBHS Ember Testing:
  + https://ibhs.org/wildfire/building-vulnerability-to-ember-exposure/
  + https://www.facebook.com/watch/?v=389602881106017
+ IBHS Preparedness:
+ FEMA Fact Sheets:
+ University of California – https://ucanr.edu/sites/fire/Prepare/Building/Vents}
Joints
(Head-of-Wall to Roof, and Bottom-of-Wall to Roof) (1.2.3)

Main Concern(s):
In general, joints and other penetrations create gaps in the continuity of a fire rated or fire resistive roof or wall assembly, providing a potential avenue for embers, hot gases, or flame to breach the exterior envelope of a building. Due to unique fire induced flows at the underside of eaves that can lead to an accumulation of hot gas and embers, head-of-wall to roof joints are particularly vulnerable to ember intrusion and exposure to hot gases. Embers can oftentimes accumulate at head-of-wall to roof joints, creating a concentrated source of heat. For bottom-of-wall to roof joints that may occur in more complex roofs (i.e., high number of vertical-to-horizontal transitions), the concern with hot gases accumulating near the joint are reduced. However, bottom-of-wall to roof joints are more susceptible to direct flaming and ember accumulation from the ignition of debris that typically collected in these locations. In addition, head/bottom-of-wall-to-roof joints are also locations where there can be different fire classification/rating levels and construction materials (which can result in one system being compromised by the other). Lastly, there is currently no fire test for any types of roof joints (including head-of-wall or bottom-of-wall joints to roof) to wildfire exposure – embers, direct flaming, or hot gases. This can create a short-circuit of a Class A rated roof assembly or fire-resistance wall detail.

Example of a complex roof and various wall-to-roof joint conditions
Example of metal flashing at a bottom-of-wall-to-roof joint.
Headwall flashing. Image courtesy of InterNACHI.
Key Terminology:

+ **Joint**: The opening in or between adjacent assemblies that is created due to building tolerances or is designed to allow independent movement of the building in any plane caused by thermal, seismic, wind or any other loading.  

+ **Fire-Resistant Joint System**: An assemblage of specific materials or products that are designed, tested and fire-resistance rated in accordance with a standard fire test to resist for a prescribed period of time the passage of fire through joints made in or between fire-resistance-rated assemblies. (Note: There are currently no fire-resistant joint system tests for wildfire exposures).

+ **Head-of-Wall**: A head-of-wall joint is the linear gap between the top of a wall assembly and bottom of a floor or roof assembly.

+ **Bottom-of-Wall**: A bottom-of-wall joint is the linear gap between the bottom of a wall assembly and top of a roof or floor assembly.

+ **Flashings**: A thin metal that is installed at joints to protect against intrusion of unwanted elements such as water and embers.

Fire Classification & Ratings:

Currently, there is no fire test standard to evaluate ember intrusion, direct flame impingement or thermal transmission of heat via convection or radiation from wildfires for joint systems (head-of-wall or bottom-of-wall-to-roof joint system). Fire rated joints are necessary in order to maintain a roof or wall system’s fire rating, integrity and/or continuity to wildfire exposure. While a variety of fire tests exist for joint systems in interior building fire exposures (e.g., ASTM E1966 or UL 2079), none are applicable to the fire conditions presented by wildfires. A range of joint systems (e.g., static joints, movement joints) and joint conditions (e.g., header or top-of-wall, footer or bottom-of-wall details) for exterior wildfire exposures are still needed.

Fire Test Standards

Currently, there is no fire test standard to evaluate ember intrusion, direct flame impingement or thermal transmission of heat via convection or radiation from wildfires for joint systems.
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Referenced Codes & Standards:
+ International Wildland Urban Interface (IWUI) Code: No explicit requirements
+ California Building Code (CBC): No explicit requirements
+ NFPA 1144 Standard for Reducing Structure Ignition Hazards from Wildland Fire: No explicit requirements

Typical Design, Vulnerability, & Mitigation Considerations:

<table>
<thead>
<tr>
<th>Joint Types at Head/Bottom-of-Wall-to-Roof</th>
<th>Design, Vulnerability, &amp; Mitigation Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>General: Roof-to-Wall Joint</td>
<td>The more intersections and shapes included in the roof design, the more opportunity there will be for leaf, needle and other vegetative debris to accumulate. Flame exposure to siding at roof-to-wall intersections can occur if vegetative debris is ignited by embers. If the siding is installed close to the roof, the siding could be ignited directly by embers (i.e., without initial ignition of vegetative debris).99</td>
</tr>
</tbody>
</table>

Other Codes & Standards:
Codes and standards will vary depending on location and adoption in individual jurisdictions.
+ Check local, county, and state amendments for additional wildfire codes and standards.
+ Check local general plan, multi-hazard mitigation plan, or zoning documents for any additional requirements.
+ IRC (if applicable – check for wildfire amendments).

99 University of California, Agriculture and Natural Resources, “Roof,“ Fire in California, accessed May 2022, https://ucanr.edu/sites/fire/Prepare/Building/Roof/
Mitigation Strategies:

+ Refer to Typical Design, Vulnerability, & Mitigation Considerations for additional mitigation options.
+ Debris should be removed from around all joints created at the roof (e.g., expansion joints, vents/chimney-to-roof joints).
+ Metal flashing should be installed at bottom-of-wall-to-roof joints to limit ember penetration or direct flame infiltrating the wall or roof substrate. Where the roof or wall underlayment is combustible, refer to appropriate protection measures in the roof and wall construction/covering section for detailing.
+ Provide fire rated caulking in any gaps at the joint between the wall and the top of roof.

Training:

+ NFPA – Assessing Structure Ignition Potential from Wildfire

Gaps in Knowledge:

+ Currently, there is no fire test standard to evaluate ember intrusion, direct flame impingement or thermal transmission of heat via convection or radiation from wildfires for joint systems.
+ It is unclear how susceptible various head/bottom-of-wall-to-roof joints are to wildfire exposures.

Other References:

+ University of California, Agriculture and Natural Resources – Home Survival in Wildfire-Prone Areas: Building Materials and Design Considerations:
  https://anrcatalog.ucanr.edu/pdf/8393.pdf
Structural Hardening

Wall Systems
Exterior Wall Construction & Cladding (1.3.1)

Main Concern(s):
Exterior wall surfaces may provide a means for fire intrusion due to the level of combustibility of the exterior cladding and how the exterior cladding is maintained. A secondary, but direct impact for fire intrusion into a structure through exterior cladding is the method in which the surface was installed and to what degree measures were taken to make a fire brand resistant membrane maintain continuity in ember resistance. Exterior walls often have a sublayer that is of combustible materials which depends on the integrity of the exterior cladding to protect the internal framing of the structure from fire. Small openings or gaps in the siding and trim provide a sufficient entry path or point of receptive ignition that would adversely impact the structure. An often-overlooked area of ember intrusion is the foundation overlap where a gap between the foundation and the siding can provide nesting or retention of embers against a combustible surface, including stucco or masonry cladding.

+ Any opening in exterior surfaces provides an entry point for ember intrusion including pet doors, HVAC plumbing, unsealed sill cocks, mail slots, vent stacks for cooking ranges, fireplaces and wood stoves.
+ Combustible items attached to the siding or exterior cladding will impact the integrity of the exterior cladding including plastic conduit for utility access to the structure and ornamental plastic fixtures such as decorative shutters made of plastic.
+ Wood cladding may by its nature and method of manufacture may provide significant ember purchase points for windblown embers that may go undetected for long periods of time.
+ Exterior cladding of less cell density such as Cedar provides rapid pre-heating and propagation of fire across the entire surface and adds to the generation of fire brands.
Wall Systems 1.3

Furthermore, current building codes do not require fire resistance ratings for exterior walls for single family residences regardless of fire separation distances to adjacent properties or structures. This presents challenges to limiting structure-to-structure spread in high-density housing.

Key Terminology:

- Exterior Cladding: The construction material applied over another to provide a skin or layer used to provide a degree of thermal insulation and weather resistance. 100

Fire Classifications & Ratings:
The fire resistance of external wall assemblies to interior and exterior fire exposures is defined by ASTM E119 or UL 263 Standard Test Methods for Fire Tests of Building Construction and Materials. This test standard is applicable to assemblies of masonry units and to composite assemblies of structural materials for buildings, including loadbearing and other walls and partitions, columns, girders, beams, slabs, and composite slab and beam assemblies for floors and roofs. 101

Vinyl siding.  
Corrugated steel.

The standard is used to measure and describe the response of materials, products, or assemblies to heat and flame under controlled conditions, but does not by itself incorporate all factors required for fire hazard or fire risk assessment of the materials, products or assemblies under actual fire conditions. This is due to limitations of the size of the specimens tested, size of the furnace, standard fire exposure, etc. However, the test standard is one of the most widely adopted methods for comparing the performance of building construction materials, elements and assemblies to a standard fire exposure.\(^{102}\)

The test method includes measurements of exposed and unexposed surface temperature, as well as the ability of an element or assembly to maintain structural stability, integrity and insulation when exposed to a severe, standard fire exposure. The standard fire exposure simulates severe interior building fire conditions during flashover conditions. How the wall assembly performance against the performance criteria for stability, integrity and insulation, the wall can achieve anywhere from 30-min, 1-hour up to 4-hour fire resistance rating.

<table>
<thead>
<tr>
<th>Performance Category</th>
<th>Technical Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stability</strong></td>
<td>The ability of a wall assembly to sustain the applied load during the fire-resistance test, as well as a hose stream test.</td>
</tr>
<tr>
<td><strong>Integrity</strong></td>
<td>The ability of a wall assembly to limit the passage of flames or gases hot enough to ignite cotton waste, and the passage of water from a hose stream test.</td>
</tr>
<tr>
<td><strong>Insulation</strong></td>
<td>The ability of the wall assembly to limit transmission of heat to the unexposed side such that the temperature on the unexposed surface do not exceed more than 250°F (139°C) above the initial temperature.</td>
</tr>
</tbody>
</table>

**Note:** In most cases, fire rated walls are typically rated as “assemblies”. This means that the entire wall assembly creates the containment, including the covering, underlayment, studs or interior structural support, interior-side underlayment, screw types and spaces, etc. Thus, assessing the fire resistance rating of an exterior wall in the field will likely not be possible.

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Fire Test Standards

+ UL 263 Fire Tests of Building Construction and Materials: [https://global.ihs.com/doc_detail.cfm?document_name=UL%20263&item_s_key=00097028](https://global.ihs.com/doc_detail.cfm?document_name=UL%20263&item_s_key=00097028)
+ ASTM E84 Standard Test Methods for Surface Burning Characteristics of Building Materials
+ UL 723 Test for Surface Burning Characteristics of Building Materials

Referenced Codes & Standards:

+ 2021 International Wildland Urban Interface (WUI) Code: Section 504.5, 505.5 Exterior Walls
+ 2019 California Building Code (CBC): Section 707A.3 Exterior Walls
+ 2018 NFPA 1144 Standard for Reducing Structure Ignition Hazards from Wildland Fire: Section 5.6 Exterior Vertical Walls, Section 5.7 Exterior Openings

Other Codes & Standards:

Codes and standards will vary depending on location and adoption in individual jurisdictions.

+ Check local, county, and state amendments for additional wildfire codes and standards.
+ Check local general plan, multi-hazard mitigation plan, or zoning documents for any additional requirements.
+ IRC (if applicable – check for wildfire amendments).
Typical Design, Vulnerability, & Mitigation Considerations:

<table>
<thead>
<tr>
<th>Exterior Wall Types</th>
<th>Vulnerability &amp; Mitigation Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete, Fiber-Cement Panels or Siding, Exterior Fireretardant Treated Wood Siding or Panels, Stucco, Masonry, and Metal</td>
<td>These materials will not melt or burn when used as exterior wall covering materials.</td>
</tr>
<tr>
<td>Wood Siding That Is Not Fire-Retardant-Treated, Vinyl Siding, Metal Siding Susceptible to Warping, and an Exterior Insulation Finish System</td>
<td>These materials may melt or burn when used as exterior wall covering materials. This would allow the fire to reach underlying wall components and penetrate the interior of the building.103</td>
</tr>
</tbody>
</table>

Mitigation Strategies:

+ Refer to Typical Design, Vulnerability and Mitigation Considerations for additional mitigation options.
+ Maintain an ember-resistance zone far at least 5ft from all exterior walls of the structure. Remove combustibles fuel loads including wood mulch, propane tanks, trash containers, plastic storage bins, BBQs, vegetation of all kinds (if possible, otherwise remove all high fire hazard vegetation).
+ Maintain landscaping and general housekeeping with the home ignition zone. Refer to defensible space requirements.
+ Consider upgrading the exterior wall cladding to include a 5/8” Type X, exterior rated gypsum board between the wall cladding and underlayment.
+ Consider upgrading exterior wall to be 1-hour fire rated where the exterior wall is within 30’ of the property line or adjacent structure.
+ Apply fire resistive gels to siding to protect from embers, radiant heat, and direct flame contact.
+ Utilize sprinkler kits provided by agencies or use home sprinklers systems. This should NOT be considered the main line of defense, as exterior sprinklers systems have no standard fire test, design criteria or performance specifications to have any certainty of its reliability and performance in a wildfire event.
+ Block any point which may allow ember penetration to structure.
+ Utilize fire resistive wrapping to protect siding from flame impact.

Wall Systems 1.3

Training:
+ NFPA – Assessing Structure Ignition Potential from Wildfire

Gaps in Knowledge:
+ Current building codes do not require fire resistance ratings for exterior walls for single family residences regardless of fire separation distances to adjacent properties or structures. While fire separation distances exist in building codes, they are primarily designed for structure-to-structure spread from adjacent properties, they do not explicitly apply to outbuildings for the same property. The underlying basis for the separation distances and ratings are likely valid but need to be specified/confirmed for SFRs and multiple-dwelling units.
+ While the standard ASTM E119 fire resistance test is based on interior building fires or structure-to-structure fires, it was not specifically designed to account for the unique aspects of wildfire fire exposures. That is, it does not capture the impact of embers of direct flame impingement. That said, interior building fire exposures are generally more severe to exterior fire exposures, and therefore may provide a reasonable proxy for anticipating a rated-wall assembly’s performance in a wildfire.
+ ASTM E119 fire testing does not account for weathering of materials prior to fire exposure. UL 263 has an accelerated weather exposure protocol prior to fire testing.
+ In most instances, it’s challenging to verify in-the-field if an exterior wall assemblies fire resistance rating of 1-hour, 2-hour, etc. (Professional judgement required.)

Other References:
Doors (1.3.2)

Main Concern(s):
Like other exterior openings, doors can compromise a home’s ability to survive a wildfire when precautions are not taken to prevent them from being an entry point for embers and/or flames. During a wildfire, a door can be compromised due to an extended radiant heat exposure from surrounding vegetation or due to flames when embers have ignited vegetative debris near the door.\textsuperscript{104} Deteriorating weather stripping and glass panels are the most vulnerable parts of the door. If the weather stripping has deteriorated around the door causing a poor seal, embers and flames can penetrate around the door into the structure. If the glass panels in a door break during a wildfire, embers and flame can easily enter a structure.\textsuperscript{108} Similarly, non-fire rated combustible doors and combustible door frames can ignite or fail, leading to ember intrusion and ultimately ignition of other material inside of the structure. Therefore, doors must be able to resist the following exposures:

+ A radiant exposure severe enough to break the glass in a door or ignite the door or door frame. Burning vegetation in close proximity to a door could also ignite non-fire rated combustible doors and combustible door frames.\textsuperscript{106}
+ A flame contact exposure that could result from embers igniting vegetation and/or exterior cladding that burns up to the door(s).\textsuperscript{107}

See window section below for additional guidance on glass panels in doors.

Key Terminology:
+ **Weather Strip**: A strip of material to cover the joint of a door or window and the sill, casing, or threshold to exclude rain, snow, and cold air.\textsuperscript{108}
+ **Sidelite**: The side panels on either side of the door. Filled with glass or wood and usually appear in pairs, though can exist solo.


\textsuperscript{105} University of California, Agriculture and Natural Resources, "Windows," Mariposa County, accessed April 2022, https://cemariposa.ucanr.edu/Fire_Information/Wildfire_Preparation/Preparing_Your_Home_SPR/Windows.

