



Wildfire Mitigation Plan Final Report

August 30, 2023

SHF Grant #2022-M2-001
Form+Works Project No. 22-040

Wildfire Mitigation Plan

August 30, 2023

**Deliverable #10
SHF Grant #2022-M2-001**

Prepared For:

History Colorado, The State Historical Fund
1200 Broadway
Denver, Colorado, 80203
Attn: Jenny Deichman, Preservation Planning Specialist

Prepared By:

Natalie Lord, RA, LEED AP BD+C
Preservation Architect and Principal
Form + Works Design Group, LLC
P.O. Box 476
Eastlake, Colorado, 80614

Ron Anthony,
President, Wood Scientist and Wildland Fire Consultant
Anthony & Associates, Inc.
P.O. Box 271400
Fort Collins, Colorado, 80527

TABLE OF CONTENTS

I. PROJECT INTRODUCTION	4
A. WILDFIRE RISK OVERVIEW	4
1. BASICS OF FIRE BEHAVIOR	4
II. SOI STANDARDS	13
III. PHYSICAL INTERVENTIONS FOR HISTORIC WOOD-FRAMED BUILDINGS	18
A. INTRODUCTION ON FIRE CHEMICALS	20
1. Class A Foams	20
2. Water-enhancing Gels	23
3. Fire/Flame Retardant Coatings	24
4. Fire Retardants	25
B. INTUMESCENT COATINGS	26
C. BUILDING WRAPS / FIRE SHIELDS	28
1. FireGuard (FireGuard, 2021) , Aluminized Fiberglass Fabric Wildfire Protection	29
2. Firezat, Inc. (Firezat, 2023), Fire Resistant Fire Shield	30
D. SPRINKLER SYSTEMS	33
1. MARK-3 (Waterax, 2023), Portable Fire Pump	34
2. Code3 Water (Code 3 Water, 2023), Portable Wildfire Pump	36
3. Colorado Fire Break (Colorado Firebreak, 2023), Installed Wildfire Mitigation System	38
4. Defense System 2 (Frontline Wildfire Defense, 2023), Installed Wildfire Sprinkler System	39
E. OPENING PROTECTION: COVERS, INSECT SCREENS, FIRE SHUTTERS	41
1. Enviroblind Rolling Shutters (Environblind, 2021)	42
F. REPLACEMENT MATERIALS	47
1. Roofing	48
2. Windows & Glazing	52
3. Cladding & Trim	56
4. Decking & Walkways	70
5. Vents	73
6. Other Building Products:	81
IV. PHYSICAL INTERVENTION SUMMARY MATRIX	84
V. AREAS OF FURTHER STUDY	87

APPENDIX A: BIBLIOGRAPHY	89
APPENDIX B: LIST OF FIGURES	95
APPENDIX C: SHF DELIVERABLE #3 List of Research Stakeholders & Resources	97
APPENDIX D: ADDITIONAL INFORMATION	105

I. PROJECT INTRODUCTION

The project consultant team was led by Natalie Lord, RA, LEED AP BD+C, of Form+Works Design Group, LLC. Form+Works Design Group was started in 2017, to specialize in Historic Preservation Architecture in Colorado. Ron Anthony, FAPT, of Anthony & Associates, Inc. provided expertise in the preservation of historic wood structures, the field of wood science and wildland fire.

This report is a compilation of information available at the time of its writing and is not exhaustive of all products / manufacturers / treatments available, but rather a look at a select number of examples of currently available / advertised wildfire mitigation treatments for consideration in relation to historic wood-framed buildings in high-risk Wildland Urban Interface (WUI) landscapes. Specialized historic preservation consultation with preservation authorities who review or approve a project shall still be critical to evaluate individual projects and possible wildfire mitigation solutions based on their historic materials / appearance / integrity / significance / etc. The following is a summary of information compiled and updated from the Part 1 Chautauqua Wildfire Mitigation Plan completed in September 2022, but provides a helpful introduction and background information:

A. WILDFIRE RISK OVERVIEW

Risks from wildfire drive the importance of developing and implementing a mitigation plan for any cultural resource that could be impacted by wildfire. Reducing risks is more urgent as fire season now extends through all months of the year in Colorado and fire behavior becomes more extreme. However, not all wildfires are of such intensity or result in the degree of destruction seen in the news. The vast majority of wildfires are controlled within the first few days after ignition. Mitigation efforts often contribute to minimizing the damage from these incidents. For extreme incidents, such as the Marshall Fire in 2022, few mitigation efforts prior to the fire, if any, could have reduced the damage. It is not those fires that we address with a mitigation plan but the much more frequent lower-intensity fires. The goal of mitigation is to keep the small fires small.

1. BASICS OF FIRE BEHAVIOR

It is not the objective to present a dissertation on fire behavior but only to provide sufficient information for stakeholders to understand why there is a risk to their cultural resource from wildland fire. Additionally, the goal is not to make stakeholders fire behavior experts but rather to give them a clear, concise understanding of the factors that impact fire behavior and things stakeholders can do on site to reduce the risk of loss or damage due to fire. Most of the recommendations focus on actions that should be taken well before a wildland fire threatens a

historic resource, not during an incident where the presence of well-intentioned actions of individuals serve to impede responders from safely fighting the fire.

The Wildland Urban Interface (WUI) is a transition zone between largely unoccupied land and human development. It is a geographic zone where structures or other human development, interspersed with undeveloped wildland or vegetative fuels, are present. According to the U.S. Fire Administration, between 2002 and 2016, an average of over 3,000 structures per year were lost to WUI fires in the United States and the WUI area continues to grow by approximately 2 million acres per year (U.S. Fire Administration, 2022). While the number of losses is significant, the number of structures and cultural resources saved, in part, through mitigation efforts is far more significant.

Fuels, weather, and topography are the key factors in wildland fire behavior. As shown in the well-known fire triangle in Figure 1, it is the interaction of these three variables that responders must address when allocating resources to protect life and property.

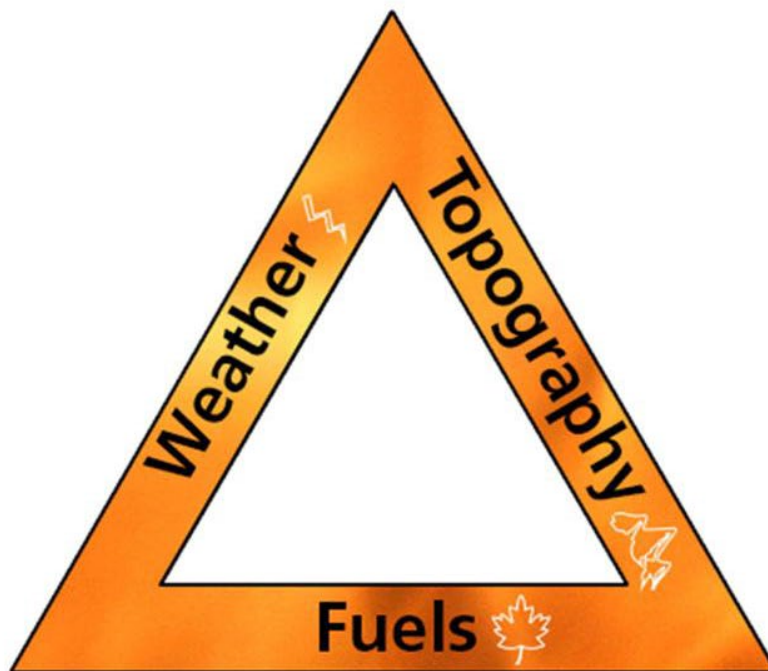


Figure 1: The Fire Triangle

What is fuel? Fuel is anything that is combustible. Most commonly, vegetation is the primary fuel for wildfire. The vegetation may be grasses, trees, shrubs, and plants that make up the landscape. Fuels are categorized by size and how rapidly they can adapt to changes in relative humidity and temperature (affecting the moisture content of the fuel). Grasses are considered fine fuels because they are easy to ignite and will dry very quickly (within hours) as temperatures increase and relative humidity decreases. **Structures are also fuel.** While the materials used on the exterior of the structure affect the probability of ignition, the contents on the interior are subject to ignition from radiant or convective heat from a fire.

What is topography? Topography is the form and features in a landscape. Canyons, mountains, steepness of slope, and elevational differences are examples of topographic features that will influence fire behavior. In most cases, the topography of a site cannot be altered or controlled. On sites that have only slight grade changes (i.e., relatively flat in nature), fire behavior would be influenced more by fuels (structures, vegetation, etc.) and wind during an incident than the topography of the property. However, in areas where topography varies significantly in terms of steepness of slope, elevation, aspect, and other features that can significantly affect fire behavior, particularly, the fire intensity and rate of spread.

What is weather in the context of wildfire behavior? Temperature, relative humidity, and wind are the primary weather factors that affect fire behavior. Precipitation, exposure to ultraviolet radiation, and lightning are other factors that can influence fire behavior. Understanding the impact of changes in weather patterns, primarily higher temperatures, lower precipitation, and high wind speeds in many fire-prone areas is key to anticipating fire behavior on a given site. Many of the recent devastating wildfires in Colorado (and elsewhere) have been the result of extreme winds which carry embers (a phenomenon called spotting) much further distances than during fires from only a few decades ago. It is typically the embers during a wind-driven fire nearby that are the greatest risk to a site or structure. According to the National Institute of Standards and Technology embers can travel several miles ahead or away from a wildfire (Brewer, et al., 2021).

REDUCING THE RISK BY MODIFYING POTENTIAL FIRE BEHAVIOR

The two primary means of significantly reducing the immediate risk to structure in the WUI are fuels mitigation and creating defensible space. Fuel mitigation involves removing or trimming vegetation to reduce the total volume of material that can burn (the fuel load) while reducing the horizontal and vertical continuity of the fuel to lower the likelihood of the fire being able to spread without interruption, as across a grassy meadow (see Diagram Horizontal Fuel and Vertical/Ladder Fuels Figure 2). Horizontal fuel continuity is vegetation or other fuel that is continuous, or touching, across the horizontal plane, e.g., there is little or no separation from tree to tree, shrub to shrub, or grasses in a large meadow. Similarly, vertical fuel / ladder fuels continuity is a lack of separation vertically, e.g., grass to shrubs to tree branches to the crowns of the trees would be a typical example.