\textsuperscript{106} University of California, Agriculture and Natural Resources.

\textsuperscript{107} University of California, Agriculture and Natural Resources.

Fire Rated Assemblies:

Fire ratings for doors or door assemblies are defined by a number of standards, as follows:
+ NFPA 252 Standard Method of Fire Tests of Door Assemblies
+ UL 10C Standard for Positive Pressure Fire Tests of Door Assemblies
+ UL 10B Standard Test for Fire Tests of Door Assemblies
+ ASTM E152 Standard Methods of Fire Tests of Door Assemblies

These test standards prescribe specific fire and hose stream test procedures for fire door assemblies in order to standardize a method for determining the degree of fire protection provided by such assemblies in retarding the spread of fire (flame, heat, and hot gases) through door openings in fire resistive wall when exposed to a severe, standard fire exposure. The standard fire exposure simulates severe interior building fire conditions during flashover conditions. It does not represent the wildfire exposures that may also include embers and direct flame impingement. How the door assembly performs against the performance criteria defined in the standards, the door can achieve anywhere from 20-min, 1-hour up to 3-hours (typically) fire resistance rating.

Fire Test Standards:
+ ASTM E152 Standard Methods of Fire Tests of Door Assemblies
+ ASTM E2112 Standard Practice for Installation of Exterior Windows, Doors, Skylights: [https://www.astm.org/e2112-19c.html](https://www.astm.org/e2112-19c.html)
+ NFPA 252 Standard Methods of Fire Tests of Door Assemblies

Wall Systems 1.3

Referenced Codes and Standards:
+ 2021 International Wildland Urban Interface (IWUI) Code: Chapter 5, Sections 504.9, 505.9 Exterior Doors
+ 2019 California Building Code (CBC) and California Residential Code (CRC): Chapter 7A , CBC 708A/CRC R337.8

Other Codes & Standards:
Codes and standards will vary depending on location and adoption in individual jurisdictions.
+ Check local, county, and state amendments for additional wildfire codes and standards.
+ Check local general plan, multi-hazard mitigation plan, or zoning documents for any additional requirements.
+ IRC (if applicable – check for wildfire amendments).

Typical Design, Vulnerability, & Mitigation Considerations:

<table>
<thead>
<tr>
<th>Door Types</th>
<th>Vulnerability &amp; Mitigation Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid Core Wood</td>
<td>Solid core wood doors are still vulnerable due to their combustibility; however these doors offer greater protection than a hollow core door. These doors should be maintained in good condition with proper weather stripping.</td>
</tr>
<tr>
<td>Steel</td>
<td>Steel doors are the most resilient to wildfire as they are noncombustible. These doors may offer a greater increase in absorbed radiative heat and should be considered a viable option for exterior pedestrian doors.</td>
</tr>
<tr>
<td>French Doors</td>
<td>French doors come in a variety of options including multiple doors or sidelite options. These doors typically contain glazing which should be in accordance with the glazing requirements located in the applicable building codes. The variation in these doors can present vulnerabilities due to the larger surface areas and glass panels. Risk can be reduced by providing rated glazing.</td>
</tr>
<tr>
<td>Sliding Glass Doors</td>
<td>Sliding glass doors are the most vulnerable due to the large surface area of the glass panels. To reduce risk these glass panels should be rated glazing.</td>
</tr>
</tbody>
</table>
Mitigation Strategies:

+ Refer to Typical Design, Vulnerability and Mitigation Considerations for additional mitigation options.
+ Provide, where possible, ignition resistant or noncombustible framing materials (e.g., metal or metal-clad wood).
+ Replace old hollow core doors with solid core or steel doors.
+ Consider using tempered glass for sliding glass doors or glass panel inserts, which is stronger than annealed glass and will provide additional protection during a wildfire.\textsuperscript{110}
+ Fabricate covers (for example, ½” plywood covers), cut to size and marked so that it can easily be installed over a door prior to evacuation. Shutters or other roll-down devices could also be installed.\textsuperscript{111}
+ During a wildfire event, make sure all doors remain closed to avoid ember intrusion into structures.
+ Manage vegetation and other types of items that could catch fire in the areas nearest to doors. This includes maintaining the surrounding vegetation and using noncombustible mulch and ignition resistant materials for yard and garden structures near doors.\textsuperscript{112}
+ The recommended glazing products for homes in wildfire zones are laminated glass, tempered glass, glass with a low-emissivity, fiberglass-reinforced translucent glazing, and insulated glazing units (IGUs). Glazing products that are not recommended are annealed glass, ceramic glass, and plastic glazing.\textsuperscript{113}

Training:

+ NFPA – Assessing Structure Ignition Potential from Wildfire

\textsuperscript{111} Division of Agriculture and Natural Resources, University of California.
\textsuperscript{112} Fire Safe Marin, “Fire-Resistant Windows,” Fire Safe Marin, accessed April 2022, \url{https://firesafemarin.org/harden-your-home/fire-resistant-windows}.
Wall Systems 1.3

Gaps in Knowledge:

+ Currently, there is no fire test standard to evaluate ember intrusion, direct flame impingement or thermal transmission of heat via convection or radiation from wildfires for doors.
+ Some gels and foams marketed for structure protection during wildfires indicate they will also protect doors, but verification of these claims by an independent source is not currently available.\(^\text{114}\)
+ Glass breaking and/or fall-out is still within the realm of active fire testing and research for all the ranges of glazing types with associated frame types (e.g., wood, vinyl, aluminum, vinyl- and aluminum-clad wood, and fiberglass).

Other References:

+ University of California, Fire in California Windows: [https://ucanr.edu/sites/Prepare/Building/Windows/](https://ucanr.edu/sites/Prepare/Building/Windows/)
+ Fire Safe Marin, Fire Resistant Windows: [https://firesafemarin.org/harden-your-home/fire-resistant-windows/](https://firesafemarin.org/harden-your-home/fire-resistant-windows/)
+ Fire Safe San Mateo County, Windows: [https://firesafesanmateo.org/preparedness/home-hardening/windows](https://firesafesanmateo.org/preparedness/home-hardening/windows)

Garage Doors (1.3.3)

Main Concern(s):
Roll up garage doors present vulnerabilities to the structure. These doors are not typically sealed very well due to lack of heating or cooling in these spaces. Gaps around garage doors provide entry point for embers into the garage structure. Homeowners often have large amounts of storage and other types of combustible fuels in garages, which may present higher risks if embers enter the garage space. Garages are not typically finished out with drywall, so the open studs provide exposed combustible material that is vulnerable to ignition. Some garage doors are also provided with small windows. These windows are vulnerable to direct flame impingement. For more information, see windows section.

Key Terminology:
+ Weather Strip: A strip of material to cover the joint of a door or window and the sill, casing, or threshold so as to exclude rain, snow, and cold air. 
+ Sectional Garage Doors: Sectional garage doors are made up of panel sections that are connected with hinges. As the door opens and closes, wheels at the edge of each panel roll inside a vertical track on each side of the door opening.

Wall Systems 1.3

Fire Rated Assemblies:
Residential roll up garage doors are not fire rated.

Fire Test Standards:

Referenced Codes & Standards:
+ International Wildland Urban Interface (IWUI) Code: No explicit requirements
+ California Building Code (CBC): No explicit requirements
+ NFPA 1144 Standard for Reducing Structure Ignition Hazards from Wildland Fire: No explicit requirements

Other Codes & Standards:
Codes and standards will vary depending on location and adoption in individual jurisdictions.
+ Check local, county, and state amendments for additional wildfire codes and standards.
+ Check local general plan, multi-hazard mitigation plan, or zoning documents for any additional requirements.
+ IRC (if applicable – check for wildfire amendments).

Typical Design, Vulnerability, & Mitigation Considerations:

<table>
<thead>
<tr>
<th>Garage Door Types</th>
<th>Vulnerability &amp; Mitigation Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sectional Garage Doors</td>
<td>Sectional garage doors are the most common. These doors, if not sealed well, present openings around the edges for embers to enter the garage.</td>
</tr>
<tr>
<td>Slide to the Side Doors</td>
<td>Slide to the side doors are similar to sectional doors, however these doors slide to the side instead of retracting overhead. These doors face the same vulnerabilities as sectional doors.</td>
</tr>
</tbody>
</table>
Mitigation Strategies:

+ Refer to Typical Design, Vulnerability and Mitigation Considerations for additional mitigation options.
+ Install ignition resistant or noncombustible framing materials (e.g., metal or metal-clad wood).
+ Ensure any weather stripping is in good condition and provides a tight seal.
+ Consider using tempered glass, where glass panels are provided, which is stronger than annealed glass and will provide additional protection during a wildfire.
+ During a wildfire event, make sure all windows remain closed to avoid ember intrusion into structures.
+ Relocate any combustible or hazardous materials away from garage door or other openings to limit ignition, in the event embers enter the garage space.
+ Ensure storage of goods and other hazardous materials are properly maintained and in appropriate containers, and that general housekeeping is maintained.
+ Manage vegetation and other types of items that could catch fire in the areas nearest to garage doors. This includes maintaining the surrounding vegetation and using noncombustible mulch and ignition resistant materials for yard and garden structures near garages.  

Training:

+ NFPA – Assessing Structure Ignition Potential from Wildfire

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117 Debbie Dey, "What are the 6 Types of Garage Doors? (And How to Choose One)," puls, accessed July 2022, https://blog.puls.com/what-are-the-6-types-of-garage-doors.
**Wall Systems 1.3**

**Gaps in Knowledge:**

+ Field and/or lab research is limited on the performance of garage doors during wildfire events.
+ Fire testing of sealants around garage doors for radiant heat, direct flame impingement and/or ember exposure is currently unavailable.
+ Methods for providing fire protection for concrete surface below the garage door where the concrete has settled.

**Other References:**

+ University of California, Fire in California, Windows: [https://ucanr.edu/sites/fire/Prepare/Building/Windows](https://ucanr.edu/sites/fire/Prepare/Building/Windows)
+ Fire Safe Marin, Fire Resistant Windows: [https://firesafemarin.org/harden-your-home/fire-resistant-windows](https://firesafemarin.org/harden-your-home/fire-resistant-windows)
+ Fire Safe San Mateo County, Windows: [https://firesafesanmateo.org/preparedness/home-hardening/windows](https://firesafesanmateo.org/preparedness/home-hardening/windows)
Windows (Including Dormer/Attic Windows) (1.3.4)

Main Concern(s):

Windows can compromise a home’s ability to survive a wildfire when precautions are not taken to prevent them from being an entry point for embers and/or flames. During a wildfire, a window can be compromised due to an extended radiant heat exposure from surrounding vegetation or to flames when embers have ignited vegetative debris near the window. The glass is the most vulnerable part of the window. If the glass in a window breaks during a wildfire, embers and flame can easily enter a structure. Similarly, combustible window frames can ignite or fail, leading to ember intrusion and ultimately ignition of other material inside of the structure. Therefore, windows must be able to resist the following exposures.\textsuperscript{119}

\begin{itemize}
  \item A radiant exposure severe enough to break the glass in a window or ignite the exterior siding directly below it. Burning vegetation in close proximity to a window could also ignite combustible siding.\textsuperscript{120}
  \item A flame contact exposure could result from embers igniting vegetation and/or exterior cladding that burns up to the window(s).\textsuperscript{121}
\end{itemize}

Glass breakage occurs because of thermally induced strains caused by temperature differences between the shielded glass near the frame edge and the exposed glass away from the frame. This non-uniform heating causes the glass to expand at different rates.\textsuperscript{122} The presence of a rigid frame also restrains the glass from expanding, leading to cracking of the glass. If the temperature differences are large enough, the cracks grow potentially leading to failure of glass and fall out.

Key Terminology:

\begin{itemize}
  \item **Double-Pane Window:** Window provided with two panes of glass in order to slow the heat transfer across the window. This also provides a security factor should one pane break during a fire event.
\end{itemize}


\textsuperscript{120} Division of Agriculture and Natural Resources, University of California.

\textsuperscript{121} Division of Agriculture and Natural Resources, University of California.

\textsuperscript{122} Division of Agriculture and Natural Resources, University of California.
Fire Rated Assemblies:
Windows can comply with several different requirements in order to resist the effects of fire. Applicable options are as follows:
+ Be constructed of multi-pane glazing with a tempered pane.\(^{123}\)
+ Be constructed of glass block units.\(^{124}\)
+ Have a fire-resistance rating of not less than 20 minutes when tested in accordance with NFPA 257.
+ Have a fire-resistance rated glazing with performance tested in accordance with ASTM E119.

Fire Test Standards:
+ ASTM E 2112 Standard Practice for Installation of Exterior Windows, Doors, Skylights: [https://www.astm.org/e2112-19c.html](https://www.astm.org/e2112-19c.html)
+ NFPA 257 Standard on Fire Test for Window and Glass Block Assemblies

Referenced Codes & Standards:
+ International Wildland Urban Interface (IWUI) Code: 2018 International Wildland Urban Interface Code (IWUI) Chapter 5, Sections 504.8, 505.8 Exterior Glazing
+ NFPA 257 Standard on Fire Test for Window and Glass Block Assemblies
+ NFPA 252 Standard Method of Fire Tests of Door Assemblies
+ NFPA 80 Standard for Fire Doors and Other Opening Protectives

Other Codes & Standards:
Codes and standards will vary depending on location and adoption in individual jurisdictions.
+ Check local, county, and state amendments for additional wildfire codes and standards.
+ Check local general plan, multi-hazard mitigation plan, or zoning documents for any additional requirements.
+ IRC (if applicable – check for wildfire amendments).

\(^{123}\) Rodolfo Uribe, Factors Leading to Structure Loss on the Thomas Fire (San Luis Obispo: California Polytechnic Institute, 2021), [https://digitalcommons.calpoly.edu/theses/2341](https://digitalcommons.calpoly.edu/theses/2341)

\(^{124}\) Uribe.
### Wall Systems 1.3

#### Typical Design, Vulnerability, & Mitigation Considerations:

<table>
<thead>
<tr>
<th>Window Types</th>
<th>Vulnerability &amp; Mitigation Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>General</strong></td>
<td>• The wall aspect, as well as whether the window or glazed unit is facing the wildfire or burning structure will markedly influence its performance. Prioritizing mitigations for single-pane or large-bay window that are facing potential high-fire exposure (e.g., continuous dense vegetation, drainages, ravines, steep aspects, structures within 30').</td>
</tr>
<tr>
<td><strong>Single Pane</strong></td>
<td>• Testing has shown that single-pane windows are highly vulnerable to breaking when exposed to wildfire conditions.</td>
</tr>
<tr>
<td><strong>Double or Triple Paned</strong></td>
<td>• Testing has shown that dual-pane and triple-pane windows provide better wildfire protection. In fire tests, the outer pane of glass has been observed to break in some cases but has not fallen out. In all cases, the inner panes of glass remain intact.</td>
</tr>
<tr>
<td></td>
<td>• Multi-pane window also provide added protection to ember strikes or other flying debris during a wildfire that could cause the glass fail due to impact alone. For these types of windows, the inner panes remain intact limiting ember intrusion.</td>
</tr>
<tr>
<td><strong>Large-Bay Windows</strong></td>
<td>• Large bay windows increase the vulnerability of the structure due to the size and surface of the windows.</td>
</tr>
<tr>
<td><strong>Wooden and Plastic Frames</strong></td>
<td>• Wooden and plastic frames are highly combustible, and are at high risk of igniting, melting and failing leading to failure and/or fall out of the glazing. Debris should be kept clear of framing materials. If possible, replace framing with noncombustible materials such as metal.</td>
</tr>
<tr>
<td><strong>Metal framing</strong></td>
<td>• Metal window framing is noncombustible and there would not be susceptible to ignition. However, metals have relatively high thermal conductivity that can transfer heat and high temperature to combustible materials inside a building if not provided with noncombustible insulation (e.g., mineral wool) to limit thermal transmission. Multi-pane window also provide added protection to ember strikes or other flying debris during a wildfire that could cause the glass fail due to impact alone. For these types of windows, the inner panes remain intact limiting ember intrusion.</td>
</tr>
<tr>
<td></td>
<td>• In some cases, metal framing can be more rigid/stiff compared to wooden or plastic frames, which may make the window/glazed unit more susceptible to thermal stresses, cracking and fallout of the glass pane.</td>
</tr>
</tbody>
</table>

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126 Fire Safe Marin.
### Typical Design, Vulnerability, & Mitigation Considerations cont.:

<table>
<thead>
<tr>
<th>Glass Type</th>
<th>Details</th>
</tr>
</thead>
</table>
| Laminated Glass                     | • Provides resistance to windborne firebrands. If a firebrand strikes with enough momentum to break the glass, the plastic film in the core of the glass will keep the glazing in the frame, allowing the broken glass to continue to resist firebrand impacts, embers, and hot gases. If the plastic film in the core gets sufficiently hot, the pane will delaminate whether the glass has been broken or not.  
  • If laminated glass is present, it should either be protected by shutters, or combined with tempered glass in an IGU.  |
| Tempered Glass                      | • More resistant to heat and flames than laminated glass or annealed glass. The resistance of tempered glass can be enhanced with a low-e coating or proprietary reflective coating. Firebrands with sufficient momentum can break tempered glass.  
  • To avoid breakage, the glass can be protected by shutters.  
  • Another alternative is to specify and install an IGU with a laminated glass inner pane.  |
| Low Emissivity Coated Glass         | • Provides a higher level of resistance to radiant heat than other types of glazing because the coating reflects radiant heat, reducing the probability that the heat will be able to enter the building. The coating should be on the inner surface of the exterior pane.  |
| Proprietary Fiberglass Reinforced    | • Proprietary fiberglass-reinforced translucent glazing material. The window glazing material has a Class A rating.  |
| Translucent Glazing                 |                                                                 |
| Insulated Glazing Unit (IGU)        | • An IGU consists of two or three panes of glass that are separated by a sealed air space. Double-paned annealed units last about 10 minutes in a wildfire, which is about twice as long as single-paned windows.  
  • In many cases, 10 minutes is long enough to provide protection from the fire. If the first pane fails, the second pane must still be penetrated. Laminated glass, tempered glass, and glass with a low-e coating can be combined in various ways into an IGU.  |

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128 FEMA.
129 FEMA.
130 FEMA.
131 FEMA.
132 FEMA.
133 FEMA.
134 FEMA.

Mitigation Strategies:

+ Refer to Typical Design, Vulnerability and Mitigation Considerations for additional mitigation options.
+ Install ignition resistant or noncombustible framing materials (e.g., metal or metal-clad wood).
+ Replace old single-pane windows with dual-pane windows.
+ Close all window during a wildfire or before leaving during evacuation.
+ Consider using tempered glass, which is stronger than annealed glass and will provide additional protection during a wildfire.\textsuperscript{135}
+ Consider using insect screens. Screens fabricated from noncombustible materials are preferred.
+ Fabricate covers (for example, 1/2" plywood covers), cut to size and marked so that it can easily be installed over a window prior to evacuation. Shutters or other roll-down devices could also be installed.\textsuperscript{136}
+ During a wildfire event, make sure all windows remain closed to avoid ember intrusion into structures.
+ Install noncombustible window screens of at least 1/16”.
+ Manage vegetation and other types of items that could catch fire in the areas nearest to windows. This includes maintaining the surrounding vegetation and using noncombustible mulch and ignition resistant materials for yard and garden structures near windows.\textsuperscript{137}
+ Exterior shutters can provide protection in a wildfire. Solid metal shutters that are unlikely to ignite or melt are therefore recommended over wooden or plastic shutters. For enhanced protection, an insulated metal shutter can be designed and fabricated. If the building is located in a windborne debris region within a hurricane-prone region, the shutter should meet the windborne debris criteria in ASCE 7-05. Note that temporary shutters are only effective if the homeowner has sufficient time to put the shutters into place.\textsuperscript{138}
+ The recommended glazing products for homes in wildfire zones are laminated glass, tempered glass, glass with a low-emissivity, fiberglass-reinforced translucent glazing, and insulated glazing units (IGUs). Glazing products that are not recommended are annealed glass, ceramic glass, and plastic glazing.\textsuperscript{139}

\textsuperscript{135} Division of Agriculture and Natural Resources, University of California, "Windows," Homeowner's Wildfire Mitigation Guide, accessed April 2022, \url{https://ucanr.edu/sites/Wildfire/Side_of_House/Windows}.
\textsuperscript{136} Division of Agriculture and Natural Resources, University of California.
\textsuperscript{137} Insurance Institute for Business & Home Safety, "Protect Your Property from Wildfire: California Edition," Northstar Community Services District, accessed April 2022, \url{https://www.northstarcd.org/media/Fire/Prevention/Defensible%20Space.pdf}.
\textsuperscript{139} FEMA.
Training:
+ NFPA – Assessing Structure Ignition Potential from Wildfire

Gaps in Knowledge:
+ Some gels and foams marketed for structure protection during wildfires indicate they will also protect windows, but verification of these claims by an independent source is not currently available. 140
+ Glass breaking and/or fall-out is still within the realm of active fire testing and research for all the ranges of glazing types with associated frame types (e.g., wood, vinyl, aluminum, vinyl- and aluminum-clad wood, and fiberglass).
+ Theoretically it would be possible to polish the edges of the glass for windows, thereby minimizing the number of edge flaws present, making the glass less vulnerable. Whether this could be a long-term solution in terms of maintaining the polished edge during the processing in making the window has not been determined. 141

Other References:
+ University of California, Fire in California, Windows: https://ucanr.edu/sites/fire/Prepare/Building/Windows/
+ Fire Safe Marin, Fire Resistant Windows: https://firesafemarin.org/harden-your-home/fire-resistant-windows/
+ Fire Safe San Mateo County, Windows: https://firesafesanmateo.org/preparedness/home-hardening/windows


Joints (Around Windows, Doors, Bottom-of-Wall to Foundation, and Wall-to-Wall Intersections) (1.3.5)

Main Concern(s):
In general, joints create gaps in the continuity of a fire rated or ignition resistant wall assembly, presenting a potential avenue for embers, hot gases, or flames to breach the wall assembly and into the building interior. Joints can also create places for the accumulation of combustible debris that can be easily ignited by embers, hot gases, or direct flaming. Embers can oftentimes accumulate at windowsills, door framing, and at wall-to-wall intersections, creating a concentrated source of heat that may compromise the integrity of the wall, window, or door. In addition, there is currently no fire test for joints in wall assemblies to wildfire exposures—embers, direct flaming, or hot gases. This can create a short-circuit of a fire resistance rated (e.g., 1-hour, 2-hour), ignition resistant, or fire resistive exterior wall.

Applying fire caulking around window-to-wall joints.  
Gaps in door undercuts.
Wall Systems 1.3

Fire Test Standards:
Currently, there is no fire test standard to evaluate ember intrusion, direct flame impingement or thermal transmission of heat via convection or radiation from wildfires for joint systems (wall joints or otherwise).

Key Terminology:
+ **Joint**: The opening in or between adjacent assemblies that is created due to building tolerances or is designed to allow independent movement of the building in any plane caused by thermal, seismic, wind or any other loading.\(^{142}\)
+ **Fire-Resistant Joint System**: An assemblage of specific materials or products that are designed, tested and fire-resistance rated in accordance with a standard fire test to resist for a prescribed period of time the passage of fire through joints made in or between fire-resistance-rated assemblies.\(^{143}\) (Note: There are currently no fire-resistant joint system tests for wildfire exposures.)
+ **Flashing**: A thin metal that is installed at joints to protect against intrusion of unwanted elements such as water and embers.
+ **Expansion Joint**: A physical discontinuity that spans the entire breadth of an element in a building, creating two separate sections of the element instead of one bigger one. They are designed and configured to allow the different building sections to move independently of each other, so the structures don’t become overstressed and crack or break\(^{144}\) under various loads (e.g., thermal expansion/contraction, seismic movement).

Fire Classification & Ratings:
Currently, there is no fire test standard to evaluate ember intrusion, direct flame impingement or thermal transmission of heat via convection or radiation from wildfires for joints in wall assemblies. Fire rated joints are necessary in order to maintain a walls assembly’s fire rating, integrity and continuity to wildfire exposure. While a variety of fire tests exist for joints in interior building fire exposures (e.g., ASTM E1966 or UL 2079), none are explicitly designed for the fire conditions presented by wildfires. A range of joint systems (e.g., static joints, movement joints) and joint conditions (e.g., window-to-wall, door-to-wall, wall-to-wall, expansion joints) for exterior wildfire exposures are still needed.

Referenced Codes & Standards:
+ **International Wildland Urban Interface (IWUI) Code**: No explicit requirements
+ **California Building Code (CBC)**: No explicit requirements
+ **NFPA 1144 Standard for Reducing Structure Ignition Hazards from Wildland Fire**: No explicit requirements

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\(^{143}\) International Code Council, Inc.

## Wall Systems 1.3

### Typical Design, Vulnerability, & Mitigation Considerations:

<table>
<thead>
<tr>
<th>Joint Types at Exterior Walls</th>
<th>Design, Vulnerability, &amp; Mitigation Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wall-to-Wall Joints</strong></td>
<td>Static wall joints between different wall systems or panels can create construction gaps providing an avenue for embers, hot gases, and/or flame to enter the building. To increase the resistance of these joints to wildfires, various systems are available depending on the wall construction type and location in the wall (e.g., mid wall or corner). For example, for typical wood stud wall construction with composite panel siding, metal flashing with an underlying mineral surfaced cap sheet can be incorporated into the assembly. For concrete-to-concrete wall construction, 1&quot; and 1.5&quot; polyethylene backer rod compressed into the joint and recessed 1/2&quot;, followed by a minimum 1/2&quot; fire sealant flush to the exterior wall surfaces (same to the interior side of the walls). Combustible materials are often used to fill wall joints, and thus it’s important to confirm that fire rated firestopping products (e.g., sealants, caulking) are used to limit ignition of combustible fillers and provide a proper seal on the exterior surface of the joint.</td>
</tr>
<tr>
<td><strong>Window-to-Wall Joint</strong></td>
<td>Windows can oftentimes have gaps around the interface of the window frame and the wall assembly. These gaps can create an avenue for embers, hot gases and/or flame to enter the building, even if the window is fire rated. As windowsills and frame can also provide a location for debris and/or embers to collect, maintaining a proper joint protection system is key. Window construction should typically incorporate the use of rigid cap flashing at the bottom-of-wall-top-of-window between the underlayment and wall siding. However, this may not always be the case. Depending on the size of the gaps and type of weather seals need around the edges of the window joint, a range of firestopping and/or through penetration materials/products may be needed. This may include the use of firestopping products (e.g., sealants, caulking) to limit ignition of combustible fillers and provide a proper seal on the exterior surface of the joint. Ensure there is no vegetation or other combustible materials within 5’ of windows.</td>
</tr>
<tr>
<td><strong>Doors-to-Wall</strong></td>
<td>Doors, due to their functional need for opening and closing, present numerous gaps around the interface of doors, the door frame and the wall assembly. These gaps can create an avenue for embers, hot gases and/or flame to enter the building, even if the window is fire rated. Door construction should incorporate the use of rigid cap flashing around the joint of the wall-to-door frame interface, between the underlayment and wall siding. However, this may not always be the case. Depending on the size of the gaps and type of weather seals needed around the edges of the door frame-to-wall joint, a range of firestopping and/or through penetration materials/products may be needed. This may include the use of firestopping products (e.g., sealants, caulking) to limit ignition of combustible fillers and provide a proper seal on the exterior surface of the joint.</td>
</tr>
</tbody>
</table>

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145 University of California, Agriculture and Natural Resources, “Roof,” Fire in California, accessed May 2022, [https://ucanr.edu/sites/fire/Prepare/Building/Roof/](https://ucanr.edu/sites/fire/Prepare/Building/Roof/)
### Wall Systems 1.3

#### Typical Design, Vulnerability, & Mitigation Considerations cont.

<table>
<thead>
<tr>
<th>Doors-to-Wall cont.</th>
<th>In addition, to accommodate the functional movement of doors, gaps around the top, side and undercut of the door can range from 1/8” (around top and sides) up to ¾” (bottom of door). These gaps should be provided with weather stripping or gaskets to limit the intrusion of embers. All combustible materials should be cleared away from doors both interior and exterior spaces. Ensure there is no vegetation or other combustible materials within 5’ of glass doors.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expansion Joint</td>
<td>Exterior wall expansion joints are not very common in residential homes but can be found in commercial building. The joint allows the wall assembly to expand and contract in sync with the building, without compromising the wall. Wall expansion joints accommodate a range of building movements, such as thermal movement (most common), wind sway (more common for tall buildings), seismic activity (common in high seismic regions), building settlement (common where new construction connects to an existing building). There are numerous types of details and systems to accommodate these movements. Expansion joints typically consist of a joint cover to protect the joint from weather elements (e.g., water, dirt, dust). The materials used at the expansion joint can consist of a range of combustible and noncombustible materials (e.g., foam, neoprene, sealant, metal). If the materials are combustible or have metal flashing without sufficient, noncombustible thermal insulation, they can present a vulnerability in the wall assembly for embers, hot gases or flames. Surface mounted covers require a square, clean joint. Be mindful of floor fire barriers above and below for proper transitioning.</td>
</tr>
</tbody>
</table>
| Bottom-of-Wall to Foundation | The joints between the wall footer and façade cladding may create small gaps, or corners. These gaps are intentional to allow moisture to ventilate from behind the siding. However, these gaps encourage dry leaves, pine needles, and other combustible litter or debris to gather. Debris ignition from flying embers would present a source of flame exposure to the façade and structure.  
- Clapboard (also known as bevel siding, lap siding, and weatherboard) is a type of siding of a building that comes in long, narrow planks installed horizontally, often overlapping. This is a common design that creates gaps between the cladding and foundation. These gaps should be blocked with firestopping materials (e.g., mineral wool, fire caulkings and sealants).  
- Horizontal siding with more complicated lap joints (e.g., tongue and groove and ship lap) are more resistant to flame penetration into the stud cavity.\(^{146}\) |

Wall Systems 1.3

Other Codes & Standards:
Codes and standards will vary depending on location and adoption in individual jurisdictions.
+ Check local, county, and state amendments for additional wildfire codes and standards.
+ Check local general plan, multi-hazard mitigation plan, or zoning documents for any additional requirements.
+ IRC (if applicable – check for wildfire amendments).

Mitigation Strategies:
+ Refer to Typical Design, Vulnerability and Mitigation Considerations for additional mitigation options.
+ All combustible materials should be cleared away from doors both on the interior and exterior sides.
+ Ensure there is no vegetation or other combustible materials within 5’ of windows and glass doors.
+ Clear debris from windowsills, wall-to-wall joints and other surfaces where combustible debris collects near wall joints.
+ Seal any gaps at wall joints with firestopping and through-penetration systems as needed to maintain the continuity of the exterior wall assembly.
+ Repair damage to foundation wall and cladding to reduce the accumulation of embers and fire brands between damaged materials.

Training:
+ NFPA – Assessing Structure Ignition Potential from Wildfire

Gaps in Knowledge:
+ Currently, there is no fire test standard to evaluate ember intrusion, direct flame impingement or thermal transmission of heat via convection or radiation from wildfires for joint systems.
+ It is unclear how susceptible various wall joints or functional gaps around doors are to wildfire exposures.

Other References:
Architectural Embellishments & Ornaments (1.3.6)

Main Concern(s):
Architectural embellishments are decorative in nature and not part of the engineered structure. In this sense these attachments do not add to the structure's stability but can significantly compromise the structure by providing locations for ember accumulation or transfer of heat through connecting methods to the structure itself. In some cases, the architectural features can present a fuel load itself, if comprised of combustible, unprotected materials. Some balconies on buildings are solely architectural embellishments, where they are purely for aesthetics and not load-bearing. (Note: Refer to balcony section for additional information where decorative balconies are provided.)

Key Terminology:
+ **Architectural Embellishment**: A decorative detail or feature added to the exterior of the building to enhance the aesthetics.
+ **Ornament**: An applied embellishment in various styles that is a distinguishing characteristic of buildings. Ornamentation often occurs on entablatures, columns, and the tops of buildings and around entryways and windows, especially in the form of moldings.  