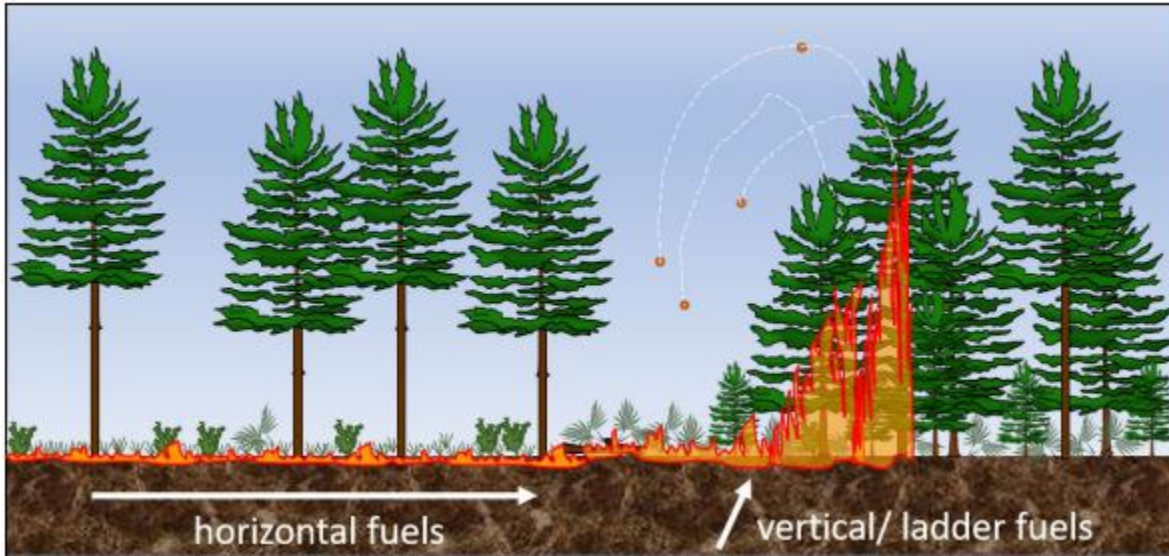


Figure 2: Diagram Horizontal Fuel and Vertical/Ladder Fuels (Campbell, 2020)

The volume of fuels that needs to be reduced and removed through trimming or cutting is typically quite extensive and for historic buildings where the surrounding landscape is a defining feature, this can be a difficult thing to execute. However, when considering the survivability of a significant historic building a critical look at drastically reducing the surrounding fuel load and horizontal and vertical continuity is often the best defense.

Defensible space around a structure to reduce the likelihood of significant damage or loss of the structure is a concept that has been promoted for decades, along with an understanding of the role of building materials on the risk of damage or loss due to fire. Figure 3 and **Error! Reference source not found.** show examples of what are promoted as best practices for establishing defensible space around newly planned residential structures in fire-prone areas prior to construction. These recommendations are good guidance for many single structures in the WUI but not so appropriate for sites with closely spaced buildings and with designated landscape and/or site features that have a historic designation or may be eligible for one. For this reason, consultation between cultural resource specialists, wildfire personnel, and building stewards is likely to result in a compromise when evaluating and determining a fuels mitigation plan and creating defensible space around a historic building or site, rather than the idealized mitigation approaches conveyed in Figure 3 and Figure 4.

DEFENSIBLE SPACE ZONES



Figure 3: Idealized defensible space that is recommended around a single residential structure. This approach is often not feasible for cultural resource sites due to proximity of other structures, heritage trees, or other features that are significant to the cultural landscape.

TREE SPACING

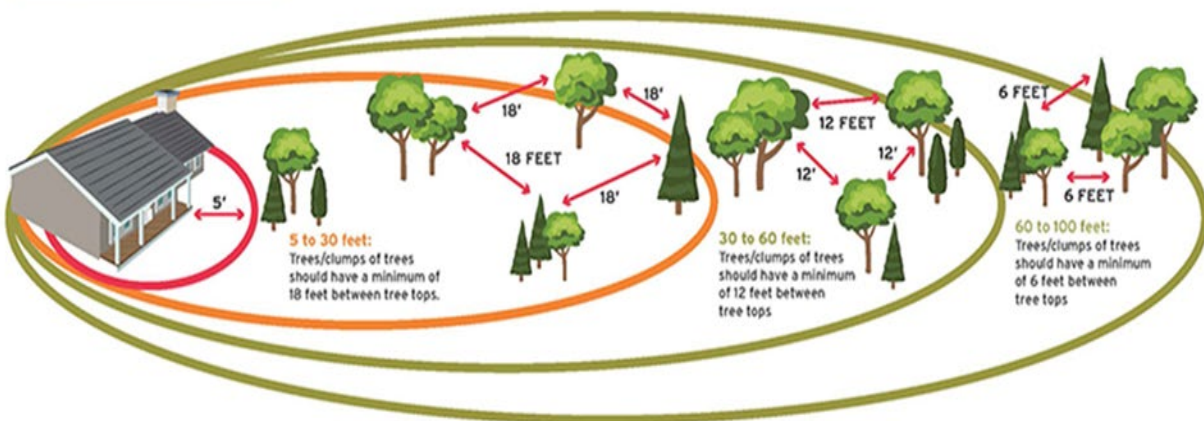


Figure 4: Defensible space as recommended by removing or trimming vegetation to eliminate horizontal and vertical fuel continuity to reduce the risk of the fire spreading and making fire operations more challenging and less safe. As is the case for Figure 3, this approach is often not feasible for cultural resource sites due to proximity of other

HEAT TRANSFER AND IGNITION

Fuel ignites from a variety of means during a wildfire. Historically, most people are concerned with surface fires where there is direct flame contact. More recently, wind-driven fires of extreme intensity are becoming more frequent and far more destructive than surface fires. In either case, fuels adjacent to a building (vegetation, wood, and structures) that are in direct contact with the flame front may ignite. However, it is easy to confuse heat transfer and ignition during a wildfire. Said another way, “it might get hot, but it doesn’t necessarily burn.” Reducing the fuel load, by conducting fuels mitigation and creating a defensible space, can reduce the possibility of a building burning even though it may “get hot.”

Heat transfer occurs through convection, radiation, or conduction. Convection is the movement of hot air due to heating of the air molecules. Convection is the primary means of fire spread by pre-heating fuels in advance of the fire, including the upper crowns of trees. Radiation is the movement of heat energy as waves pass through the air. The heat is transferred when the wave reaches a physical object that conducts heat. Radiant heat from a wildfire can ignite combustible materials inside a structure from several hundred feet away in extreme events. Conduction occurs when heat is transferred from molecule to molecule through direct contact, such as when one touches a hot skillet, see Figure 5.

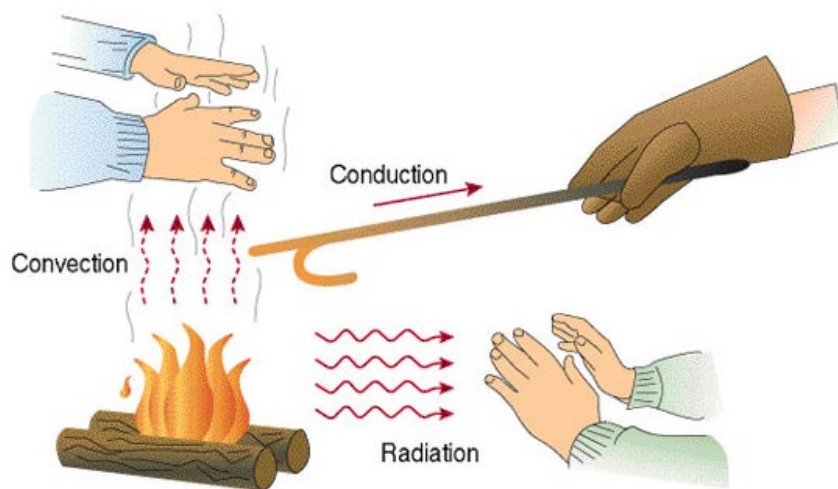


Figure 5: Diagram of Convection, Conduction, and Radiation Heat (Shirley, 2015)

Firebrands, or embers, are airborne burning materials that can cause ignition when they come in contact with unburned fuel. Embers can be from vegetation (pinecones, sticks, leaves, etc.), structures (roofing, siding, even roof sections, etc.), or other burning materials. Wind can carry

the embers long distances, farther than convection or radiation can transfer heat for combustion, and upon landing can ignite vegetation or get into openings (e.g., uncovered vents) in structures and start fires on the interior before the flames ever reach the structure, see Figure 6. While embers have always been a concern during wildfires, the wind speeds and gusts recorded in relatively recent fires can travel, or spot, well over a mile in extreme wind events where gusts exceed 60 to 80 mph. Most structures lost to wildfire are the result of embers causing ignition of the structure itself, or traveling from ignition of the landscape or elements nearby, thus reinforcing the need for fuels reduction and mitigation.



Figure 6: Illustration of Firebrand / Embers Traveling from Fire to Structure (Walls, 2023)

Ignition occurs when a combustible material reaches a temperature sufficient to support combustion of that material. A general rule is that the majority of fuels will ignite during a wildfire at a temperature of approximately 500 degrees Fahrenheit. Embers (firebrands) that travel through the air due to wind or air currents (such as a convective column, see Figure 7, often seen on large wildfires) are the most common source of structure ignition through spotting. If the embers are large enough to retain heat or are burning when they land on a combustible material, an ignition can occur. Addressing the probability of ignition to or in a structure is critical to reducing the potential impact of embers, particularly during wind-driven fires. Erratic winds can put embers in tight openings that, through conduction, will result in an ignition. Continued maintenance of structures is critical to prevent embers from getting into openings. Ensuring that paint is maintained on exterior woodwork and conducting regular visual inspections to determine entry points for embers should be part of routine maintenance, see Figure 8.