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Wall Systems 1.3

Fire Classification & Ratings:
There are currently no fire classifications or ratings for architectural embellishments and ornaments.

Fire Test Standards:
Currently, there is no fire test standard to evaluate the performance of architectural embellishments during wildfires. There are also no fire tests to assess the contribution of these architectural features to the vulnerability of buildings in wildfire incidents (e.g., if they significantly contribute to building ignition, heat transfer to interior spaces, lead to ignition of exterior walls).

Referenced Codes & Standards:
+ International Wildland Urban Interface (IWUI) Code: No explicit requirements
+ California Building Code (CBC), 2019: Section 710A Accessory structures
+ NFPA 1144 Standard for Reducing Structure Ignition Hazards from Wildland Fire: No explicit requirements

Other Codes & Standards:
Codes and standards will vary depending on location and adoption in individual jurisdictions.
+ Check local, county, and state amendments for additional wildfire codes and standards.
+ Check local general plan, multi-hazard mitigation plan, or zoning documents for any additional requirements.
+ IRC (if applicable – check for wildfire amendments).

Mitigation Strategies:
+ Remove combustibles (e.g., furniture, firewood, BBQs, mulch, non-fire adapted vegetation, ornamental landscaping) from areas under decorative overhangs that could create a localized fire that ignites these decorative features.
+ Seal any openings that may allow passage of embers or flame into structure with firestopping and fire caulking.
+ Upgrade attachment points of artwork and other decorative panels such that they fixed further away from the exterior wall where embers could collect.
+ Consider replacing combustible architectural embellishments with noncombustible materials.
### Typical Design, Vulnerability, & Mitigation Considerations:

<table>
<thead>
<tr>
<th>Architectural Embellishments</th>
<th>Design, Vulnerability, &amp; Mitigation Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Decorative Overhang/Balconies</strong></td>
<td>Decorative overhangs &amp; balconies can be constructed of a range of combustible and noncombustible materials. The combustible materials could present sources of fuel, particularly as these types of features collect debris, pine needles and other fuels over time. Decorative overhangs/balconies can also provide locations where embers can accumulate and potentially create hot spots where heat can transfer to the exterior wall causing ignition. Furthermore, the attachments where the overhang connects to the structure may present a gap or breach in the continuity of the exterior wall envelope and fire rated wall assembly (where applicable). Where possible, architectural embellishments should be comprised of noncombustible materials or fire retardant treated wood. Debris and other vegetative materials should be regularly cleaned off these elements. Firestopping should also be provided for any gaps around connection points to the exterior wall systems or building structure.</td>
</tr>
<tr>
<td><strong>Decorative Shutters, Wall Panels &amp; Artwork</strong></td>
<td>Decorative shutters, wall attachment and artwork can be constructed of a range of combustible and noncombustible materials. The combustible materials could present sources of fuel, particularly as these types of features collect debris, pine needles and other fuels over time. These decorative features can also provide locations where embers can accumulate and potentially create hot spots where heat can transfer to the exterior wall causing ignition. Furthermore, the attachments where the overhang connects to the structure may present a gap or breach in the continuity of the exterior wall envelope and fire rated wall assembly (where applicable). Where possible, these decorative features (if combustible) could be attached off the wall to prevent ember collection and thermal heat transfer.</td>
</tr>
<tr>
<td><strong>Other Decorative Trims, Moldings and Treatments</strong></td>
<td>These features can collect vegetative debris and other fuels over time. Regular clearing of these materials and general housekeeping can minimize the risk of ignition.</td>
</tr>
</tbody>
</table>
Wall Systems 1.3

Training:
+ NFPA – Assessing Structure Ignition Potential from Wildfire

Gaps in Knowledge:
+ There is no fire test standard to evaluate the performance of architectural embellishments during wildfires.
+ There are no fire tests to assess the contribution of these architectural features to the vulnerability of buildings in wildfire incidents (e.g., if they significantly contribute to building ignition, heat transfer to interior spaces, lead to ignition of exterior walls).
+ There are limited codes and standards on the resiliency of these elements to wildfires.
Balconies, Decks & Porches Construction & Surfaces (1.3.7)

Main Concern(s): Balconies and decks can pose a significant hazard in the event of a wildfire. One of the main concerns associated with balconies and decks is the large surface area they present for collecting embers, leading to ignition of materials located on the balcony/deck or the balcony/deck itself. Similar to eave overhangs, unique fire induced flows can lead to the accumulation of embers and hot gases in the underside of balconies or elevated decks, potentially leading to ignition of the balcony/deck particularly where the framing elements are exposed and of combustible construction. In addition, most homeowners tend to store various types of combustible fuel loads below and on balconies/decks, such as combustible furniture, BBGs, wood piles etc. Balconies/decks can also introduce additional interfaces with the main structure, presenting numerous joints and potential gaps in the continuity of the exterior wall envelope, which may or may not be fire rated.

For decks and other similar features (e.g., stairs) that are at or near grade, these building components are also susceptible to direct flame impingement from surface fuels and other proximate vegetation. Many existing commercial or residential decks are constructed with less expensive, combustible materials such as untreated woods, plastics, and wood-plastic composite products, which are vulnerable to ember and heat exposure in a wildfire event. Decks are often built at the top of a slope, likely in direct line of a wildfire. Therefore, building and deck orientation must be considered. Embers and firebrands can easily become trapped under and around the deck/patio. Material selection, orientation, design, storage and landscaping practices around the deck are all critical to reducing the risk of ignition of the deck and the home.

Key Terminology:
+ **Balcony**: A platform enclosed by a wall or balustrade on the outside of a building, with access from an upper-floor window or door.\(^{149}\)
+ **Deck**: A flat surface capable of supporting weight, similar to a floor, but typically constructed outdoors, often elevated from the ground, and usually connected to a building.\(^{150}\)
+ **Flashing**: A sheet of thin, impervious material used to prevent water penetration or seepage into a building and to direct the flow of moisture in walls.\(^{151}\)

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**Fire Classification & Ratings:**

As occupiable floor areas, balconies are oftentimes treated as floor assemblies by code. As such, balconies and their supporting construction can achieve fire-resistance ratings (e.g., 1-hour, 2-hour).

There are currently no fire rated floor assemblies to a wildfire exposure. That said, most exterior floor spaces requiring a fire rating are based on interior building fire test standards. The fire resistance of floor assemblies to interior fire exposures is defined by ASTM E119 or UL 263 Standard Test Methods for Fire Tests of Building Construction and Materials. This test standard is applicable to assemblies of masonry units and to composite assemblies of structural materials for buildings, including loadbearing walls and partitions, columns, girders, beams, slabs, and composite slab and beam assemblies for floors and roofs.\(^{152}\)

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\(^{149}\) Education4Each, “Balcony,” education4each.com, accessed April 2022, [https://education4each.com/balcony](https://education4each.com/balcony)

\(^{150}\) Prince George’s County, MD, “Decks,” Prince George’s County, MD, accessed April 2022, [https://www.princegeorgescountymd.gov/2662/Decks](https://www.princegeorgescountymd.gov/2662/Decks)


The standard is used to measure and describe the response of materials, products, or assemblies to heat and flame under controlled conditions, but does not by itself incorporate all factors required for fire hazard or fire risk assessment of the materials, products, or assemblies under actual fire conditions. This is due to limitations of the size of the specimens tested, size of the furnace, standard fire exposure, etc. However, the test standard is one of the most widely adopted methods for comparing the performance of building construction materials, elements, and assemblies to a standard fire exposure.153

The test method includes measurements of exposed and unexposed surface temperature, as well as the ability of an element or assembly to maintain structural stability, integrity and insulation when exposed to a severe, standard fire exposure. The standard fire exposure simulates severe interior building fire conditions during flashover conditions. Depending on how the floor assembly performs against the performance criteria for stability, integrity and insulation, the floor can achieve anywhere from a 1-hour up to a 4-hour fire resistance rating.

<table>
<thead>
<tr>
<th>Performance Category</th>
<th>Technical Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stability</td>
<td>The ability of a floor assembly to sustain the applied load during the fire-resistance test.</td>
</tr>
<tr>
<td>Integrity</td>
<td>The ability of a floor assembly to limit the passage of flame or gases hot enough to ignite cotton waste.</td>
</tr>
<tr>
<td>Insulation</td>
<td>The ability of the floor assembly to limit transmission of heat to the unexposed side such that the temperature on the unexposed surface does not exceed more than 250°F (139°C) above the initial temperature.</td>
</tr>
</tbody>
</table>

Note: In most cases, fire rated floors are typically rated as “assemblies.” This means that the entire floor assembly creates the containment. Thus, assessing the fire resistance rating of a floor assembly in the field will likely not be possible.

Additionally, the State of California, has its own set of State Fire Marshall Standards (SFM) which also test decking materials. Decking materials need to meet the performance requirements of these standards. Chapter 7A of the California Building Code provides a complete list of assembly options for the walking surface material of decks, porches, balconies and stairs in relation to the fire test standards listed below.

**Referenced Codes & Standards:**
- International Wildland Urban Interface (IWUI) Code, 2021: 504.6 & 505.6 Underfloor enclosure, 504.7 & 505.7 Appendages and projections
- California Building Code (CBC), 2019: Section 707A.7 Floor projection, 707A.8 Underfloor protection, 709A Decking
- NFPA 1144 Standard for Reducing Structure Ignition Hazards from Wildland Fire, 2018: Section 5.4 Overhanging Projections
  - A structural assessment rating form and guide included in Appendix A provides an assessment of siding and deck building construction material.

Fire Test Standards:

- ASTM D2898 Standard Practice for Accelerated Weathering of Fire-Retardant-Treated Wood for Fire Testing: [https://www.astm.org/d2898-10r17.html](https://www.astm.org/d2898-10r17.html)
- ASTM D6662 Standard Specification for Polyolefin-Based Plastic Lumber Decking Boards: [https://www.astm.org/d6662-17.htm](https://www.astm.org/d6662-17.htm)
- SFM Standard 12-7A.4, Decking: A two-part test consisting of a heat release rate (Part A) deck assembly combustion test with an under-deck exposure of 80 kW intensity direct flame for a 3-minute duration, and a (Part B) sustained deck assembly combustion test consisting of a deck upper surface burning ember exposure with a 12 mph wind for 40 minutes.
- SFM Standard 12-7A.4A Decking: Alternate Method A. A heat release rate deck assembly combustion test with an under-deck exposure of 80 kW intensity direct flame for a 3-minute duration.
- SFM Standard 12-7A.5 Ignition-resistant Material: A generic building material surface burning flame spread test standard consisting of an extended 30-minute ASTM E84 or UL 723 test method as issued for fire-retardant-treated wood.

Other Codes & Standards:

Codes and standards will vary depending on location and adoption in individual jurisdictions.

- Check local, county, and state amendments for additional wildfire codes and standards.
- Check local general plan, multi-hazard mitigation plan, or zoning documents for any additional requirements.
- IRC (if applicable – check for wildfire amendments).
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Typical Design, Vulnerability, & Mitigation Considerations:

<table>
<thead>
<tr>
<th>Types of Balconies and Decks</th>
<th>Design, Vulnerability, &amp; Mitigation Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balconies or Decks with Solid Surface Decking</td>
<td>Constructed using a continuous, solid surface (e.g., tiles, concrete or brick) on top of a substrate. A solid surface deck can be applied over a substrate, that has a polymer-based waterproofing membrane topping surface. The exposed walking surface can be a combustible or noncombustible material. Similar to solid surface decking, balconies with gapped board decking are also susceptible to ember exposure to the top of the deck. Additionally, embers and hot gases can become lodged or trapped under balconies and in the gaps between board decking. Consider using noncombustible or fire-resistant materials for decking surfaces, railings, and siding.</td>
</tr>
<tr>
<td>Balconies or Decks with Gapped Board Decking</td>
<td>Constructed using spaced deck boards (e.g., wood, plastic or wood-plastic composite products). Most commercially available deck boards are combustible (including redwood, cedar, ipe, and plastic composite lumber decking products). Balconies with solid surface decking are susceptible to ember exposure to the top of the deck. Additionally, embers and hot gases can become lodged or trapped under balconies. Consider increasing the size of the gap between deck boards to 1/4&quot; so that vegetative debris can fall through rather than accumulate on the deck. Consider using noncombustible or fire-resistant materials for decking surfaces, railings, and siding.</td>
</tr>
</tbody>
</table>

Mitigation Strategies:

+ For exposed undersides of balconies and decks of combustible construction, consider enclosing to grade (with solid fire-resistant materials or 1/16" screening) or replacing structural supports and exposed underside of the balcony or deck with (1) noncombustible material, (2) ignition-resistant material, (3) one layer of 5/8" Type X gypsum sheathing applied behind an exterior covering on the underside of the balcony or deck (4) the exterior portion of a 1-hour fire resistive exterior wall assembly applied to the underside of the balcony or deck. Note: Heavy timber supporting elements do not require protection.156
+ Provide a fire resistant coating over wood surfaces and elements to enhance fire resistant characteristics, apply at cycles recommended by manufacturer. Alternatively replace with fire-retardant treated wood.
+ Create an ember-resistant zone (0-5') around and under the deck, and make sure that all combustible items are removed from underneath and around the deck (this is especially important to maintain where a deck overhangs a slope). Lay weed barrier or gravel under and around the deck to prevent vegetation from growing under or near the deck.
+ Replace combustible furniture with noncombustible materials, where kept on or under balconies or decks.
+ At the connection point of decks and balconies to the main structure, consider installing metal flashing on ledger boards that are attached without gaps to create a barrier to embers and prevent water from penetrating. Seal any gaps and joints with appropriate firestopping and fire caulking to prevent ember or flame intrusion.157

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155 FEMA.
+ Change any electrical fixture or box cover that is plastic with metal fixtures/cover.
+ Repair damage to deck/patio construction before they lose their fire-resistance, and to reduce the accumulation of embers and firebrands between damaged deck boards.
+ Keep the deck clear of debris, vegetation, combustible materials, (e.g., seat cushions, straw mats, rugs, pine needles, firewood, etc.). Remove needles and leaf litter from deck board gaps and the deck-to-house connection where embers may easily accumulate.

+ **Retrofitting the deck is also an option:**
  - If a deck is made of combustible decking materials, replace the board closest to the home with a noncombustible material.\(^{158}\)
  - Replace dimensional timber railings with railings constructed of fire-resistant materials such as metal, tempered glass, cables, or 3” nominal thickness fire-retardant-treated wood.\(^{159}\)
  - When the deck, balcony, stairs, or ramp can accommodate or be reinforced to accommodate additional load, install brick or concrete pavers and a suitable drainage mat over the existing decking.\(^{160}\)
  - Attach a corrosion-resistant metal flashing strip or noncombustible siding between the top of the deck, extending up the exterior combustible siding (minimum of 6”).\(^{161}\)

**Training:**
+ NFPA – Assessing Structure Ignition Potential from Wildfire

**Gaps in Knowledge:**
+ Wildfire building codes and standards do not provide a clear definition or distinction for balconies and decks. It is unclear which provisions are applicable.
+ Prioritized list of retrofit ideas which include the most effective methods to improve the fire resistance of existing decking.

**Other References:**
+ IBHS:
+ UC Extension, Agriculture, Biotechnology & Natural Resources:
  - Preparing Your Home, Decks: [https://ucanr.edu/sites/fire/Prepare/Building/Deck/](https://ucanr.edu/sites/fire/Prepare/Building/Deck/)


\(^{158}\) FEMA.

\(^{159}\) FEMA.

\(^{160}\) FEMA.

\(^{161}\) FEMA.
Structural Hardening
Bottom of Wall-to-Foundation
Crawl Space / Basement Vents  (1.4.1)

Main Concern(s):
The intrusion of embers through crawl space or basement vents is a major vulnerability that can lead to structure ignition during wildfires. The main concern with crawl space/basement vents is that they can provide several openings where windborne embers, convective heat and radiant heat from wildfires (particularly surface fuels) can be blown in or pulled into the structure leading to ignition of interior building contents and other building components. Both vent inlets and outlets are sources of vulnerability, as fire behavior can create reverse flows due to over-pressures further driving embers and hot gases into a building interior. Debris can also accumulate at crawl space/basement vent openings, providing a source of combustible fuels for ignition.

Key Terminology:
- **Crawl Space**: An unoccupied, unfinished, narrow space within a building, between the ground and the first (or ground) floor. The crawl space is so named because there is typically only enough room to crawl rather than stand (about 3’ to 5’).162
- **Crawl Space Vents**: Active or passive openings or vents through foundation walls or exterior walls providing aeration of the under-floor space between the bottom of the floor joists and the earth under a building (except space occupied by a basement).163

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**Fire Classification & Ratings:**

The ember and direct flame impingement resistance of vents mounted on vertical walls is defined by ASTM E2886 Standard Test Method for Evaluating the Ability of Exterior Vents to Resist the Entry of Embers and Direct Flame Impingement. This test standard prescribes two individual methods to evaluate the ability of the vent opening to resist embers and flame. The ability of such vents to completely exclude entry of flames or embers is not evaluated. Acceptance criteria are not provided in this standard. However, performance criteria are specified in the California Building Code (CBC), Section 706A.2 and NFPA 1144, Section 5.3.3.

<table>
<thead>
<tr>
<th>Vent Fire Test</th>
<th>Technical Description</th>
</tr>
</thead>
</table>
| Ember Penetration Test | This test method provides for a direct ember exposure to vents. The apparatus allows for embers to fall vertically and impinge on the vent mounted horizontally on ledges within the test chamber. An induction fan located at the bottom of the apparatus pulls the air stream through the vent, allowing any embers that pass through the vent to impinge on a combustible target material (e.g., cotton). [CBC and NFPA 1144 requirements – No flaming ignition of the cotton material, and maximum temperature of the unexposed side of the vent shall not exceed 662°F or 350°C.]

| Direct Flame Impingement Test | This test method provides for the evaluation of direct flame impingement on a vent mounted in a test assembly as described in Test Method E912. The flame source is directed into the test assembly and directly impinges the vent that is mounted in either a vertical or horizontal position. [CBC and NFPA 1144 requirements – No flaming ignition and maximum temperature of the unexposed side of the vent shall not exceed 662°F or 350°C.]

| Non-Mechanical Fire Dampers Used in Vented Construction | This fire-test-response standard assesses the ability of non-mechanical fire dampers used in vented construction in its open state to limit passage of hot gases, radiation, and flames during a prescribed fire test exposure. The fire exposure condition in this test method is sudden direct flame impingement, which produces these hot gases, radiation, and flames. This test method does not circumvent or eliminate the fire-resistance rating requirements for construction. |

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166 National Fire Protection Association.

Fire Test Standards:
+ ASTM E2886/E2886M-1 Standard Test Method for Evaluating the ability of Exterior Vents to Resist the Entry of Embers and Direct Flame Impingement: https://www.astm.org/e2886_e2886m-20.htm

Referenced Codes & Standards:
+ International Wildland Urban Interface (WUI) Code, 2021: 504.10 Vents
+ California Building Code (CBC): 706A Vents
+ NFPA 1144 Standard for Reducing Structure Ignition Hazards from Wildland Fire: 5.3.3 Vent Assemblies

Other Codes & Standards:
Codes and standards will vary depending on location and adoption in individual jurisdictions.
+ Check local, county, and state amendments for additional wildfire codes and standards.
+ Check local general plan, multi-hazard mitigation plan, or zoning documents for any additional requirements.
+ IRC (if applicable – check for wildfire amendments).

Mitigation Strategies:
+ Common 1/4" screens are ineffective and should be replaced.
+ Install vents that are listed to ASTM E2886.
+ Cover existing vents with wire mesh screen having openings with a maximum of 1/8". Preferably 1/16". Research has shown that 1/8" mesh screening can still lead to embers with sufficient energy to ignite fine fuels in the attics.
+ Replace screens that have painted over or detached from the substrate.
+ Vent and covering materials used shall be noncombustible and corrosion resistant. Do not use fiberglass or plastic mesh because they can melt and burn.169
+ Use fire rated caulking around penetrations to seal openings.
+ Inspect and maintain vegetation in the vicinity of crawl space vents.170 Remove combustible fuel loads including vegetation within 0-5’ of building perimeter.171

170 Division of Agriculture and Natural Resources, University of California, ‘Vents,’ Homeowner’s Wildfire Mitigation Guide, accessed April 2022, https://ucanr.edu/sites/Wildfire/Vents
+ Clean vents on a regular basis to minimize buildup of debris in the mesh.\(^{172}\)
+ Remove debris that accumulates near crawl space or basement vents.\(^{173}\)
+ Consider making vent covers that can be installed prior to the approach of a wildfire (and removed after the wildfire has passed).\(^{174}\)
+ Refer to Typical Design, Vulnerability and Mitigation Considerations for additional mitigation options.

**Typical Design, Vulnerability, & Mitigation Considerations:**

<table>
<thead>
<tr>
<th>Crawl Space Vent Type</th>
<th>Design, Vulnerability, &amp; Mitigation Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Active Venting</strong></td>
<td>In some cases, homes will be provided with mechanically circulated air for the crawl space or basement. In this case, the foundation walls are provided with insulation of an appropriate R-value for the regional climate and a vapor retarder. Active systems may not require the need of perimeter vent inlets in the crawl space, and therefore are not vulnerable to ember, hot gas or flame intrusion.</td>
</tr>
<tr>
<td><strong>Passive Venting</strong></td>
<td>Individual vents are the most widely used crawl space or basement vent type. The ventilation openings are typically 1 sq. ft. for each 150 sq. ft. of under-floor area unless the ground surface is covered by a Class 1 vapor retarder (then 1:1500). Passive crawl space vents are typically comprised of expanded sheet metal plates not less than 0.047&quot;, perforated sheet metal plates not less than 0.07&quot;, cast iron grill or grating, extruded load-bearing brick vents, hardware cloth of 0.035&quot; or and corrosion-resistant wire mesh of 0.125&quot;.(^{168}) As the vents are typically of metal, they are noncombustible and therefore will not ignite in a wildfire. However, most crawl space vents will only use screens of 1/4&quot; to keep out rodents. These screens are not small enough to limit the passage of embers. The noncombustible mesh should be no more than 1/8&quot;, preferably 1/16&quot;. Research has shown that 1/8&quot; mesh screening can still lead to embers with sufficient energy to ignite fine fuels in the attics. With finer mesh screening additional vents may be needed to satisfy building officials. In addition, crawl space/basement vents are of particular concern as they are located in close proximity to the grade level where vegetative debris and other combustible fuel loads accumulate or are stored. This presents high potential for embers, direct flame impingement and hot gases to directly enter the building and ignite a range of fuels that are often stored in basements. It’s critical to keep the 0-5’ zone around the perimeter of the building clear of any combustible fuel, as well as frequently maintained clear of vegetative debris, particularly in close proximity to the crawl space vents.</td>
</tr>
</tbody>
</table>


\(^{173}\) Fire Safe Marin.

\(^{174}\) Fire Safe Marin.
Training:

+ NFPA – Certified Wildfire Mitigation Specialist (CWMS) Certification

Gaps in Knowledge:

+ Fire testing does not account for weathering of materials prior to fire exposure or the impact of general wildfire environmental conditions (e.g., high winds, flying debris, impact from objects).
+ ASTM E2886 does not evaluate the ability of vents to completely exclude entry of flames or embers. 175
+ In most instances, it’s challenging to verify in-the-field if a vent has been fire-tested. (Professional judgement and discussion with the homeowner are required.)
+ Air flow calculations may need to be reconsidered or redesign where fire rated vents are installed in existing structures, to ensure sufficient airflow is still satisfied for non-fire purposes.

Other References:

+ FEMA – Home Builder’s Guide to Construction in Wildfire Zones:

Window / Light Well  (1.4.2)

Main Concern(s):
The design of the well creates deep corners with the exterior wall which encourages dry leaves, pine needles, and other combustible litter or debris to gather. Debris ignition would present a source of flame exposure to the structure, particularly at the window opening it surrounds. The configuration of these wells creates a hazardous condition where those combustible materials that have collected will be directly adjacent to the window and frame which already experience their own vulnerabilities.

Key Terminology:

- **Window / Light Well**: U-shaped, ribbed metal or plastic product designed to fit around basement windows, providing a space between the window and the surrounding earth to allow light into sub-grade structures. More notably, a window well can prevent water damage to a basement while also providing a route from an emergency escape and rescue opening with a finished sill height below the adjacent ground level during an emergency.\(^{176,177}\)

- **Window/lightwell covers**: A physical barrier between the well and the ground elements to prevent debris build-up in the well. The covering can be constructed of mesh, plastic bubble covers, grill-type, etc. Covers are also provided to prevent injuries from falls and to discourage children and animals from entering the wells and becoming injured or trapped.\(^{178}\)

- **Defensible Space**: The selection, location, grouping, and maintenance of vegetation on the property in such a manner that the opportunity for a fire to burn directly to a structure is minimized.\(^{179}\)

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\(^{176}\) Square One, “Window Wells,” Square One, September 12, 2022. [https://www.squrereone.ca/resource-centres/getting-to-know-your-home/window-wells](https://www.squrereone.ca/resource-centres/getting-to-know-your-home/window-wells)


\(^{178}\) Square One, “Window Wells.”

\(^{179}\) University of California, Agriculture and Natural Resources, “Defensible Space,” Fire in California, accessed April 2022. [https://ucanr.edu/sites/life/Prepare/landscaping/DefensibleSpace/](https://ucanr.edu/sites/life/Prepare/landscaping/DefensibleSpace/)
Bottom of Wall-to-Foundation 1.4

Fire Rated Assemblies:
No standard or tested assemblies exist for light wells installed in the Wildland Urban Interface.

Fire Test Standards:
None

Referenced Codes & Standards:
None

Example of aluminum window well grate. Example of window well components include drainage. Image courtesy of InterNACHI.

Other Codes & Standards:
Codes and standards will vary depending on location and adoption in individual jurisdictions.

+ Check local, county, and state amendments for additional wildfire codes and standards.
+ Check local general plan, multi-hazard mitigation plan, or zoning documents for any additional requirements.
+ IRC (if applicable – check for wildfire amendments).
Typical Design, Vulnerability, & Mitigation Considerations:

<table>
<thead>
<tr>
<th>Light Well Types</th>
<th>Design and Construction Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Window Wells</strong></td>
<td>Sizing for window wells need to account for fully equipped firefighters conducting emergency rescue operations. Window wells may be designed to provide an emergency point of egress in conjunction with emergency escape and rescue openings from windows below grade. Window wells may be designed to drain excess rainwater away from the building's foundation. Replace combustible lightwells and associated covers (e.g., polycarbonate plastic or fiber glass) with noncombustible materials. Maintain areas in and around lightwells to be clear of debris, and combustible materials. Do not store combustible items, such as firewood, in a lightwell.</td>
</tr>
<tr>
<td><strong>Window Well Covers</strong></td>
<td>Window well covers are generally custom fitted. Covers are generally constructed of mesh, plastic bubble covers, and grill-type metal. Bars, grilles, covers, and screens for window wells need to comply with minimum required opening sizes. These devices are required to be releasable or removable from the inside without the use of a key, tool, or force greater than that which is required for normal operation of any emergency escape and rescue opening that is being served. Window wells and their covers are often constructed with combustible materials such as plastic and bubble covers. It is recommended that covers be provided to keep debris out of the well. Recommend using noncombustible covers. Metal window well covers are referred to as grates and are generally implemented to protect the building from intrusion. Where a mesh cover is provided, clean vents on a regular basis to minimize buildup of debris in the mesh.</td>
</tr>
</tbody>
</table>

Gaps in Knowledge:

+ No codes or standards related to the appropriate design, installation, and material selection of light wells in the Wildland Urban Interface.
+ Wildfire home hardening guidance does not mention material selection or design of light wells.
+ Manufacturers do not have specific guidance for homeowners installing lightwells on their property in the Wildland Urban Interface.
+ No research has been conducted related to lightwell performance and impact in a wildfire.

Mitigation Strategies:

+ Replace combustible lightwells and associated combustible covers (e.g., polycarbonate plastic or fiber glass) with noncombustible materials.
+ Maintain areas in and around lightwells to be clear of debris, and combustible materials.
+ Do not store combustible items, such as firewood, in a lightwell.
+ Provide a lightwell cover, constructed of noncombustible material to limit build-up of debris in the lightwell.
+ Where a mesh cover is provided, clean vents on a regular basis to minimize buildup of debris in the mesh.
+ Provide a minimum of 6” noncombustible vertical separation between the bottom of the lightwell and the siding/exterior wall.
+ Refer to Typical Design, Vulnerability and Mitigation Considerations for additional mitigation options.

Training:

+ NFPA – Certified Wildfire Mitigation Specialist (CWMS) Certification
+ NFPA – Assessing Structure Ignition Potential from Wildfire

Other References:

+ NFPA 1144 Standard for Reducing Structure Ignition Hazards from Wildland Fire: 5.6.4. Exterior vertical walls
+ FEMA – Home Builder’s Guide to Construction in Wildfire Zones:
Foundation (1.4.3)

Main Concern(s):
The foundation of a building is often the first area to come into contact with a spreading wildfire, as it is the closest part of the structure to the ground. Debris can easily accumulate at the base of the foundation, which can be ignited by embers and surface fuels fires. These embers can ignite combustible foundation, siding, and penetrate crawl space vents and breach basement windows. Where the underside of the first floor is supported by pile or piers of combustible construction (i.e., timber), direct flaming impingement and/or embers could ignite the structure and lead structural instability and damage.

Key Terminology:

+ **Basement Foundation**: Full basement foundations cover the building’s perimeter and are typically constructed of poured concrete walls and footing approximately 6-8’ below ground level. Full basements can either be finished or unfinished; finished basements are insulated and installed with drywall and flooring, providing living and storage space. Unfinished basements are usually not insulated, and their walls and floors are left bare.

+ **Crawl Space Foundation**: Crawl space foundations are elevated several feet off footings, leaving a small, protected space (usually three or four feet) between the ground and base of the building. The foundation walls are built partially underground and shorter than basement foundation walls. They are shallower than full basements.

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3. **MT Copeland Technologies, Inc.**
Fire Rated Assemblies:

The fire resistance rating of foundation structural elements is determined by the construction type of the building. The fire resistance of structural elements and systems is defined by ASTM E119 or UL 263 Standard Test Methods for Fire Tests of Building Construction and Materials. This test standard is applicable to assemblies of masonry units and to composite assemblies of structural materials for buildings, including loadbearing walls and partitions, columns, girders, beams, slabs, and composite slab and beam assemblies for floors and roofs (inclusive of foundations). 186

The standard is used to measure and describe the response of materials, products, or assemblies to heat and flame under controlled conditions, but does not by itself incorporate all factors required for fire hazard or fire risk assessment of the materials, products, or assemblies under actual fire conditions. This is due to limitations of the size of the specimens tested, size of the furnace, standard fire exposure, etc. However, the test standard is one of the most widely adopted methods for comparing the performance of building construction materials, elements, and assemblies to a standard fire exposure. The test method includes measurements of exposed and unexposed surface temperature, as well as the ability of an element or assembly to maintain structural stability, integrity, and insulation when exposed to a severe, standard fire exposure. The standard fire exposure simulates severe interior building fire conditions during flashover conditions. Depending on how the floor assembly performs against the performance criteria for stability, integrity, and insulation, the structural element can achieve anywhere from a 1-hour up to a 4-hour fire resistance rating.