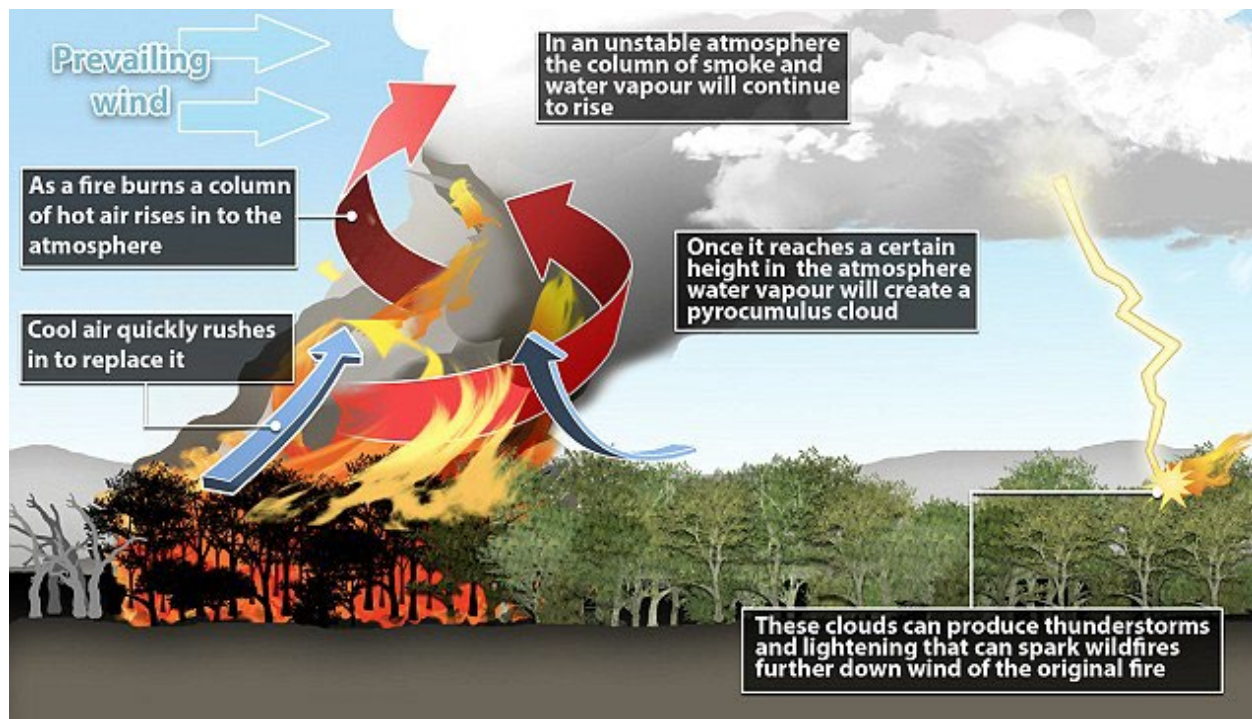


Figure 7: Diagram of a convective column (Pedrógão Grande Fire Timeline, 2018)



Figure 8: Deteriorated fascia board that provides an entry for wind-blown embers can result in an ignition on the interior of the structure.

The above brief introduction and discussion of fire behavior; ignition sources and pathways; fuel loads and fuel mitigation, aims to provide a general introduction and method for evaluating risks to a wood-framed building. A building with close, overhanging trees and dense shrubs and grasses right up next to the base of the building, provides direct pathways for fire to approach a building. If these can be removed or greatly reduced, a building has a better chance. Maintenance of exterior materials is also critical to reducing pathways. As wildfire risk becomes a top concern for building owners, many look to building material “hardening” options to reduce risk to ignition. Wildfire “hardening” means taking steps to reduce vulnerability to embers and heat that accompany most wildfires (Harden Your Home, 2023). A web search will reveal a multitude of companies offering building materials that are formulated to resist ignition. For a new building being constructed in a WUI zone, there are many options to building a more resistant structure. For a historic property in the WUI zone, whether it be currently designated, eligible for designation or likely to be eligible in the future, greater care, consideration and consultation with historic authorities is required prior to replacement of the building’s materials. For designated structures, their materials are often a defining feature of their integrity. Removing original materials would risk potential and current designations.

II. SOI STANDARDS

The Secretary of the Interior's Standards for the Treatment of Historic Properties (SOI Standards), provide guidance for owners, managers, architects, contractors, and project reviewers in order to best care for historic properties and maintain their integrity. A summary of the four treatments is provided below. There has been recent discussion at the professional level with the National Park Service whether the Standards should be updated to respond to more current challenges and risks to historic structures. An example of updated guidelines for flood adaptation, provided below, illustrates the identification of the need and the follow-through response to such threats in order to increase the survivability of historic buildings. Issues related to the treatment of historic properties as it relates specifically to wildfire are not adequately addressed in the current Standards. Further, the use of alternative materials is a very dynamic topic as new products enter the market, particularly related to alternatives to wood products.

The SOI Standards address four treatments: preservation, rehabilitation, restoration, and reconstruction (Part 68 The Secretary of the Interior's Standard for the Treatment of Historic Properties, 2023) . Per 36 CFR Part 68, the federal regulation establishing the standards, "one set of standards...will apply to a property undergoing treatment, depending upon the property's significance, existing physical condition, the extent of documentation available, and interpretive goals, when applicable. The Standards will be applied taking into consideration the economic and technical feasibility of each project." The following are the definitions for the four treatments:

Preservation: the act or process of applying measures necessary to sustain the existing form, integrity and materials of an historic property. Work, including preliminary measures to protect and stabilize the property, generally focuses upon the ongoing maintenance and repair of historic materials and features rather than extensive replacement and new construction. New exterior additions are not within the scope of this treatment; however, the limited and sensitive upgrading of mechanical, electrical and plumbing systems and other code-required work to make properties functional is appropriate within a preservation project.

Rehabilitation: the act or process of making possible an efficient compatible use for a property through repair, alterations and additions while preserving those portions or features that convey its historical, cultural or architectural values.

Restoration: the act or process of accurately depicting the form, features and character of a property as it appeared at a particular period of time by means of the removal of features from other periods of time by means of the removal of features from other periods in its history and reconstruction of missing features from the restoration period. The limited and sensitive upgrading of mechanical, electrical, and plumbing systems and other code-required work to make properties functional is appropriate within a restoration project.

Reconstruction: the act or process of depicting, by means of new construction, the form, features and detailing of a non-surviving site, landscape, building, structure or object for the purpose of replicating its appearance at a specific period of time and in its historic location.

When evaluating the applicable four treatments, each project needs to be considered on its own. For structures that are in active residential or public use, the Rehabilitation Standards are likely the most applicable, although careful consideration would be needed prior to each project pursuit. The Rehabilitation Standards provide flexibility for updating and adapting historic buildings for continued use by the public. The SOI Standards ten principles for Rehabilitation are:

- (1) A property will be used as it was historically or be given a new use that requires minimal change to its distinctive materials, features, spaces and spatial relationships.*
- (2) The historic character of a property will be retained and preserved. The removal of distinctive materials or alteration of features, spaces and spatial relationships that characterize a property will be avoided.*
- (3) Each property will be recognized as a physical record of its time, place and use. Changes that create a false sense of historical development, such as adding conjectural features or elements from other historic properties, will not be undertaken.*
- (4) Changes to a property that have acquired historic significance in their own right will be retained and preserved.*
- (5) Distinctive materials, features, finishes and construction techniques or examples of craftsmanship that characterize a property will be preserved.*
- (6) Deteriorated historic features will be repaired rather than replaced. Where the severity of deterioration requires replacement of a distinctive feature, the new feature will match the old in design, color, texture and, where possible, materials. Replacement of missing features will be substantiated by documentary and physical evidence.*
- (7) Chemical or physical treatments, if appropriate, will be undertaken using the gentlest means possible. Treatments that cause damage to historic materials will not be used.*
- (8) Archeological resources will be protected and preserved in place. If such resources must be disturbed, mitigation measures will be undertaken.*
- (9) New additions, exterior alterations or related new construction will not destroy historic materials, features and spatial relationships that characterize the property. The new work will be differentiated from the old and will be compatible with the historic materials, features, size, scale and proportion, and massing to protect the integrity of the property and its environment.*

(10) New additions and adjacent or related new construction will be undertaken in such a manner that, if removed in the future, the essential form and integrity of the historic property and its environment would be unimpaired.

The wildfire mitigation treatment options provided in this document were evaluated based on the above ten principles. The intent of this document is to provide a list of options for wildfire mitigation for wood-framed structures that will not negatively impact their historic integrity, thus risking the loss of their historic designation status or eligibility for designation. As illustrated by the ten principals above, “distinctive materials” are a key feature of a historic building’s identity. Historic roofing, siding, windows, and doors are often what stand out to the onlooker to identify it as old.

In November 2019 the National Park Service issued a document “The Secretary of The Interior’s Standards for Rehabilitation & Guidelines on Flood Adaptation for Rehabilitating Historic Buildings” (Eggleston, Parker, & Wellock, 2019). This more recent update to the Standards shows recognition of a need for adaptation of preservation standards in response to this specific weather event. Per the document:

The goal of the Guidelines on Flood Adaptation for Rehabilitating Historic Buildings is to provide information about how to adapt historic buildings to be more resilient to flooding risk in a manner that will meet The Secretary of the Interior’s Standards for Rehabilitation. Resilience in this publication means the capacity of a historic property to withstand and recover from a flooding event.

Although a similar document does not currently exist as a guideline for wildfire adaptation for rehabilitating historic buildings, parallels to the Flood Adaptation document can be drawn.

The treatments described here are a means of preserving historic properties located in flood-prone areas and making them more resilient to flooding hazards. Flood events can be particularly destructive to historic buildings and therefore may require greater adaptive treatments. While many of these treatments can be undertaken with minimal effects on the historic character of a property, some may require more change than would normally be acceptable. Such treatments are generally not appropriate when a historic building does not have a flood risk. The treatment selected should always be one that minimizes changes to the building’s historic character. Adaptation treatments should reduce the risk of flood damage as much as possible, but should do so without destroying significant historic materials, features, or spaces.

Assuming a similar goal for wildfire adaptation for rehabilitation historic buildings, this more recent document can perhaps provide a framework for a similar document for historic buildings at high risk for wildfire. The process for evaluation for historic buildings with high flood risks does require more consultation with preservation specialists and detailed evaluation would be

necessary to develop a specific treatment plan. Information on this process from the Flood document would give insight on what this might require for projects in high risk WUI areas:

Before undertaking any work to adapt a historic building to be more resilient to potential flooding, research about the actual flood risk as well as about the historic property must be undertaken. Proposed alterations to the property will need to be adequate to address the identified risk.

Property owners should take into account the characteristics of the potential flood. These characteristics include the direction the water will likely flow the expected speed and depth of the water, the duration of the flood,The applicable Federal, state, and local code requirements and regulations must also be considered.

...Prior to planning or undertaking any work, the spaces, features, materials, and finishes of the historic property affected by the flooding or the proposed adaptive treatment should be documenting. The property's existing capacity to sustain and recover from flooding, as well as its physical condition and use, should be evaluated. Those spaces, features, and materials that are important to the historic character and significance of the property should be identified for retention and preservation.

...Planning and risk assessment for potential flooding should therefore be undertaken proactively, and properties should be maintained in good condition, monitored regularly, and appropriately documented as part of any treatment plan for the property....When a new adaptive treatments are needed, they should be carried out in a manner that will have the least impact on the historic character of the building, its site, and setting. In adapting a building to be more resilient to flooding risks, the goal should always be to minimize the impacts to the building's historic character to the greatest extent possible. It is helpful to record the decision-making process for future evaluation.

All planning and assessment for reducing flood risks should include the following:

- *Identify the historic property's flood risks and vulnerabilities and any existing capacity for resilience.*
- *Monitor the condition of the property and regularly reevaluate its flooding risks and vulnerabilities.*
- *Document the historic property. The Secretary of the Interior's Standards for Architectural and Engineering Documentation or Preservation Brief 43: Preparation and Use of Historic Structure Reports can serve as a guide.*
- *Review and understand the compliance requirements of the local floodplain ordinance and related local regulations.*
- *Identify and assess all feasible adaptation treatment options to determine how they will address the flooding risk.*
- *For each treatment option, evaluate the impacts of any potential alterations to the historic property's character defining spaces, features, and materials, and its site and environment.*

- *Consideration should be given to how local communities have decided to adapt to the risk of flooding hazards and treat historic properties impacted by these risks. Also consider the future viability of community infrastructure, such as roads, sewers, and other utilities and services.*
- *Select the time frame for which the adaptation treatment is expected to adequately reduce the risk. This could be tied to the length of a mortgage or some other point in the future.*
- *Always select an adaptive treatment that minimizes the impacts to the historic character and appearance of an individual property and/or a larger historic district.*

The document includes a series of planning and assessment recommendations, the following select recommendations have similar application projects in high risk WUI areas:

- *Assessing the potential impacts of known vulnerabilities on character-defining features of the building, its site, and setting. Reevaluating and reassessing potential impacts on a regular basis.*
- *Maintaining the building, its site, and setting in good repair, and regularly monitoring character-defining features.*
- *Using and maintaining existing historic and non-historic characteristics, features, and materials of the historic building, its site, setting, and larger environment (such as a site wall that keeps out flood waters) that may help to avoid or minimize the impacts of flooding.*
- *Undertaking work to prevent or minimize the loss, damage, or destruction of the historic property while retaining and preserving significant features and the overall historic character of the building, its site, and setting.*
- *Ensuring that, when planning work to adapt for flooding, all feasible alternatives are considered, and that the options requiring the least alteration are considered first.*
- *Considering adaptive options, whenever possible, that would protect multiple historic resources, if the treatment can be implemented without negatively impacting the historic character of the overall historic property, district, or archeological resources, other cultural or religious features, or burial grounds.*

Conversely the document includes a list of things that are not recommended:

- *Carrying out adaptive measures intended to address the impacts of flooding that are unnecessarily invasive or will otherwise adversely impact the historic character of the building, its site, or setting.*
- *Failing to plan for flood risk and to make a treatment decision, even if the decision is that no intervention is currently necessary.*
- *Failing to consider other properties nearby in planning flood adaptations, therefore increasing the risk or exposure to neighboring properties.*

The following evaluation of wildfire mitigation options based on conformance to the SOI Standards and effectiveness on historic structures was not based on laboratory research but rather on a review of published technical literature (as opposed to marketing information). The questions asked when reviewing various products / treatments were (1) how effective the treatment is in protecting a structure (or vegetation), (2) does technical test data exist on the impact on historic fabric (in this case, wood; e.g., does it change the color of raw wood), and (3) is there a long-term effect (e.g., is it reversible).

III. PHYSICAL INTERVENTIONS FOR HISTORIC WOOD-FRAMED BUILDINGS

Wildfire management during an incident generally includes tactics to directly attack the edge of the fire. In addition, fire suppressants and retardants are used to enhance the capabilities of water, with many suppressants used as short-term retardants to reduce the fire intensity so that firefighters can directly engage the fire. Most people are familiar with the red retardants that are dropped from aircraft. To fight fires that threaten values at risk, crews may also use suppressants, such as gels that carry water and superabsorbent polymers (such as those found in diapers). These gels are frequently used as short-term retardants on buildings in the path of encroaching fires, but they lose effectiveness once the water entrapped in them evaporates – something that may occur in less than an hour during normal wildland fire conditions.

Foams, gels, and retardants have been applied to structures during a wildfire, either intentionally or inadvertently, as a passive approach to protect a structure. Responders apply foam, gel or retardant shortly before arrival of the flame front or, in some cases, building owners are proactive and apply coatings to their structure long before a fire occurs. The goal during a fire is to attempt to prevent the loss of the structure to the fire; but not to consider the effects of the foam, gel, or retardant on the historic fabric of the structure. Even slight changes in color are not considered when requesting a retardant drop from an air tanker adjacent to a structure. Any of the conventional chemical treatments will generally retard the fire intensity or progress (rate of spread) and, perhaps, allow for firefighters to apply direct attack techniques to protect the structure. If that is successful, the fire-fighting operation may move on, and it is left to the owner or building steward to deal with the after-effects.

The National Center for Preservation Technology and Training has conducted research on the effect of a limited number of fire chemical products on historic materials and reports that:

Repetitive swelling and contracting of the exterior of wood can exfoliate the surface. This changes the wood texture, which leaves the surface with a fuzzy appearance and increases the potential for future soiling and accelerated decay. Additionally, it has been observed that paint or varnish is stripped from wood as fire chemicals dry on the

material. Soluble salts and swelling liquids found in fire chemicals have the potential to reduce the mechanical properties relating to the stability of wood.

The effects that fire chemicals have on heritage building materials are interconnected. Saline water and the deposition of salts within and on the materials cause much of the deterioration to cultural resources exposed to fire chemicals. Fugitive color agents can leave a resource looking unattractive or out of place. Due to the many hazards of fire chemicals to cultural resources, it is necessary to clean them appropriately. This entails identifying an effective yet gentle method for removing fire chemicals that does not compound or enhance the harmful effects of fire chemicals (Eldredge, 2022).

Note: The above source referenced report, *Fire Suppressants and Cultural Resources*, by Katherine Eldredge (2022) is an internal draft report referenced with permission from the National Center for Preservation Technology and Training. The official report has not been released to the public and all information referenced should be considered as a draft status until formal publishing has occurred.

The after-effects can be quite varied but may include color changes, changes in texture, or damage to the historic fabric, among other detrimental effects. What is typically unknown are the effects on the material itself - whether the application of a chemical (foam, gel, retardant, or, discussed later, intumescent paints) alters the fundamental properties of the wood in ways that reduce the service life of the wood. **For virtually all the fire chemicals discussed below, technical data do not exist that answers the question of whether the wood is altered (harmed) by applying the chemical such that the historic nature of the wood and the structure is negatively impacted.** There is limited information that the chemicals act only on the surface of the wood but whether it is truly reversible requires that technical research be conducted to determine whether that is the case.

Is there a debate to be made that without applying foam, gel, or retardant that the structure may be lost to the fire, and would that not be preferable to reducing the service life of the wood siding from, say, 40 years to 10 years? Yes, but that is not the goal of this report. The review of various product categories in this report focused on the data that is currently available and, in general, it was found that data on the effects on historic wood are lacking. Manufacturers are generally sympathetic and interested in exploring the effects but recognize that their primary market is not historic structures. As this report is not intended to recommend any specific brand or product, the following is not an exhaustive list by any means but does look at information and types of physical interventions from a handful of manufacturers.

A. INTRODUCTION ON FIRE CHEMICALS¹

Class A foam and fire-fighting gels (sometimes called water-enhancer gels) are chemicals added to water to enhance the fire-fighting effectiveness of the product. Fire retardants are chemically based products that alter the combustibility of the fuel to which the retardant is applied. The goal of any of these families of products is to assist prior to or during fire-fighting operations by slowing the progress of the fire or reducing its ability to ignite vegetation or construction materials.

There is very limited technical data on the effect of foams, gels, and retardants on historic materials, including wood. This makes it challenging to recommend specific products when the possibility of detrimental effects on the historic fabric are unknown. One might assume a Class A foam applied to wood cladding could simply be washed off the surface with water, and manufacturers advertise this to be the case. However, the question of whether the foam penetrates into the wood, particularly exposed or uncoated wood, and results in a shortened service life or impacts the ability of the wood to retain a traditional coating, such as a paint or stain, has not been answered. As mentioned, reduced service life is likely much preferred to losing the structure but again, that debate is not the focus of this report. Rather, the topic addressed is what potential treatments or products are available and does their use meet the SOI Standards for the Treatment of Historic Properties based on currently available data.

1. Class A Foams

Foam additives have been used for firefighting since the early 20th century. Modern foams were first used primarily as fire-extinguishing agents for flammable and combustible liquids classified as Class B fuels. Class A foams were developed in the 1980s for fire suppression of Class A fuels, which comprise solid combustible materials such as brush, wood, and paper, and are used to control wildfires and structure fires. Class A foams are versatile fire chemicals applied to protect the material against fire, suppress an existing fire, and prevent reignition by extinguishing embers.