<table>
<thead>
<tr>
<th>Performance Category</th>
<th>Technical Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stability</td>
<td>The ability of the structural element or assembly to sustain the applied load during the fire-resistance test.</td>
</tr>
<tr>
<td>Integrity</td>
<td>The ability of a structural element or assembly to limit the passage of flame or gases hot enough to ignite cotton waste.</td>
</tr>
<tr>
<td>Insulation</td>
<td>The ability of a structural element or assembly to limit transmission of heat to the unexposed side such that the temperature on the unexposed surface does not exceed more than 250°F (139°C) above the initial temperature. Note: This is primarily for floor/roof assemblies.</td>
</tr>
</tbody>
</table>

**Fire Test Standards:**
- UL 263 Fire Tests of Building Construction and Materials: [https://global.ihs.com/doc_detail.cfm?document_name=UL%20263&item_s_key=00097028](https://global.ihs.com/doc_detail.cfm?document_name=UL%20263&item_s_key=00097028)

**Referenced Codes & Standards:**
- International Wildland Urban Interface (WUI) Code, 2021: No explicit requirements
- California Building Code (CBC), 2019: Section 707A.3.2 Extent of exterior wall covering shall extend from the top of the foundation to the roof, Section 602 Construction Classification, Section 703 Fire Resistance Ratings and Fire Tests
- NFPA 1144 Standard for Reducing Structure Ignition Hazards from Wildland Fire: 5.6.4 Exterior vertical walls

188 ASTM International.
**Typical Design, Vulnerability, & Mitigation Considerations:**

<table>
<thead>
<tr>
<th>Foundation Types</th>
<th>Design, Vulnerability, &amp; Mitigation Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Slab-on-Grade Foundation</strong></td>
<td>Slab-on-grade foundations are shallow foundations typically constructed of approximately 6” reinforced concrete (i.e., noncombustible) and footings 2’ into the ground. As the foundation directly rests on the ground below at a shallow depth, it is less vulnerable to exposure to embers, direct flame impingement or hot gases from wildfire threats. In particular, this foundation type does not have crawl space vents, which are vulnerable to ember intrusion. However, the portion of the foundation that is above grade has been shown in past fire incidents to experience high temperatures, leading to spalling and damage.</td>
</tr>
<tr>
<td><strong>Crawl Space Foundation</strong></td>
<td>Crawl space foundations are an elevated foundation with footings for support, typically raised 18” to 4’ above ground. Concrete or cinder blocks extend past the footings and close off unvented areas. As these foundations are primarily constructed of noncombustible materials, they are not vulnerable to ignition. Crawl space foundations are common in warm, moist climates where it is advantageous to raise the structure slightly off the ground to avoid moisture. To minimize moisture build-up in crawl spaces, crawl spaces require several vents around the perimeter of the foundation. As described in the crawl space vents section, these vents are highly vulnerable to ember intrusion, hot gases and/or direct flame breaching the interior crawl space to do surface fuel fires or other proximate vegetation to the crawl space vents catching fire. Refer to crawl space vent section for mitigations. Combustible items stored in basements or crawlspaces (such as household goods in cardboard boxes) can become fuel in a fire.</td>
</tr>
<tr>
<td><strong>Basement Foundation</strong></td>
<td>Full basement foundations consist of structural foundation walls that bear on foundation footings running along the perimeter. Basement foundations are typically constructed of concrete, cement block, brick, or stone. All these materials are noncombustible, and therefore less vulnerable to wildfire threats. That said, high intensity wildfires have been observed to cause spalling or other damage to the top of basement foundations that are above grade. Similar to crawl space foundations, full basements require some form of ventilation. Direct flame, embers, or hot gases can enter through crawl space vents or breached basement windows. Refer to crawl space/basement vents section for vulnerabilities and mitigations. Combustible items stored in basements or crawlspaces (such as household goods in cardboard boxes) can become fuel in a fire.</td>
</tr>
</tbody>
</table>

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## Typical Design, Vulnerability, & Mitigation Considerations cont.:

<table>
<thead>
<tr>
<th>Open Foundation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pier &amp; beam style foundations</strong> are considered “open foundations” and can be comprised of a range of combustible (e.g., wooden piers) and noncombustible (e.g., concrete, CMU, brick) construction. As this style of foundation is raised and open around the perimeter, it is highly vulnerable to ember intrusion and ignition of debris or other combustible materials below the foundation (or even the foundation itself). Wood lattice screens can be ignited by direct flame, embers, or hot gases. Lattice screens often trap combustible debris such as leaves and paper, increasing the potential for ignition. Ignition of a lattice screen can lead to ignition of the underside of the first floor. Combustible debris or storage items (such as firewood or gas in a container) in an open foundation can be ignited, leading to ignition of the underside of the first floor.</td>
</tr>
</tbody>
</table>

To mitigate potential ember intrusion or direct flame impingement from a surface fuels fire, a fire-resistant or ignition-resistant enclosure could be provided around the perimeter of the foundation. However, ventilation would need to be provided with appropriate ember protection. Alternatively, the structural elements could be provided with a 1-hour rated jacket around the piers, along with an ignition-resistant or fire-resistant enclosure for the underside of the substructure floor. (Attach 5/8” thick exterior Type X gypsum board to the underside of the joists. Attach fire-retardant-treated plywood, fiber-cement panels, or metal siding panels over the gypsum board**194**). An ember resistant zone (0-5’) should also be maintained around the perimeter of the foundation, as well below.

### Mitigation Strategies:

- Refer to Typical Design, Vulnerability and Mitigation Considerations for additional mitigation options.
- Where possible, provide at least 6” vertical clearance of noncombustible materials along the exterior wall from the ground to the siding.
- Maintain a 5’ ember resistant zone around the building by clearing debris, dead vegetation and any combustible items within this zone.
- Repair damage to foundation and fill in any gaps at joints with firestopping to minimize embers intrusion.
- Where an existing building has an open foundation:
  - Where possible, open foundations should be enclosed to remove the opportunity for debris, vegetation, and combustible items from accumulating under the building.
  - Remove any combustible items under the structure, and keep it clear of debris, vegetation and storage.
  - Protect the underside of the floor structure and supporting structure with fire rated, noncombustible, or fire-resistant materials.
  - Provide noncombustible skirting to help reduce the accumulation of debris under the building (1/16” wire mesh).

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**195** FEMA.
Gaps in Knowledge:

+ Minimal guidance related to the design, material selection and maintenance of foundation walls in the Wildland Urban Interface.
+ Minimal guidance related to mitigation options for open foundation configurations in the Wildland Urban Interface.

Other References:

  - See Fact Sheet #7, Exterior Walls, for guidance on walls and wall coverings.
  - See Fact Sheet #8, Vents, for guidance on crawlspace vents.
  - See Fact Sheet #10, Windows and Skylights, for guidance on windows.
Structural Hardening

Attachments
**Fencing (1.5.1)**

**Main Concern(s):**
Fences can become hazardous in the event of a wildfire, particularly if they connect directly to a structure. Typical wooden post-and-board fences particularly when old and weather beaten can provide a “wick” leading directly to the structure. The bottom of fences collect debris that, when combined with combustible fencing, can become a fuel source to carry fire directly to the structure and ignite the building through radiant heat, convective heat, or direct flame contact. Since fences are often just below the eaves of a house, there is the potential to carry the fire up to the eaves and thus to the roof. Additionally, fences can also create access problems for fire crews trying to enter a yard during an emergency.

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**Key Terminology:**
+ **Noncombustible:** In building construction material, noncombustible means one of the following:
  - Material of which no part will ignite and burn when subjected to fire. Any material passing ASTM E136 will be considered noncombustible.\(^{197}\)
  - Material having a structural base of noncombustible material as defined above, with a surfacing material not over 1/8” thick which has a flame-spread index of 50 or less.\(^{198}\)

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\(^{198}\) Quarles.
Attachments 1.5

Fire Rated Assemblies:
None

Fire Test Standards:
There are no test standards for fencing assemblies.

Referenced Codes & Standards:
+ International Wildland Urban Interface (IWUI) Code, 2021: No explicit requirements
+ California Building Code (CBC), 2019: No explicit requirements
+ NFPA 1144 Standard for Reducing Structure Ignition Hazards from Wildland Fire: Section 5.6.3 Appendages and projections

Cedar split rail fence.

Stone privacy fence.

Other Codes & Standards:
Codes and standards will vary depending on location and adoption in individual jurisdictions.
+ Check local, county, and state amendments for additional wildfire codes and standards.
+ Check local general plan, multi-hazard mitigation plan, or zoning documents for any additional requirements.
+ IRC (if applicable – check for wildfire amendments).
## Typical Design, Vulnerability, & Mitigation Consideration:

<table>
<thead>
<tr>
<th>Fencing Types</th>
<th>Vulnerability &amp; Mitigation Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wooden Post-and Board Fences</strong></td>
<td>Can become fuel for a wildfire, especially when weather-beaten. Fences can collect embers and firebrands in a wildfire and act as a horizontal ladder fuel by allowing the fire to travel along the fence toward the main building. Wooden fences typically have no fire resistance. Dense hardwoods such as red oak, white oak, hickory/pecan, and walnut are more fire resistant than pines and other softwoods.</td>
</tr>
<tr>
<td><strong>Vinyl Fences</strong></td>
<td>Although less vulnerable to embers, can ignite through direct flame exposure if vegetative debris has accumulated at its base. The vinyl will deform and melt when exposed to radiate heat.</td>
</tr>
<tr>
<td><strong>Metal Fences:</strong></td>
<td>Metal fences are more fire-resistant than plastic fences. Wire fences such as barbed wire, hog wire, and chain link have little or no effect on fire passage. It should be noted that if combustible materials have accumulated in or around the fence or the fence contains combustible materials such as wooden posts, the fence can act as a ladder fuel.</td>
</tr>
<tr>
<td><strong>Concrete, Stone, or Masonry:</strong></td>
<td>Noncombustible and can act as a barrier to a wildfire by deflecting flames away from a building, but the passage of airborne embers and firebrands will not be significantly altered. These materials are the most effective at minimizing the potential for damage to a building from a wildfire.</td>
</tr>
</tbody>
</table>

## Gaps in Knowledge:

+ Fire testing and standards do not exist for fencing installed in the Wildland Urban Interface.
+ Design and installation guidelines do not exist for fencing in the Wildland Urban Interface.

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200 FEMA.
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Mitigation Strategies:

+ If practical, replace combustible fences using noncombustible (i.e., masonry, metal) or ignition-resistant materials (i.e. fire retardant treated lumber for exterior exposure or thicker dimension lumber).
+ If existing wood fences cannot be fully replaced, replace the portion of the fence within 5’ from the building with noncombustible materials (e.g., a metal gate that is attached to the fence on one side and to the exterior siding on the other side).
+ Remove combustible materials such as trash bins, firewood, mulch, or other combustible materials against the fence. Ensure that all combustible components are at least 5’ from the building to prevent heat and flames from igniting the building.
+ Remove combustible mulch near fences and replace with noncombustible mulch, gravel or other similar material.
+ Remove debris and dead vegetation at the bottom of fences.
+ Remove plants where the fence is being used as a trellis as it creates and traps ignitable vegetative debris.
+ Ensure the fence or gate is not an access problem for fire crews.
+ Maintain physical condition of fence and replace any damaged, deteriorated components.

Training:

+ NFPA – Certified Wildfire Mitigation Specialist (CWMS) Certification

Other References:

- NIST – Structure Vulnerability to Firebrands from Fences and Mulch: https://www.nist.gov/publications/structure-vulnerabilityfirebrands-fences-and-mulch
Coverings (Canopies, Awnings, Shades)  (1.5.2)

Main Concern(s):
Attachments directly protruding from the façade of the building, such as window awnings, shades, patio covers, and canopies can pose a significant hazard in the event of a wildfire. These components are susceptible to both direct flame exposure and firebrand accumulation, and if combustible, can become a fuel source to carry fire directly to the structure. Awnings are oftentimes comprised of fabric or other such lightweight material that can become readily ignited providing a direct flame impingement on the structure. Material selection, design and debris clearance of these attachments are critical to mitigation the impact of wildfire.

Key Terminology:
+ **Awnings**: A sheet of canvas or other material stretched on a frame and used to keep the sun or rain off a storefront, window, doorway, or deck.\(^{204}\)
+ **Canopy**: Any fixed structure, framework, appendage, appurtenance, shelter or shade, without enclosing walls, covered with canvas, cloth, galvanized iron, aluminum, approved slow-burning plastic or similar material erected, constructed or maintained at or over the entrance way to a building or place of business within a building, and extending over any public street or sidewalk supported by an individual framework from the ground except such projections from buildings.\(^{205}\)


Fire Classifications & Ratings:

+ The International Building Code (IBC) provides several requirements for the fire-resistant design and construction of awnings and canopies in Section 3105.
+ The frames supporting awnings can be rated to achieve a 1-hour fire resistance rating per ASTM E119.
+ The materials of awnings and canopies can be classified based on their performance to NFPA 701, or their flame spread index per ASTM E84 or UL 723 or performance to NFPA 286.

Note: There is no wildfire specific fire classification or rating.

Fire Test Standards:

+ ASTM E84 Standard Test Methods for Surface Burning Characteristics of Building Materials
+ UL 723 Test for Surface Burning Characteristics of Building Materials
+ NFPA 701 Standard Methods of Fire Tests for Flame Propagation of Textiles and Films
+ Currently, there are no wildfire specific fire test standards to assess the performance of awnings, covers or shades to embers.

Referenced Codes & Standards:

+ International Building Code (IBC), 2021: Section 3105 Awnings and canopies
+ International Wildland Urban Interface (IWUI) Code, 2021: No explicit requirements
+ California Building Code (CBC), 2019: No explicit WUI requirements. Section 3105 Awnings and Canopies.
+ NFPA 1144 Standard for Reducing Structure Ignition Hazards from Wildland Fire: No explicit requirements
Typical Design & Construction Considerations:
+ Attached canopies/awnings can either be attached to a building or can also be mounted on the ground by the support of posts. Retractable canopies are popular for their space-saving solution.
+ Freestanding, portable, umbrella shades may also be used.
+ Material selection: Awnings or canopies are typically constructed of fabric, wood, polycarbonate or metal.
+ Combustible materials: Fabrics, including canvas, vinyl and acrylic are typically the cheaper option, with easier installation. In addition, wood or polycarbonate materials may be used. These materials are combustible and should be avoided in the Wildland Urban Interface.
+ Noncombustible or ignition resistant materials: Metals including aluminum, steel and copper provide a more durable option. Due to the weight of the components, it is typically more costly, and requires professional installation. Metal coverings are suggested in the Wildland Urban Interface.

Mitigation Strategies:
+ Ensure awnings and canopy materials consist of Class A flame spread per ASTM E84 or satisfy other alternative specified in Section 3105 of the IBC.
+ Keep all awnings and canopies clear of debris and vegetation. Remove needles and leaf litter accumulation on or around the covering or retractable mechanism.
+ Repair damage to awnings and canopies to reduce the accumulation of embers and firebrands between damaged materials.
+ Where any gaps or holes are presented at the attachment points to the structure provided with appropriate firestopping and fire caulking.

Training:
+ NFPA – Certified Wildfire Mitigation Specialist (CWMS) Certification

Gaps in Knowledge:
+ Currently, there are no wildfire specific fire test standards to assess the performance of awnings, covers or shades to embers.
+ The contribution of awnings and canopies to the vulnerability of homes to wildfire threats is uncertain.
Structural Hardening
Sprinkler Systems
Sprinkler Systems

Main Concern(s):
Interior building fire sprinkler systems are not effective under significant exterior exposure and typically do not provide protection to exterior construction elements. There is no design standard for exterior sprinklers with respect to wildland fire exposure or guidance for extension of interior residential fire sprinkler systems to protect exterior portions. Available exterior exposure protection sprinkler system information is based on building-to-building exposures and is not relevant to residential wildfire exposure. Other main concerns with exterior protection sprinkler system include:

- Lack of fire test standards, design criteria and performance specifications for the sprinkler system (e.g., design area, flow rates, duration), water supplies (e.g., robustness of water supply, duration, source), activation method (e.g., manual, detection device) etc., for the range of scenarios that may occur during a wildfire incident.
- Due to the lack of testing, the effectiveness of an exterior sprinkler system is uncertain for the range of potential exposure types (i.e., radiation, convection, hot gases, embers) from the wildfire or adjacent structures on fire with a range of exposure durations and extended intensities.
- A municipal water source may not provide sufficient water flow and pressure during a wildfire, particular as first responders will likely be drawing from the same system. Water supplies dependent on pumps may also be rendered ineffective during wildfire incidents when power can typically be lost due the wildfire itself. Additionally, extensive adoption of automatic exterior exposure sprinklers for residences could present a concern for water supply in affected areas for firefighting operations if widely adopted by homeowners.
Attachments 1.5

+ The most threatening wildfires occur during high-wind events. Exterior sprinkler systems in high-wind conditions, in particular, may not be effective at protecting the desired asset due to the uncertain distribution/transport of water droplets as well as evaporative losses.
+ Reliable system activation is also questionable in terms of the appropriate approach, technology and its associated needs for independent and reliable power supply.