Fire-fighting Class A foams combine water, foam concentrate, and air to create a homogenous foam blanket over the material surface. The foam concentrate is formulated with surfactants that have an affinity for carbon, resulting in improved foam penetration into carbon-rich combustible materials such as wood. The ability of a surfactant to decrease the water surface tension leads to increased wetting effectiveness and water saturation of Class A fuels compared to water. When in the foam form, water can remain on vertical and horizontal surfaces without beading and runoff for a considerable time, thus being better able to absorb heat. However, this is generally limited to hours prior to the arrival of a fire. Moreover, a foam blanket of an actively

¹ The authors would like to thank Suzana Radivojevic, PhD for her assistance and contribution to the research on fire chemicals.

burning structure smothers the fire by preventing air from contacting the fuel, eventually lowering the fuel temperature to below its ignition point. This is often seen in photos or films of structure fires in an urban setting and is used by most fire departments. The protective action of a foam blanket is manifold since it combines the benefits of reflection of the radiant heat due to the white color of the foam, provides a physical barrier formed by a mass of bubbles that act as an insulating blanket, and provides an increased moisture content to Class A fuels.

Foam concentrate generally comprises surfactants (e.g., hydrocarbons, detergents, siloxanes, and proteins), and various additives, such as organic solvents (e.g., trimethyl-trimethylene glycol and hexylene glycol), foam stabilizers (e.g., lauryl alcohol), and corrosion inhibitors (The use of PFAS and fluorine-free alternatives in fire-fighting foams, 2020). Foam solutions are generated by mixing the water with the foam concentrate at a prescribed mixing rate prior to application, which is then aerated during application to create a foam blanket. These are some of the chemicals that are effective for firefighting but have unknown effects on the wood fabric.

Class A foams are versatile fire-fighting chemicals used for direct fire suppression, fire prevention by surface pretreatment of threatened buildings and surrounding vegetation with a protective foam blanket, and the post-fire mop-up (Group, 1993) (Liebson). They can be applied manually or automatically with conventional discharge devices and compressed air foam systems or dropped from the aircraft using standard water fog or air-aspirating foam nozzle equipment for greater foam expansion capability. Modern foam concentrates allow the mixing of fresh, sea or brackish water in the water stream. In indirect attack fire prevention, foams provide an effective method for protecting surfaces in front of the fire by introducing moisture into wood and creating a foam blanket while allowing the fire to reach the structure. Pretreatment with a blanket of Class A foam is often necessary or advised for exposure protection of structures. In addition, Class A foams are also used during the overhaul/mop-up process to reduce water usage and increase water absorption by fuels by emulsifying hydrophobic materials such as resins, waxes, and oils present in wood or wood finishes (Chemguard, Specialty Chemicals & Equipment: Use and Benefit of Class "A" Foam Concentrate in Water, 2005). Finally, high expansion Class A foams designed for use with air-aspirating or forced air devices are available for application to confined and inaccessible areas such as basements and attics (Fighting).

Adding even a small amount of a Class A foam concentrate into a water stream has been reported to increase the water fire-fighting effectiveness up to five times (Foam-Gel-Fire Retardant Comparison Chart, 2010). However, most foams remain effective for a relatively short time following application, reportedly 8-16 hours.

There are examples of Class A foams that have been used to protect historic wood buildings and structures from wildfires. During the wildfire at The Rock Creek Station State Historical Park in Nebraska in April 2023, historic buildings were coated with "fire-resistant foam" prior to fire reaching the historical park grounds, and "the historical park's buildings were not damaged, though the fire came within feet of the structures" (Richter-Ryerson, 2023). Details of the fire intensity (which would impact the ability of the fire to impact the structure) was not provided and follow up on removal success of the foam was not discussed.

Class A foams may provide several advantages for historic buildings and structures threatened by wildfires. Class A foams are typically used at low concentrations of active components, typically 0.1%- 1% by volume of water, and are thus inexpensive while providing substantial water savings. In addition, the foam has high visibility due to its white color, which helps discern the treated areas and surfaces. Since biodegradable, environmentally safe (reportedly) foam concentrate formulations are available on the market, their selection could be recommended for use in protected or sensitive natural environments which often coincide with locations of cultural resources. Class A foams are considered non-hazardous, non-corrosive, and non-flammable when applied in recommended concentrations but these assumptions have recently been subject to debate. Foam concentrate is water soluble and can reportedly be removed by rinsing with water, which allows for the treatment's reversibility when applied to historic wood materials. It has been shown that the foam residue on treated wood surfaces of cultural resources is either invisible or appears as a water stain that should be removed by cleaning using distilled or deionized water within 30 minutes following the exposure to prevent foam drying (Eldredge, 2022).

The drawbacks of Class A foams are that they require water and are difficult to apply under windy conditions and when numerous structures are in close proximity. In addition, following application, Class A foam loses effectiveness with time due to water evaporation and can be blown away by the wind even before the wildfire front arrives.

Class A foam products are at present generally optimized for maximum fire-fighting efficacy, minimal environmental and human exposure risks, and are biodegradable under natural and sewage treatment conditions (Chemguard, Specialty Chemicals & Equipment: General Foam Information, 2005). However, there is no available published research or technical data on short- or long-term impacts on the properties and appearance of historic wood fabric associated with the application and removal of Class A foams. Additionally, there is a lack of scientific data and case studies documenting the effects of Class A foam products on the visual appearance and properties of wood in historic structures. Wood swelling has been suggested in connection to Class A foams (unclear if this is normal swelling due to introduced moisture or a change in wood swelling behavior contributed by the Class A foam chemicals) (Eldredge, 2022).

Surfactants with "degreasing ability" are intended to facilitate penetration of Class A fuels (in our discussion, the wood) by the water. As a result, they are able to emulsify oily substances such as paints, grease and wax and potentially cause damage to both uncoated and coated wood surfaces (Chemguard, Specialty Chemicals & Equipment: Use and Benefit of Class "A" Foam Concentrate in Water, 2005). Class A foam is formulated with synthetic detergent hydrocarbon surfactants, which can emulsify grease, petrochemicals, or paints and deplete wood extractives from uncoated wood (Fornell, 1991). This can potentially have a permanent effect on the appearance and composition of wood and wood coatings. As the foam breaks down, the aqueous foam solution can become absorbed by the material on which it was applied. In the case of uncoated wood surfaces, there is a potential for increased moisture content (secondary mechanism of action).

Examples of Class A foam products:

- Chemguard (Chemattack, Class A Plus, Directattack, Extreme) (Class A Foam Concentrates, 2023)
- PHOS-CHEK WD881 (Phos-Check WD881, 2023)

2. Water-enhancing Gels

Water-enhancing gels are based on superabsorbent polymers (SAP) that can absorb and retain extremely large amounts of water and other liquids relative to their mass. They were first developed in the 1950s and became widely used in products and applications ranging from diapers and surgical pads to waste stabilization. Water-absorbing SAP in fire-fighting gels can absorb water hundreds of times their mass by forming tiny "bubbles" that encapsulate water in a polymer shell, similar to fire-fighting foam bubbles, which contain air. However, water-containing bubbles can absorb more heat and are more efficient than air-containing bubbles.

Water-enhancing gels can be used for structure protection as a short- to medium-term retardant applied on buildings and surrounding vegetation in the wildfire path and are very effective for a direct attack in wildfire suppression. Gels are, along with foams, classified as "water enhancers" and termed "water-enhancing gels" when used as a fire suppressant for direct application.

Water-enhancing gels are typically applied with ground-based equipment. They remain effective until water evaporates from the gel. Although they can be re-hydrated and their fire resistance potentially restored, there is a risk of gels being washed off the material during attempted rehydration and the failure of the product to regain its original consistency (Water Enhancers Fact Sheet, 2017). Depending on the fire and weather conditions, the protection lasts from one to 48 hours, but during wildland fire conditions, they were reported to lose efficacy within an hour (Yu, et al., 2019) (Water Enhancers Fact Sheet, 2017) (Firelce Pro (Dry Concentrate), 2023) rendering it ineffective for application in clusters of structures. Newer formulations are resistant to winds and effective for over 6 hours (Barricade Fire Blocking Gel, 2023).

Fire-retardant gels (FR gels) are primarily cross-linked polyacrylates and polyacrylamides. Products are often marketed as eco-friendly and nontoxic to aquatic or terrestrial organisms at recommended application rates. FR gels are manufactured as clear or colored with orange or blue fugitive colorants added as effectiveness indicators. Orange and clear gels can be removed by rinsing with water, and blue gels must be cleaned up with an oil-based solvent (After the Fire: Cleaning Up Fire Retardant and Fire Suppressants, Undated). Some polymer ingredients break down in the environment over time and with UV exposure. Many products are classified in technical literature as stable, non-reactive and non-corrosive. However, mixtures outside the recommended ratios have increased the potential for some types of corrosion.

Records documenting the use of fire-fighting gels on historic resources or their impacts on historic wood fabric are generally unavailable. While the water-enhancing performance of the fire-fighting gels is evidently superior to that of Class A foams, their use on historically designated buildings should be approached with caution since they have been reported to cause damage or irreversible change to the building surfaces and other negative effects may be anticipated based on their properties. Some gels can cause discoloration such as white stains

and paint peeling during the removal of solidified gel. Recent research on the removal of wildland fire chemicals from cultural resources conducted by the NCPTT, shows that they can appear as a blue stain, or water stains on wood, or as deposits with white streaks with a sheen and dry gel clumps on numerous various historic materials (Eldredge, 2022). In addition to adverse effects on historic wood resulting from changes to the original fabric's color and appearance, removing the dry gel from the wood surfaces can be difficult, costly, and carries a high risk of further damage. Technical literature suggests that some products can be removed by rinsing the surface with clean water (Foam-Gel-Fire Retardant Comparison Chart, 2010) (Firelce Pro (Dry Concentrate), 2023). While cleaning of gels from historic wood can be accomplished with water if done immediately after exposure before the gel completely dries (usually one hour), removal of dry gel requires more elaborate and time-consuming methods such as use of poultice that are more appropriate for small areas (Eldredge, 2022). Gel-coated surfaces are slippery and can create hazardous conditions during mitigation and building cleanup.