Key Terminology:
+ **Exterior Sprinkler**: A sprinkler either deployable or fixed on the structure that operates independent of human interaction to douse the structure, portions of the structure, and/or surrounding vegetation with water.
+ **Non-Residential Fire Sprinkler System**: An in-building sprinkler system that meets the requirements of NFPA 13.
+ **Residential Fire Sprinkler System**: An in-home sprinkler system that meets the requirements of NFPA 13D or 13R.
+ **Sprinkler, Automatic**: A water spray device that is designed to provide fire protection automatically, based on either heat activated operation or separate detection and control.
+ **Sprinkler, Manual**: A water spray device that is intended to provide fire protection when manually deployed and supplied with water under pressure.

Fire Rated Assemblies:
None

Fire Test Standards:
None

Referenced Codes and Standards:
+ **International Wildland Urban Interface (IWUI) Code**: No explicit requirements
+ **California Building Code (CBC)**: No explicit requirements
+ **NFPA 1144 Standard for Reducing Structure Ignition Hazards from Wildland Fire**: No explicit requirements

Other codes and standards:

**Codes and standards will vary depending on location and adoption in individual jurisdictions.**
+ Check local, county, and state amendments for additional wildfire codes and standards.
+ Check local general plan, multi-hazard mitigation plan or zoning documents for any additional requirements.
+ IRC (if applicable – check for wildfire amendments).
### Typical Design, Vulnerability and Construction Considerations:

<table>
<thead>
<tr>
<th>Sprinkler System Types</th>
<th>Design and Construction Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Interior Sprinklers (per NFPA 13)</strong></td>
<td>Interior sprinkler systems designed to NFPA 13 requirements must meet higher demand and density/area application requirements. Where the design water supply is maintained during fire exposure, these types of systems are more likely to sustain effectiveness during a larger fire exposure to the structure. Non-residential sprinkler systems typically do not provide any features to address exterior/wildland fire exposure. Use of sprinkler systems to address building fire exposures is also uncommon.</td>
</tr>
<tr>
<td><strong>Interior Sprinklers (per NFPA 13R, 13D)</strong></td>
<td>Interior sprinkler systems design to NFPA 13R and 13D are only intended to provide occupant protection during an interior fire exposure; they are specifically not designed to provide protection to the building. Residential sprinkler systems typically do not provide features to address exterior/wildland fire exposure.</td>
</tr>
<tr>
<td><strong>Building Exposure Sprinklers (per NFPA 80A)</strong></td>
<td>The only technical requirements that are provided for exterior exposure sprinklers on buildings is within NFPA 80A, titled Recommended Practice for Protection of Buildings from Exterior Fire Exposures. This building exposure sprinkler criteria is primarily oriented toward urban exposures and commercial buildings and is not readily applicable to residential buildings and wildland fire exposure.</td>
</tr>
<tr>
<td><strong>Exterior Sprinklers, Automatic</strong></td>
<td>The installation of wildfire sprinkler systems is not common, regulated or well-documented. There are limited examples of successful performance in wildfire incidents. Successful systems generally rely on protection of the home and adjacent vegetation, some degree of pre-wetting and the formation of a humid microclimate adjacent to the structure. One concern with even successful performance is that the protected area must be maintained after the incident to avoid ignition from surrounding hotspots that remain.</td>
</tr>
<tr>
<td><strong>Exterior Sprinklers, Manual</strong></td>
<td>These sprinklers must be manually positioned in advance of wildfire threat but are otherwise similar to automatic exterior sprinklers. Attachments to ground, vegetation and structure must be reliable enough to keep the sprinklers in place during exposure after occupants have vacated.</td>
</tr>
</tbody>
</table>

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Mitigation Strategies:
+ Where an existing exposure sprinkler is provided, consult with a licensed fire protection professional or wildfire professional to assess the existing installation and provide recommendations.
+ Where exposure sprinkler protection is considered, several factors must be addressed including: system detection/activation methods, potential pumping systems for water pressure, potential water storage for reliability. A licensed fire protection professional should be involved with the design and installation of wildfire exposure sprinkler protection.
+ Given the potential issues regarding performance, it’s recommended that sprinkler use be a supplement to, and not a replacement for, already proven mitigation strategies, such as the reduction of potential fuels throughout the home ignition zones, along with removal of roof and gutter debris, and use of noncombustible and fire/ember ignition resistant building materials and installation design details. Sprinkler protection of any type does not allow for reduction or relaxation of other recommendations.

Gaps in Knowledge:
+ There is little information on how well these systems actually perform under wildfire exposure or what system features can improve their performance.
+ There is no design standard or performance criteria.

Other References:
References


Vegetation Management

Fuel Type
(Ornamental/Non-native vs. Native Vegetation)
Fuel Type

Main Concern(s)
Embers are responsible for the majority of home and structure ignitions (estimated to be at least 2/3 of ignitions\textsuperscript{1}). Embers can be produced from the burning of vegetative fuels or other combustible such as building construction, ornamental vegetation and other fuels in the built environment. Several parts or features (e.g., roof, vents) of buildings are vulnerable to the accumulation and/or infiltration of embers that can lead to the ignition of building materials or directly enter the structure and ignite interior building contents. In addition, the wildland fuels, landscaping, and other combustible materials directly surrounding the structure or below the structure are also highly susceptible to ember ignitions and increase the risk of building ignition. Vegetation and combustible materials can also limit the space necessary to provide firefighters with a relatively safe place for conducting operations. Some of the key concerns in the area surrounding a structure/home (0-100') include:

\begin{itemize}
  \item Non-combustible materials within 5'.
  \item Non-combustible landscaping with canopy spacing.
  \item Example of increased spacing on a slope.
\end{itemize}

Wildland vegetation (e.g., grass, brush, timber)
+ These fuels can burn with great intensity over a range of burn times, producing radiative and convective heat, hot gases, and embers.

\textsuperscript{1} Alex Maranghides and William Meill, “A Case Study of a Community Affected by the Witch and Guejito Fires,” NIST Technical Note, no. 1635 (2009), \url{https://doi.org/10.6028/NIST.TN.1635}. 
**Fuel Type**

**Landscape vegetation**
+ Landscaping can consist of a wide range of managed vegetation typologies (e.g., trees, shrubs, gardens, grasses), plant characteristics (e.g., height, growth type and extent), fire ecology, native/ non-native, arrangements, practices, purposes (e.g., food, shade, recreation) and quality of ongoing maintenance. These fuels can be equally as combustible as wildland vegetation and can easily spread fire from wildland vegetation to the structure both horizontally via surface fuels or vertically as ladder fuels from grasses and other surface fuels to low branches.

**Fire Adapted and Prohibited Plants**
+ Many jurisdictions have compiled lists of both fire adapted and prohibited plants to guide homeowners in landscaping design. The ability or inability to resist ignition is based on the physical features of the plant. While these lists are beneficial to homeowners, they can be incomplete or misleading. These lists are highly dependent on a variety of local factors that may not be relevant to other locations. Numerous factors (e.g., plant species, genius, plant structure, location, setting, surface mass, branching patterns, foliage size, density, litter production and retention, maintenance practices, placement, weather, weather history, etc.) influence whether a plant should be considered “hazardous” or “approved.” Due to the large variety and detailed nuances of plant flammability, evaluation of plant “safety” should be conducted by an expert from a holistic and scientific perspective. Even “approved” plants can burn under extreme fire conditions.
+ Plant characteristics should be verified to confirm their hazard. Plants on the prohibited list are often invasive, contain volatile oils or resins, have waxy leaves, and accumulate litter around the tree. Fire adapted plants are often native species, drought resistant, slow growing, and wind resistant.

**Other fuels in built environment:**
+ There is a wide range of other types of combustible fuel loads that landowners or homeowners may have stored around and in close proximity to the primary structure. This can include wood piles, outdoor grills, propane tanks, outdoor furnishings, lawn mowers, trash bins, vehicles, and decorative landscaping (e.g., artificial grass). The type, quantity, and characteristics of these other fuel loads range dramatically and present challenges in understanding the additional fire hazard, burning characteristics and contribution they may have during a wildfire incident.

**Outbuildings (e.g., sheds, gazebos, pergolas):**
+ Outbuildings are often comprised of combustible materials, and once ignited, can contribute to structure-to-structure fire spread.

**Key Terminology:**
+ **Defensible space:** Defensible space can be described as the area or space around homes and buildings where vegetation and other factors are managed for a specific distance to keep fire at a point where it cannot ignite the structure. This managed area or space literally provides a “defense” against the fire to reduce the structure’s exposure to flame radiation (heat), flame impingement, and ignition from firebrands (burning embers), which are considered the three principal factors in igniting a fire.²

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Fuel Type

+ Ember (firebrands): Burning or smoldering particles of vegetation from tree branches, parts of shrubs or chaparral, or other combustible materials (e.g., building materials) that ignite and burn during a wildfire and are carried by high winds in front of the wildfire at varying distances (e.g., ½ - 2 miles). This creates a wind-driven fire hazard that is unique to wildfire incidents.

+ Ember resistant zone: The ember-resistant zone is the space immediately around and under a structure (typically 0 – 5'), where no form of fuel load or combustible is permitted. The intent is to keep fire or embers from materials that can spread to the structure and cause ignition. 4

+ Fire-resistant plants: Fire-resistant plants are those that do not readily ignite from a flame or other ignition sources. These plants can be damaged or even killed by fire; however, their foliage and stems do not significantly contribute to the fuel and, therefore, the fire's intensity. There are several other significant factors that influence the fire characteristics of plants, including plant moisture content, age, total volume, dead material, and chemical content.

+ Hardscape: Any non-living materials that are incorporated into a landscape. 5 This can include paved areas, driveways, retaining walls, sleeper walls, stairs, walkways, and any other landscaping made up of hard wearing materials such as wood, stone, and concrete, as opposed to softscape, the horticultural elements of a landscape.

+ Home ignition zone (HIZ): The concept of the home ignition zone was developed by retired USDA Forest Service fire scientist Jack Cohen in the late 1990s, following some breakthrough experimental research into how homes ignite due to the effects of radiant heat. The HIZ is divided into three primary zones (e.g., immediate zone, intermediate zone and extended zone). 6 Although variations have emerged since the original concept, the HIZ generally accounts for the 0 – 100’ space around a structure.

+ Ladder fuels: Surface vegetation or other fuels that allow fire to climb up from the landscape or forest floor to the tree canopy above. Common ladder fuels include tall grasses, shrubs, and tree branches, both living and dead. Nonvegetative ladder fuels include woodpiles, fenceposts, etc. The removal of ladder fuels is part of defensible space ‘firescaping’ practices. 7

Fire Classification and Ratings:

None

Fire Test Standards:

Currently, there are no standardized methods for determining plant or ornamental plant flammability, plant heat release rates or standardized criteria for landscaping plant recommendations. Refer to the Other References section for available information.

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Fuel Type

Referenced Building Codes and Standards:
+ International Wildland Urban Interface (IWUI) Code: Section 603, A105.4.1 (woodpiles)
+ California Building Code (CBC), 2019: Chapter 49 Section 4906 Hazardous Vegetation and Fuel Management, Section 4907 Defensible Space
+ California Code of Regulations (CCR): Title 14, Section 1299
+ California Assembly Bill (AB) 3074: Fire prevention: wildfire risk: defensible space: ember-resistant zones.
  https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201920200AB3074
+ California, Public Resources Code, 4291: Defensible space requirements
+ NFPA 1140 Standard for Wildland Fire Protection: Sections 25.9, A.25.9 (outbuildings), 25.12.5 (woodpiles), 25.11 (vehicle parking areas), Chapter 26 (Fuel Modification Area).

Other Codes and Standards:
Codes and standards vary depending on location and adoption in individual jurisdictions.
+ Check local, county, and state amendments for any additional requirements.
+ Check local general plan, multi-hazard mitigation plan or zoning documents for any additional requirements.
+ Consult the local or state fire agency or a qualified fire management specialist about codes, requirements, and standards related to defensible space.8
+ IRC (if applicable – check for wildfire amendments).

Typical Designs, Vulnerabilities and Mitigation Considerations:
Defensible space is designed to provide a buffer between the building and the wildland that surrounds it. It protects structure from direct flame impingement, reduces exposure to radiant heat and ember cast, and is essential for structure survivability during wildfires. Defensible space also allows room for fire-fighting operations. Defensible space requirements are typically subdivided into three zones, whereby the highest priorities and most restrictive measures are incorporated in the area closest to the structure or home.9 The most common zones are as follows:
+ Zone 0 (0 – 5') = “Ember-resistant zone” or “Immediate Zone”
+ Zone 1 (5 – 30') = “Intermediate Zone” or “Lean, Clean, and Green Zone”
+ Zone 2 (30 – 100') = “Extended Zone” or “Reduced Fuel Zone”

Note: California is currently in the process of developing and adopting local regulations to implement an “ember-resistant” zone within 5' of a structure or occupied dwelling located in a fire hazard severity zone (i.e., the highest designated wildfire prone/risk areas) adjoining a mountaneous area, forest-covered land, brush-covered land, grass-covered land or land that is covered with flammable materials.10

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9 University of California, Agriculture and Natural Resources, "Defensible Space," accessed April 2022. https://ucanr.edu/sites/fire/Prevent/Landscaping/DefensibleSpace/
<table>
<thead>
<tr>
<th>Fuel Type</th>
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<thead>
<tr>
<th>Typical Conditions or Typologies</th>
<th>Design, Vulnerability and Mitigations</th>
</tr>
</thead>
</table>
| **Zone 0**<br>0 – 5'             | This is considered the most important defensible space zone, and includes areas immediately surrounding a structure/building, as well as areas under any attached decks or overhangs. Establishing a five-foot ember-resistant zone around a structure to eliminate materials that will likely be ignited by embers provides important protection measures that enhance a home’s chance of surviving a wildfire. These protection measures include:  
- Remove anything combustible including vegetative and “urban” type fuels (e.g., woody plants, mulch, woodpiles, combustible trellises, trash bins, vehicles, woodpiles, and other stored combustible items). This is particularly important for homes or structures that include combustible siding such as wood or vinyl.
- Move any trash, recycling, or compost bins further than 5’ from any structures (in Zones 1 or 2) or store them within a hardened garage or outbuilding.
- Relocate woodpiles to Zone 2 (>30’ from structures) or within a well-sealed, protected structure (e.g., hardened garage or shed), with a minimum of 10’ separation from other fuels; 40’ if adjacent to multiple woodpiles.
- Remove any dead/dying vegetative debris (e.g., leaves, pine needles).
- Consider replacing existing landscaping in zone 0 with hardscaping such as pavers, concrete, rock mulch, pea gravel or non-combustible mulch.
- Consider replacing the bottom 6” of the exterior wall with non-combustible materials (e.g., brick, stone veneer, exposed concrete, stucco) from the foundation to the exterior siding.
- Trim back all trees, shrubs and any other vegetation so that it’s not within this zone, particularly around chimney and stovepipe outlets.
- Limit combustible items (e.g., outdoor furniture, grills) on top of decks and balconies.
- Remove combustible fencing, gates and arbors attached to the structure with noncombustible materials.
- If the home/structure is comprised of non-combustible siding such as fiber-cement and plants in this zone are still desirable, limit the selection to varieties that grow no more than 12” in height. Avoid planting below windows or near openings (e.g., vents, crawl space openings). Ensure that the plants are well watered and cared for as any plant can become highly flammable if it is dead, dried out, or not well maintained. |

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12 University of California, Agriculture and Natural Resources, “Defensible Space,” accessed April 2022, [https://ucanr.edu/sites/fire/Prepare/Landscaping/DefensibleSpace/](https://ucanr.edu/sites/fire/Prepare/Landscaping/DefensibleSpace/).
13 University of California.
## Fuel Type

<table>
<thead>
<tr>
<th>Typical Conditions or Typologies</th>
<th>Design, Vulnerability and Mitigations</th>
</tr>
</thead>
</table>
| Zone 1  
5 – 30’                      | This zone is considered critical to creating defensible space and limiting structure-to-structure fire spread. Note: This designation also applies to the area within 10’ of driveways, access roads, or public roads adjacent to the property.  
- Minimize fuel in this zone – plants should be low growing, low-volume, nonwoody, and properly watered. Note: Research shows that plant moisture is one of the most influential characteristics that influence plant flammability.  
- Cut or mow grass to 4” or less height  
- Remove all dead or dying vegetation (e.g., grass, weeds, pine needles)  
- Trim trees to maintain a minimum of 10’ distance between trees (including branches).  
- Remove all tree branches at least 6’ from ground to limit fire ladders.  
- Trim and prune vegetation per horizontal and vertical separation requirements (as indicated in associated diagrams, NFPA Firewise, or other local guidance). Additional separations may be needed for steep slopes. See section below.  
- Separate all vegetation from each other and from other items which could ignite – create “islands” of vegetation surrounded by nonflammable materials such as gravel walkways, non-combustible patios.  
- Remove any branches/tree limbs which extend over the roof or within 10’ of chimney or stovepipe outlets  
- Relocate woodpiles to Zone 2 (>30’ from structures) or within a well-sealed, protected structure (e.g., hardened garage or shed), with a minimum of 10’ separation from other fuels; 40’ if adjacent to multiple woodpiles.  
- Alternatively, as a more practical consideration for reducing risk of ignition, woodpiles can be provided with a securely fastened fire-resistant material (tarp that complies with, at a minimum, NFPA 701 Method 2 standard).  
- Remove or prune flammable plants and shrubs near windows to maintain 5’ clearance.  
- For many landowners/homeowners, property lines may restrict achieving 30’ of defensible space. At the discretion of the fire department, property owners may elect to increase hardscaping to offset the reduced width of zone 1. Some jurisdictions propose hardscaping or provide a non-combustible property line wall, to minimum ember transmission and/or production close to the home. |

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### Fuel Type

The goal in this zone is to interrupt the path of a wildfire, minimize flame length, and keep fires on the ground.