Examples of Water-enhancing Gels:

- Thermo-Gel (Fire Retardant - Thermo Gel and Phos Check Foam, 2023)
- PHOS-CHEK® INSUL-8 (Phos-Chek Insul-8, 2020)
- Firelce Pro (Dry Concentrate) (Firelce Pro (Dry Concentrate), 2023)

3. Fire/Flame Retardant Coatings

Fire/flame retardant coatings (often called fire retardants) impregnated into or used to coat wood have a long history of use as preventive treatments to improve fire resistance. This requires application to products during construction or repairs and has not typically been used in historic structures, other than wood shakes and shingles. More recently fire-retardant treated wood has been used when repairing existing structures or new construction. Some of these projects are evaluated later in this report.

The mechanism of action of common fire-retardant chemicals is based on their ability to reduce the flammability of wood and other combustible materials by either physically blocking the fire (by cooling, creating a protective charred layer, or releasing water and/or carbon dioxide while burning) or by initiating a chemical reaction that stops the fire. The most widely used fire retardants in wildfire suppression are based on mono- and di- ammonium phosphates and fortified with corrosion inhibitors, thickeners, and fugitive colorants that fade with exposure to sunlight and elements. They can be dropped from aircraft for direct attack or applied on the ground, especially for an indirect attack.

Fire-retardant coatings comprise several groups with different modes of action. The charred layer-producing fire-retardant coatings are formulated with water-soluble salts such as diammonium phosphate, ammonium sulfate, and sodium borate (Ross, 2010). They are designed to facilitate wood decomposition to charcoal and water rather than volatile combustible

gases. Water-soluble fire-retardant coatings are typically based on silicates, urea resins, or polyvinyl emulsions. Oil-based fire-retardant alkyd and pigmented paints can contain chlorinated paraffins and antimony trioxide as fire-retardant components and inert materials, including zinc borate, mica, kaolin, and inorganic pigments (Ross, 2010).

Many fire-retardant finishes are water-soluble and intended only for interior use. In some instances, fire-retardant chemical coatings are recommended for the exterior wood surfaces of historic structures such as timber bridges to reduce the risk or extent of damage from accidental fires and provide protection from wildfires (Lebow, et al.). The main weakness of fire-retardant coatings is their inability to insulate the substrate, which remains susceptible to damage by fire. Although water-borne formulations leach out from exterior wood surfaces, this process can be lengthy and cause undesired effects on wood properties. When used as a preventative measure, the purpose of the fire retardant is not to save the structure but to provide sufficient time for occupants to exit and firefighters to conduct a search to verify that the structure is unoccupied.

Examples of Fire/Flame Retardant Coatings:

- Fire retardant paint additive: Flamecheck M-111PA (Flamecheck M-111PA, 2023)
- Flame Control No. 10 for Cedar Shakes and Shingles (Fire Retardant Paints, 2023)

4. Fire Retardants

Aerial fire retardants dropped from aircraft are used during fire-fighting operations to provide a fireline (break in fuel), reduce the fire intensity, or suppress the fire. Fire retardants have a long record of use to control wildfires. A fire-retardant foam blanket applied with a compressed air foam system was used in the 1988 Yellowstone National Park wildfires and credited with protecting the Old Faithful Inn and most other park buildings from heavy damage (17 Structures at Old Faithful Catch Fire, 1988). Aerial fire retardants are not recommended for direct drops on structures because the weight will damage or destroy the structure.

Conventional fire retardants have in recent years come under public and regulatory scrutiny due to the growing evidence of their adverse effects on the environment, especially in naturally sensitive areas. As a result, their use is not recommended near cultural resource sites (Big Bend National Park Texas: Wildland Fire Management Plan, 2005). Fire retardant chemicals can be absorbed by the historic wood fabric or deposited on the surfaces during their application. Their residues on historic materials including wood have been reported to be colored (pink or orange), have a dull appearance with shiny flecks of crystalline deposits, often with cracked and raised layers (Eldredge, 2022). Being primarily water soluble, hygroscopic, inorganic salts, they are capable of increasing wood swelling, migrating to the surface with water movement resulting in efflorescence, interfering with adhesion of wood finishes, promoting corrosion of metal fasteners, to name a few potentially negative effects (Catelli, 2016) (Kim DW, 2014) . In addition, there is a risk of coloring agents and other additives in fire

retardant formulations causing the surface discoloration of wood material. To avoid or minimize adverse effects on wood in cultural resources, it is recommended that the surfaces are cleaned with deionized or distilled water before the fire-retardant dries completely, typically within an hour of the application (Eldredge, 2022).

A recently developed technology combines the delivery system of gels and foams with the efficacy of conventional fire-retardant. It utilizes bio-based hydrogel polymer (cellulose and colloidal (nano)silica), acting as a thickener and a delivery system for ammonium phosphate salts as an active fire-retardant component (Young Jr., 2023). As a result, the product has improved adherence and durability on vegetation and other surfaces compared to conventional fire retardants. It is marketed as a pretreatment formulation recommended for precision application from the ground early in the fire season (Phos-Chek Fortify: Season-Long Preventive Protection Against Wildfires, 2023). This formulation is a chemically stable uncolored water-soluble gel-like fluid. The treatment remains effective until a significant rain event of one inch or more. It has been used on the historic Reagan Ranch in California (Green, 2021). However, it is unclear if it was applied to the structure or only to ground vegetation.

Example:

- PHOS-CHEK LC95W (Phos-Chek LC95W, 2023)

B. INTUMESCENT COATINGS

Intumescent coatings expand during heat exposure, forming a low-density insulating film that protects the wood substrate from heat. The coating intumesces - bubbles and foams - at high temperatures and then hardens into a charred film. This protective carbonaceous film insulates the wood surface from heat and retards combustion. However, the charred film's efficacy is limited compared to natural wood char, and its main role is slowing down the spread of the flame. The charred film generally delays the onset of wood substrate burning and can reduce the risk of premature structure failure (Puri & Khanna, 2017).

Most intumescent paints are intended for internal use, with minor exceptions, such as application of a topcoat (latex paint) or in small enclosed exterior areas of structures. They are not intended for exterior cladding or logs. There is often confusion around the appropriate use of intumescent coatings because of the fire tests that the products have been evaluated under. This is also the case with some other fire chemicals as well as alternative products described later (treated wood siding products). The most common tests are the American Society of Testing and Materials (ASTM) E84 and E119 (ASTM 119-20 Standard Test Methods for Fire Tests of Building Construction and Materials, 2023; ASTM E84-21a Standard Test Method for Surface Burning Characteristics of Building Materials, 2023). The purpose of these tests is to determine the relative burning behavior of products or assemblies, often categorized by a flame spread, smoke index or a fire rating, such as 1-hour or 2-hour. These criteria are listed in building codes for determining fire resistance. Both tests state

This 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.

The disclaimer referring to *actual fire conditions* is what distinguishes the usefulness of passing or failing a particular fire test and appropriateness as a means of protection from wildfire. A laboratory test under controlled conditions is not the same as the uncontrolled conditions experienced during a wildfire. It is this distinction that must be considered to determine the appropriateness or value of using a particular product. Most manufacturers acknowledge this as a limitation of their products. Nonetheless, questions are often raised by building or site stewards about various products and, for this reason, product types are discussed in this report but not generally recommended for cultural resource sites. The key is that products may provide limited additional protection from fire of low-to-moderate intensity or short duration, but they are not fireproof.

Intumescent coatings for wood are available as various pigmented paints, clear varnishes, pastes and additives to acrylic and latex paints. They comprise a dehydrating agent, a char former, and a blowing agent. Common dehydrating agents are polyammonium phosphate, char formers include starch, glucose, and dipentaerythritol, and the blowing agents are usually urea, melamine, and chlorinated paraffins (Ross, 2010).

The treatment of wood in historic buildings must be carefully assessed because intumescent paints alter the original appearance of unpainted wood. For an intumescent paint to be effective, it must be applied to unpainted/uncoated wood. Therefore, for previously painted historic wood, the historic coatings would need to be fully stripped to expose the bare wood prior to applying the intumescent paint. This may be considered a reversible treatment, but intumescent paint removal poses similar challenges to common paint removal and can be costly, difficult, and result in surface damage and loss of the original appearance of wood. Where the wood surfaces are significant historic features, such as in log buildings, these treatments are unlikely to be appropriate.

Clear intumescent coatings are better suited for historic wood that was not painted as they preserve the original appearance of wood while providing a level of fire protection. Studies have indicated that coatings subjected to outdoor weathering are of limited durability and must be frequently reapplied, suggesting they may wear away over time. Further study and analysis of intumescent paint is warranted prior to recommendation as a treatment, at the time of this report, it is not recommended as a potential treatment as a wildfire mitigation technique. Further consideration would be needed to evaluate the effectiveness balanced with the appearance and reversibility of such a treatment.

Examples of Intumescent Coatings:

- FlameOFF® Fire Barrier Paint (FlameOFF, 2023)
- Flame Control Fire Retardant Paints (Fire Retardant Paints, 2023)

- Firefree Coatings (intumescent): Firefree 88, Firefree Wildfire System, Firefree Class A (Firefree products provide high performance fire protection., 2023)
- FBL-100 Intumescent Coating System (ICS) (FBL-100 , 2023)

C. BUILDING WRAPS / FIRE SHIELDS

Wrapping a whole building with fire blankets, also known as structure wraps (thermal shielding), is a viable way to prevent structure ignition. The intent of the wraps is to protect a building from radiant and convective heat and defeat burning embers from contact with the structure during a wildfire.

The first of many U.S. patents for fire blanket concepts was issued during World War Two (Wagner, 1944). Fire blankets have been used both for fire suppression and protection. For example, US Forest Service has used the Aluminized Structure wrap (cabin wrap) to protect historic buildings, including log cabins, when threatened by wildfire (Firezat, 2023) (Miller-Carl, 2008). There are different ways to secure the wrap. It can be installed utilizing sandbags, tire wire, chains, rocks, double sided tape, pony clamps, pipes or bars, and dirt. However, the downside of these methods is the consideration for resistance to wind. Wildfire conditions often coincide with significantly high winds. As a result, installers often resort to stapling the wrap on the building. For a basic single level 3–4-bedroom home it is estimated that a novice installer crew of 4 or 5 people can install it in 5-6 hours. Once trained the installation time can be as little as 2.5-3 hours. One of the major concerns is the quantity of staples and impact on historic wood. One installation reported that it took 6-7 hours and 15,000 staples to secure a wrap to the building (Griggs, 2014). A method for reducing the quantity of staples has been tested by various agencies where chicken wire is utilized to secure the wrap, requiring less staples to install, but resulting in additional installation time in order to form the chicken wire tightly against the structure.

A recent scientific study of various blanket technologies confirmed that they can protect an isolated structure from a relatively short wildfire attack, but that further technological developments are needed to adapt this method for application in severe fires. The study by Fumiaki Takahashi concluded:

The performance of fire blankets to block heat has been investigated experimentally in the laboratory and prescribed wildfires. Two-layer thin fabric assemblies blocked up to 92% of the convective heat and up to 96% of the radiation (with an aluminized surface). Multiple layers (or thicker single fabric) increase the heat-blocking efficiency by enhanced insulation against the convective heat exposure. On the other hand, multiple layers do not improve the performance against the radiation because the reflection and emission heat loss from the high-temperature front surface dominate the heat transfer mechanism.....The best performed fire blankets may be able to protect building

structures if the heat exposure is relatively short (<10 min). This condition would happen when a wildfire front passes an isolated structure, e.g., a historic cabin. If the heat exposure continues, the fire blanket may more likely to be deteriorated or destroyed, while the building materials are being pyrolysed and failed eventually. This situation would be the case for the structure-to-structure ignition. Therefore, for longer exposures (10min to more than 1 hour), better fire blankets (materials, layer assemblies, etc.) would be needed. The key success factors in protecting the WUI structure are (1) the fire blanket's heat-blocking capability, (2) endurance under severe heat-exposure and high-wind conditions, and (3) proper installation to prevent hot-gas and firebrand penetration. Therefore, additional studies are needed in the future in the areas of advanced material/layer developments, blanket deployment methods, and multi-structure protection strategies (Takahashi, 2019).

The controlled laboratory experiments and real-fire exposure tests for wooden structures of various sizes were conducted for four types of fabric materials: aramid, fiberglass, amorphous silica, and pre-oxidized carbon, each with and without an aluminum surface. The fiberglass or amorphous silica fabrics laminated with aluminum foil had the best performance due to high radiation reflection and emission and good thermal insulation by the fabric.

1. FireGuard (FireGuard, 2021) , Aluminized Fiberglass Fabric Wildfire Protection

FireGuard is an aluminized fiberglass fabric (AFF), aka Aluminized Structure Wrap (ASW), and this manufacturer lists three options. Option 1: Purchase and store ASW rolls on your property and wrap your structure. Option 2: FireGuard will fabricate a custom-made ASW blanket for your house. This option takes approximately 90 days. Option 3: Install a permanent ASW system for your property. This option takes approximately 120 days. FireGuard designs the ASW to fit individual architectural styles and states it offers fast and easy deployment in an emergency.

There is limited product and research provided on this product on their website. Reaching out to the manufacturer, they responded that all the research they have is on their website, which appears to be limited to a video of their product. The video depicts their product installed on a small, hipped roof one-story structure in a wooded landscape and captures an approaching fire. The caption states “Fumiaki Takahashi, Department of Mechanical and Aerospace Engineering, Case Western Reserve University, Cleveland, OH, USA”. The four-minute video, apparently utilized from the Takahashi study, shows a weather station extending from the roof and it appears there are fairly high winds with the approaching fire. Over the course of the video the fire approaches, burns the vegetation and trees around the building, but shows the AFF and structure remain in place throughout. There is no follow-up to show the condition of the building following the removal of the wrap.

Asking the manufacturer about their permanent installation option (Option 3), their response was “there are a number of potentially feasible permanently installed options, including sliding curtains in vertical closets (they said these videos are on the website, however, they were not found), drop down curtains stowed in the soffit, folded sheets on the roof in special flat housings that match the roof tiles, etc. However, these options are highly case-specific and require architectural input for a given structure to configure and finalize.”

Evaluation:

Cost: Material Only (without shipping or installation) = \$0.60-1.20 / SF

- Heavy Duty \$900 / roll, not including shipping (5 feet by 150 feet x 16 mil thick, 15 oz/sq. Yd, coverage 750 square feet, weight 76 pounds)
- Standard Duty \$450 / roll, not including shipping (5 feet by 150 feet x 8 mil thick, 7.4 oz/sy yd., coverage 750 square feet, weight 38.5 pounds)

Pro: On first appearance this seems to be similar to other aluminized structure wrap (ASW) products. There are two weights of this product: heavy duty and standard duty, giving a range of pricing.

Con: There is very limited information from the manufacturer on testing, use, and the differences between the options they provide for products.

Conclusion: This product is slightly more expensive relative to coverage than similar products studied. Unlike other products, there was limited testing information. Their Option 3: Permanent Installation Solution would likely be most convenient from the aspect of personnel and the time it would take to deploy, however, at first glance based on what the manufacturer described for their permanent installations, this would have a great impact on the historic appearance of the buildings and heavy alterations to install seem to be likely. Therefore Options 1 and 2 are likely to be the only approved methods of utilizing this product for wildfire mitigation efforts with regards to complying with the Secretary of the Interior Standards. Another consideration for deployment would be ensuring proper training for building owners / management well in advance of needing to utilize this type of system. Consideration is needed to how training occurs and is maintained with changing owners / staffing to ensure when a wildfire approaches, deployment is possible. Like other products, this system could be considered reversible and has fairly minimal impact to a historic structure when contrasting with total loss of a structure to a wildfire.

2. Firezat, Inc. (Firezat, 2023), Fire Resistant Fire Shield

This Aluminized Structure Wrap (ASW) product was adapted following the 1988 Yellowstone National Park Fires when the Park’s historic structures were under threat, but crews were forced to leave. As a last-ditch effort, the firefighters cut up their personal fire shelters, stapled them to the historic structures and the buildings were spared (see APPENDIX D: ADDITIONAL

INFORMATION for brief history of personal fire shelter development). From this incident, the technology developed and studied for personal fire shelters was adapted to create a building wrap for protection during wildfire threat.



Figure 9: Image of stack of Firezat rolls. Could be stockpiled on-site for use. Image credit: firezat.com, accessed March 21, 2023

Evaluation:

Cost: Material (without shipping or installation) = \$0.83 / SF

- \$828 / roll (5 feet wide by 250 feet long, coverage 1,000 square feet, weight 47 pounds)

Pros: Can be installed by homeowners. Minimal damage to structure if sandbags, double-sided tape and chicken wire are used for installation (chicken wire and staples is best method for high wind resistance). There is no utility requirement, but per the manufacturer, it can be combined with other mitigation measures. For example, it can be combined with a soaker hose on the roof below the wrap to provide a water curtain that will deny oxygen, dissipate heat, and saturate wood. Can be left up for days or weeks with zero performance loss. Fully encloses structure from ember infiltration. No negative environmental impact. Reusable for years with care in handling (tears or holes can be repaired with high temp foil tape). Does not support mold

or mildew, resistant to acids, alkalis, and solvents (except hydrofluoric acid). Reflect 96% of radiant heat. Reflect 92% of convective heat.

Cons: Difficult to install in high winds, which is typically when wildfire risk would be highest. Would not be a solution to be left in place year-round for useability of structures and visual impact and the time it takes to install varies depending on the experience and quantity of installers. Limiting the impact to historic structure depends on installation method and care. Stapling directly to historic wood will likely result in damage when the staples are removed. However, if the consideration is between the complete loss of the structure or having staple holes/minor damage that need to be repaired, the latter would be preferred.

Conclusion: This is a temporary protective measure that has a relatively high level of reversibility with regards to the SOI standard, i.e., holes from chicken wire with staple method of install can be filled, although installing the wrap can use thousands of staples that can damage weathered wood that is friable. It has been utilized by the Forest Service, National Park Service, and the Bureau of Land Management, to name a few, and is proven to protect critical structures from embers, radiant heat and direct flames. There are a significant amount of case studies and testing to back-up this product's performance (Firezat, 2023).



Figure 10: Firezat installation with chicken wire and staples. Building has an existing metal roof eliminating the need to wrap the roof. Image credit: firezat.com, accessed March 21, 2023

D. SPRINKLER SYSTEMS

The goal of sprinkler systems is to protect a building from wind-blown embers, radiant heat and direct flame contact. The types of sprinkler systems commonly used in wildfire risk areas include fixed systems mounted to the structure itself (on the roof, under the eaves, or both), site sprinklers mounted around the property and directed at the building and on the landscaping, and portable systems that can be set-up for an oncoming fire.

Some issues noted with sprinkler systems include the need for an adequate water supply to deliver water for the duration needed, which can sometimes be 8 hours or more. The effectiveness of a fixed structural sprinkler system is questionable when a neighboring building is on fire and would provide extended radiant heat or contact exposure. The systems are typically activated either manually or by an automated device. Ember exposure may disable or impact the ability to activate an automated system. The most threatening wildfires occur during high-wind events, and this can influence the distribution of water droplets, altering effectiveness of a system. For these reasons the Wildfire Research Institute recommends that sprinkler systems be a supplement to already proven mitigation strategies like fuel mitigation and regular cleaning of debris from roofs and gutters (Firewise USA, 2022).

In addition to the sprinklers and portable fire pump, collapsible water storage tanks may be an essential component for a successful sprinkler operation. Tanks can be stored when not in use and expanded and filled with water prior to arrival of the fire. The water supply can be domestic supply from buildings, fire hydrants (although hydrants not intended for use by the public) and can be refilled by water tenders during fire operations. They are often used during fire operations to refill fire apparatus that are too far from hydrants or other water sources to maintain continuity in the firefighting operation due to long turn-around times. Tanks can hold a few hundred gallons up to several thousand gallons of water. There is a liability of having an open water tank on site due to the risk of drowning if someone (a child) should inadvertently have access to the tank. There are various manufacturers and types of collapsible water storage tanks, a couple of manufacturers include: Feld Fire (Portable Water Tank - Steel Frame, 2023); Husky Portable Containment (Husky Portable Folding Frame Water Tanks, 2023) and Fol-Da-Tank (Fol-Da-Tank Collapsible Fire Department Frameless Water Tank, 2023). Capacity (sizes) vary per manufacturer and product but range from 250 to 10,000 gallons. Similarly costs vary from \$700 to \$8,000. Additional consideration would be needed to determine the correct sizing and product to purchase.