- Cut or mow grass to 4" or less height
- Remove all tree branches at least 6’ from ground to limit fire ladders.\(^\text{14}\)
- Create vertical and horizontal space between shrubs and trees (see images) – property on steeper slopes requires greater spacing. See section below.
- Remove heavy accumulation of ground debris/litter
- Incorporate landscape designs which can act as fuel breaks (e.g., driveways, walkways, orchards)
- Separate auxiliary structures such as a detached garage, pump house, pergola, and utility shed from the home by at least 50’. Increase the distance if the structure is used for the storage of combustible materials.\(^\text{17}\)
- Store combustible patio furniture in a location where it is protected from wildfire ignition.\(^\text{18}\)
- For many landowners/homeowners, property lines may restrict achieving 100’ of defensible space. At the discretion of the fire department, property owners may elect to increase hardscaping to offset the reduced width. In some jurisdictions, the full 100’ is achieved through community defensible space, where neighbors on adjacent properties maintain the portion of the 100’ HIZ that falls within their land.
- Note: Research shows that plant moisture is one of the most influential characteristics that influence plant flammability

### Zone 2

30 – 100’

- Where possible and within the control of the landowner, reduce fuels that are farther than 100’ from a building, particularly where the property sits on or adjacent to a steep slope. This can include thinning and pruning vegetation horizontally and vertically, as in Zone 2 but limited.\(^\text{19}\)

### > 100’

- Where possible and within the control of the landowner, reduce fuels that are farther than 100’ from a building, particularly where the property sits on or adjacent to a steep slope. This can include thinning and pruning vegetation horizontally and vertically, as in Zone 2 but limited.\(^\text{19}\)

### Prohibited Plant List

Plant species geometry has significant impact on flammability. This includes the structure of the plant itself, as well as location and setting of the plant within the managed landscape. Surface mass of a plant is a key influence on its flammability. Plant features to consider include branching pattern, foliage size and density, litter production and retention, and evergreen versus deciduous.\(^\text{20}\)

Many fire jurisdictions in high wildfire prone areas will have a list of common plants that are prohibited for use, particularly in the very high fire hazard severity zones of their administrative boundaries. These lists can be anecdotal and so should be evaluated for local relevance and from a holistic and scientific perspective. (See Other References for a sample of these prohibit plant lists)

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\(^\text{14}\) University of California, Agriculture and Natural Resources, "Defensible Space," accessed April 2022, [https://ucanr.edu/sites/fire/Prepare/Landscaping/DefensibleSpace/](https://ucanr.edu/sites/fire/Prepare/Landscaping/DefensibleSpace/)


\(^\text{18}\) FEMA.

\(^\text{19}\) FEMA.

\(^\text{20}\) Farm and Home Advisor’s Office, University of California Cooperative Extension, Research Literature Review of Plant Flammability Testing, Fire-Resistant Plant Lists and Relevance of a Plant Flammability Key for Ornamental Landscape Plants in the Western States (San Diego, CA: Farm and Home Advisor’s Office, University of California Cooperative Extension, 2016).
### Fuel Type

#### Prohibited Plant List

Some common characteristics of prohibited plants include:
- Volatile resins and oils, generally aromatic when crushed (e.g., eucalyptus)
- Narrow leaves or long, thin needles such as conifer needles
- Waxy or fuzzy leaves
- Accumulates dead leaves and twigs on and/or under the plant (e.g., Italian Cypress)
- Loose or papery bark
- Invasive species

If the areas around a home or structure includes prohibited plants with characteristics that are especially prone to wildfire and/or has an active fire history, greater clearance and separation between plants and plant groupings are recommended.

While plants on the prohibited list may present increased risk, they do not necessarily require removal. A key component of wildfire risk mitigation is the proper placement and maintenance of plants around the home.

#### Approved or “Fire-Adapted” Plant List

Approved plant lists have been developed to meet local residents’ requests for plant selection guidance and/or regulatory agencies’ permitting and enforcement needs. Even though most fire-resistant or plant flammability rating lists often include some type of warning statement that “all plants can burn under extreme fire conditions”, they can be misleading if they:
- Lack definitions
- Do not clarify criteria or methods used
- Do not provide sources or include mechanisms for an owner to request the use of non-listed plants
- Do not provide industry standards (e.g., some based on flammability, others on combustibility)
- Use inconsistent plant names (e.g., common names, genus/species, sub-species). Species in the same genus may not have the same flammability characteristics
- Do not provide guidance on seasonal influences or location/geographic area of application

Where necessary, refer to local lists of “approved” or “fire-adapted” plants. Some general characteristics of typical plants in this category include:
- Drought-resistant
- Pest-resistant
- Native to the area
- Noninvasive
- Slow-growing
- Wind-resistant
- Sustainable without supplemental fertilization

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23 Farm and Home Advisor’s Office, University of California Cooperative Extension, Research Literature Review of Plant Flammability Testing, Fire-Resistant Plant Lists and Relevance of a Plant Flammability Key for Ornamental Landscape Plants in the Western States (San Diego, CA: Farm and Home Advisor’s Office, University of California Cooperative Extension, 2016).istry of California Cooperative Extension, 2016).
24 FEMA, “Technical Fact Sheet No. 6: Eaves, Overhangs, and Soffits.”
### Fuel Type

Note: California has a compiled list of native, fire-resistant plants.

<table>
<thead>
<tr>
<th>Outbuildings (e.g., sheds, gazebos, pergolas) and other Outbuildings (e.g., sheds, gazebos, pergolas) and other</th>
</tr>
</thead>
</table>
| Outbuildings and other decorative features are common within the landscape of residential homes. As with other fuels, these are combustible materials that are an added source of heat and embers during wildfires. Use appropriate clearance or modify positioning for these features to reduce the threat from burning embers.25  
  · Any sheds should be "hardened" with sealed doors, screened vents, and surrounded by defensible space.  
  · Sheds should be removed from the immediate zone of 0-5' from the structure and reduced in the 5-30' intermediate zone, except for metal or non-combustible sheds. Increase distance of sheds beyond 50' where containing combustible fuels.  
  · Non-metal sheds in Zones 1 and 2 should have 10' of clearance consisting of bare mineral soil or similar non-combustible materials (e.g., rock mulch) and an additional 10' with no flammable vegetation.  
  · If sheds cannot be moved or retrofitted to be "hardened," remove them entirely if possible.  
  · Remove combustible materials (e.g., outdoor furniture) from, adjacent to or below any unenclosed outbuildings. |

<table>
<thead>
<tr>
<th>Vehicles</th>
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</thead>
<tbody>
<tr>
<td>Vehicles, including cars, RVs and boats, are often stored near structures and pose a risk of spreading fire to adjacent structures. Any vehicles in the home ignition zone should be stored outside of Zone 0, at a minimum. Vehicles should not be parked in a way that obstructs access to defensible space by firefighting personnel.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Steep Slopes and Winds</th>
</tr>
</thead>
</table>
| If the home is located on a steeper slope, in a drainage area, in a windy area, or in an area surrounded by unusually dense, tall, or combustible vegetation, thinning recommendations increase.26  
  As fire and heat rise, structures or homes at the top of a slope will experience more intense fire exposure and effects. In these cases, greater effort is needed for the area downslope of the home as well as the areas within Zones 0 and 1. Recommendations based on the judgement of fire professionals are given below.27  
  + Under 20% slope: Space shrubs at 2 times their height  
  + 20-40% slope: Space shrubs at 4 times their height  
  + Greater than 40%: Space shrubs at 6 times their height |

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25 University of California, Agriculture and Natural Resources, “Defensible Space,” accessed April 2022, [https://ucanr.edu/sites/fire/Prepare/Landscaping/DefensibleSpace/](https://ucanr.edu/sites/fire/Prepare/Landscaping/DefensibleSpace/).  
26 University of California, Agriculture and Natural Resources.  
**General Mitigations:**

- Design and implement defensible space
  - Create fuel breaks surrounding the house and within the HIZ.
  - Create space vertically and horizontally via plant placement and pruning.
  - Use non-combustible mulches near the house.
  - Use hardscape and non-combustible materials around structures and to separate individual plants and groups of plants.
  - Use the right plants in the right places, keeping fire, climate, and irrigation needs in mind.
  - Create plant islands that have similar sun, nutrient, and water needs.

- Maintain landscaping
  - Keep landscaping free of dry and dead wood, dry grasses, and leaf litter, especially near any structures.
  - Prune plants to provide horizontal and vertical space thoroughly.
  - Eliminate ladder fuel conditions. A grass fire can move up into shrubs and then into trees.
  - Hydrate plants with a water-wise irrigation system. All plants will burn if not well maintained or hydrated.

**Training Programs:**

- NFPA – Assessing Structure Ignition Potential from Wildfire
- Fire Adapted Communities Learning Network: [https://fireadaptednetwork.org/resource/webinar-recordinglearning-exchanges-trex/](https://fireadaptednetwork.org/resource/webinar-recordinglearning-exchanges-trex/)
- NWCG
  - S-190 – Introduction to Wildland Fire Behavior
  - S-290 – Intermediate Wildland Fire Behavior
  - S-390 – Introduction to Wildland Fire Behavior Calculations
  - S-490 – Advanced Fire Behavior Calculations
- University of Idaho – Fire Ecology and Management
  - REM 144 – Wildland Fire Management
  - FOR 326 – Fire Ecology and Management
  - FOR 433 – Fire and Fuel Modelling
  - FOR 450 – Fire Behavior
  - REM 429 – Landscape Ecology
  - GEOG 313 – Global Climate Change

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28 University of California, Agriculture and Natural Resources, “Defensible Space,” accessed April 2022, [https://ucanr.edu/sites/fire/Prepare/Landscaping/DefensibleSpace/](https://ucanr.edu/sites/fire/Prepare/Landscaping/DefensibleSpace/)
Fuel Type

Gaps in Knowledge:

+ Currently, there are no standardized methods for determining plant or ornamental plant flammability, plant heat release rates or standardized criteria for landscaping plant recommendations.
+ Defensible space requirements and guidance are based primarily on structure survivability in standardized conditions, and not necessarily across the full range of vegetative fuel types, topologies and weather. Additional separations and distance are likely needed where there will be severe weather conditions (e.g., high winds) and fire behavior (e.g., steep slopes, structure density, other urban fuels).
+ Communal defensible space requirements do not currently exist and are oftentimes difficult to enforce if property owners do not have agreements or other easements that compel them to perform vegetation management/fuel treatments on adjacent properties that are within the 100’ home ignition zone.
+ Understanding fire ecology, fire hazards and risks of all vegetation types is still developing.
+ Comprehensive lists of fire adapted vegetation and prohibited plant lists do not currently exist for all topologies, regions and weather conditions. Most information is developed at the local level and can be anecdotal and possibly misleading.
+ Best management practices, even for the same species of plant, can vary depending on the topography and local weather/climate conditions. Strategies used by residents and landscapers to alter influences to flammability (e.g. pruning and plant establishment methods), impacts to plant vigor versus flammability and other landscaping objectives still need development and industry standardization.
+ More detailed guidance is needed as well as alternatives to allow for variations in topography, siting of structure(s), ornamental landscaping, exemplar fire-adapted landscape appropriate for local conditions/context.
+ Site specific defensible space requirements need to be developed at the local level to account for local topography, vegetative typology, local construction practices, local weather/climate conditions, local environmental sensitive habitat requirements, etc.
+ Expanded options are not readily available for how building/homeowners can offset defensible space requirements due to site restrictions (e.g., small parcel sizes, limited setbacks), no control over vegetation management practices of neighboring properties within the defensible space zones, building/housing density, etc.
+ Understanding structure-to-structure fire spread and influence of building density, neighborhood layout and configuration on wildfire vulnerability and associated mitigation measures is a current topic of research.
+ Verifying the utility of fuel separation distance requirements in current building codes for wildfire applications is still developing.
+ Parcel level vs neighborhood levels of defensible space.
+ Common space or shared open space defensible space requirements.
+ There are limited codes, standards, and guidance on vehicles in the home ignition zone. There is overlap between guidance related to vehicles and other flammable items such as liquid propane tanks.

29 Farm and Home Advisor’s Office, University of California Cooperative Extension, Research Literature Review of Plant Flammability Testing, Fire-Resistant Plant Lists and Relevance of a Plant Flammability Key for Ornamental Landscape Plants in the Western States (San Diego, CA: Farm and Home Advisor’s Office, University of California Cooperative Extension, 2016).
Fuel Type

Other References:

+ University of California, Agriculture and Natural Resources
  o Preparing Home Landscaping: [https://ucanr.edu/sites/fire/Prepare/Landscaping](https://ucanr.edu/sites/fire/Prepare/Landscaping)
  o Invasive Plants and Wildfires: [https://anrcatalog.ucanr.edu/pdf/8397.pdf](https://anrcatalog.ucanr.edu/pdf/8397.pdf)
  o Vegetation and Landscaping: [https://anrcatalog.ucanr.edu/pdf/8695.pdf](https://anrcatalog.ucanr.edu/pdf/8695.pdf)
  o Home Landscaping For Fire: [https://anrcatalog.ucanr.edu/pdf/8695.pdf](https://anrcatalog.ucanr.edu/pdf/8695.pdf)

+ UCCE
  o Research Literature Review of Plant Flammability Testing, Fire-Resistant Plant Lists and Relevance of a Plant Flammability Key for Ornamental Landscape Plants in the Western States: [https://ucanr.edu/sites/SaratogaHort/files/235710.pdf](https://ucanr.edu/sites/SaratogaHort/files/235710.pdf)
  + FEMA Factsheets – [https://www.fema.gov/sites/default/files/2020-08/fema_p_737_0.pdf](https://www.fema.gov/sites/default/files/2020-08/fema_p_737_0.pdf)
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  + Be Ember Prepared (Video) – [https://www.youtube.com/watch?v=K-AujhNdF6Y](https://www.youtube.com/watch?v=K-AujhNdF6Y)
  + Ziggerer et al. (2007), Mulch Flammability, Proceedings of Emerging Issues Along Urban-Rural Interfaces II: Linking Land-Use Science and Society
  + Quarles & Smith (2011), The Combustibility of Landscape Mulches
  + Beyler et al. (2014), Development of Test Methods for Assessing the Fire Hazards of Landscaping Mulch, Technology
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