Figure 11: Image of a Husky Portable Water Tank (Husky Portable Folding Frame Water Tanks, 2023)

There are many manufacturers of sprinkler systems and accessory components. As this report is not intended to recommend any specific brand or product, the following is not an exhaustive list by any means but does look at information and types from a handful of sprinkler manufacturers.

1. MARK-3 (Waterax, 2023), Portable Fire Pump

The MARK-3 Portable High-Pressure Fire Pump is the most common portable fire pump utilized on the market. It is a lightweight pump system that has become a favorite of fire agencies and responders for some time. Originally launched in 1964, the pump is known for its high performance, reliability, and durability. In 2015 the system underwent several improvements and passed the USDA Forest Service 100-hour endurance test. This is the system utilized during the Cameron Peak Fire.

The system can be connected in series with other pumps to move water over long distances, maintaining its volume. The MK3-U unit has a maximum pressure of 380 pounds per square inch, a maximum flow of 98 gallons per minute, and a maximum head of 878 feet (meaning the maximum height a pump can raise a fluid up)



Figure 12: Waterax MARK-3 Website Photo, Accessed May 23, 2023

Evaluation:

Cost: \$5,100 for the Waterax Mark-3 MK3-U (taxes and shipping not included)

Pros: Portable and lightweight. Photographs from the website show a firefighter walking into a forest carrying the pump with straps on his back, see Figure 12 **Error! Reference source not found.** The pump itself would have no physical attachment to structures or site features. Portable sprinkler systems can be set up where they can do the most good under current fire conditions and behavior. They can be positioned well before the arrival of a fire.

Cons: More information is needed to determine how many pumps would be needed and other accessories (sprinkler heads, hoses, stands/brackets, etc.) required to protect a historic building to fully understand the costs of this system.

Conclusion: A portable fire pump system appears to be highly adaptable to specific applications on a historic building or site with many historic buildings. From a Secretary of the Interior's Standards point of view, it would be a non-attached system that could be set up in a manner to protect structures without physically harming them. Except for water damage if deployed, which would be a preferable impact when compared to total loss of a historic structure.

2. Code3 Water (Code 3 Water, 2023), Portable Wildfire Pump

This portable pump system is powered by Honda engines and is available in various sizes/capacities. The rolling cart system was developed for easy and compact storage and deployment. Developed in California for personal residential use, the system has been evaluated for use on large sites, like vineyards, ranches, and wineries. In these situations, multiple pumps can be used and connected to their water cannons, hurricane 270 roof sprinkler, post-mounted sprinkler and fence mounted sprinklers to cover the properties. Their largest product package is the MP-600v.9 Super Cart System which comes with five fire hose reels mounted to the cart, with 900 feet of 1.5-inch fire hose. The package includes three nozzles, a wye splitter and a 6x6 Manifold. The system information says it can run up to twelve fire sprinklers, one or two water cannons or one 2.5" NH fire hose (these are sold separately). This pump makes over 120 PSI of pressure. The pumps have an electric starter with a pull starter in case the battery is dead. The 6x6 water manifold is a splitter from the pump where you can hook up to twelve sprinklers via $\frac{3}{4}$ inch hoses.

The stand-mounted water cannon is manually operated by a person and says it has almost 100 feet of water spray distance.

The Hurricane 150 roof sprinklers weigh 24 pounds each, keeping them in place on the roof, and provide 140 psi of water from the pump. They cover up to 150 feet radius.

The gasoline tank on the pump systems typically runs for about 3 hours, but there is an optional propane conversion kit that allows for longer running times of the pumps.



Figure 13: Code3 Website Photo, Accessed May 23, 2023

Evaluation:

Cost: MP-600v.9 Fire Pump System Honda GX390, 2 Nozzles, Wye Splitter and 6x6 Manifold, Cart and 900 Feet of hose = \$11,999 (without tax and shipping)

Pros: Besides the fence-mounted sprinklers, there is no physical attachment to structures or site features. Sprinkler heads are located on stands that are set up around the site or on building roofs and the hoses are surface run from the pump to the sprinklers. Portable sprinkler systems can be set up where they can do the most good under current fire conditions and behavior. They can be positioned well before the arrival of a fire.

Cons: Requires maintaining a water storage source, such as a tank, river, lake, pond, or swimming pool, to draw from. Consideration would need to be given to the type of system and expandability for single versus multiple building sites.

Conclusion: This system appears to be highly adaptable to specific applications on a historic building or site with many historic buildings. From a SOI Standards point of view, it could be implemented as a non-attached system that could be set up in a manner to protect structures

without physically harming them, apart from water damage if deployed, which would be a preferable impact when compared to total loss of a historic structure.

3. Colorado Fire Break (Colorado Firebreak, 2023), Installed Wildfire Mitigation System

Colorado FireBreak is a company that designs and installs a custom installed protection system on your site. The typical system is designed to protect the building and an area of 50 feet around it. It includes wildfire detection sensors and can be activated manually or automatically via a wireless control panel. When activated, the first stage involves Firelce powder is combined with water pumped from an underground storage tank on the site. Firelce powder is a dry powder material that when added to water produces a firefighting water enhancing gel. The standalone powder product, which comes in buckets, is used by many firefighting agencies and can be pumped through their vehicles/equipment when fighting a fire. For the Colorado Fire Break system, when activated the Firelce gel is pumped through multiple fire suppression lines installed on the building and covers the building with the gel. As the fire nears, the control panel activates a second stage. In this second stage, fire suppression lines in the site / tree perimeter spray Firelce over the landscaping. The intent of the second stage is to provide a lower temperature microclimate around the building with increased humidity to create a firebreak around the building. The goal of the Colorado FireBreak System is to be fully self-contained, including storage tanks and power sources. It is customizable for specific building and site needs.

There is also a Firelce Home Defense Unit which is a portable sprayer on wheels that building owners can use on their own.

The manufacturer's reported benefits include: it is non-corrosive, environmentally friendly (approved by the US Forest Service as non-threatening to the environment), non-toxic (safe for use around pets and kids), long-lasting, cleans up easily (rinse with water, but can remain on trees and plants), consistently out-performs the best class A foams, protects from heat as high as 2000 degrees Fahrenheit

Evaluation:

Cost: Basic system starts at \$14,000 and more complex systems could be more than \$100,000. Each system is custom designed and requires consultation.

Pros: An installed fire sprinkler system can be designed and installed for custom coverage specific to each structure and its complexities. Activation would have more limited requirements and many systems provide remote or automatic activation.

Cons: Unless portable, collapsible storage tanks are used, which would require pre-fire set-up by the owner or a maintenance entity, an installed sprinkler system requires underground storage tanks for water supply and Firelce powder. Disturbance to the site would be required to run supply lines and devices. Permitting and approval would be required. Visual impacts to the

building and attachment methods would be a consideration and require discussions with historic authorities. The cost of this system would be one of the largest considerations.

Conclusion: For very complex, multiple building sites, this type of system does not appear to be the most practical and is likely not the most economical solution. Many questions should be asked prior to considering an installed sprinkler system which could not be determined prior to the completion of this report. Some questions include do the pipes remain empty until the system is activated? If water always remains in the pipes, how do you prevent freeze/thaw for exterior-run piping which would result in breakage of the piping and components? If the pipes are empty, what is the timeframe for water to charge into the system and what is the pressure of this water? Is the pressure high enough to break connections and heads? How is the system inspected and what is the inspection schedule? Additional questions and considerations are likely when evaluating an installed sprinkler system on a historic building or group of buildings.

4. Defense System 2 (Frontline Wildfire Defense, 2023), Installed Wildfire Sprinkler System

The Defense System 2, from Frontline Wildfire Defense, is an automated wildfire sprinkler system for buildings that is custom designed for individual site conditions. When activated, the system saturates the building with water and a Class A firefighting foam delivered via surface-mounted piping and heads. The foam reportedly breaks down water surface tension and allows water to be absorbed more quickly and more deeply by combustible items on a building and property. The foam is approved by the US Forest Service and utilized by firefighters. It is environmentally friendly, biodegradable, non-toxic and advertises to easily wash away after being applied during a fire (see

INTRODUCTION ON FIRE CHEMICALS).

The system offers manual and remote activation options. A typical system will use the building's primary water source first; if there is a drop in pressure, the system will automatically switch to a secondary water source such as a pool, tank or well. The system is designed to mitigate the risk of ember ignition during a wildfire.



Figure 14: Defense System 2 Website Photo Control System and Surface-Run Piping, Accessed May 23, 2023



Figure 15: Defense System 2 Website Photo Soffit Sprinklers and Foam, Accessed May 23, 2023

Evaluation:

Cost: Site dependent, requires Consultation with company and estimate.

Pros: See section above for Colorado Fire Break.

Cons: See section above for Colorado Fire Break.

Conclusion: See section above for Colorado Fire Break.

E. OPENING PROTECTION: COVERS, INSECT SCREENS, FIRE SHUTTERS

Windows and doors are vulnerable to radiant heat from nearby burning objects such as other structures or vegetation, as well as direct flame contact. The wood elements of doors and windows including the door panel, window and door frames, and trim are also ignition sources. However, studies have shown that glass is the most vulnerable part of windows and doors. If it

breaks, from temperature differentiation or impact from flying debris, embers and flames have a direct path into a building. Depending on the type of glass and level of exposure, breakage can occur in as little as 1-3 minutes when exposed to radiant heat or direct flames (Insurance Institute for Business & Home Safety, Undated). Some solutions studied to help protect window and door openings include covers, insect screens and fire shutters.

Covers typically refer to a fabricated element, custom sized for each opening. These can be fabricated by an Owner out of plywood or other materials. But could also be fabricated by a specialty Contractor. The challenge of custom covers for openings is the storage space needed, the need for a deployment plan and education, and then the time necessary to install.

Research by the Division of Agriculture and Natural Resources at the University of California has shown that insect screens improved the performance of glass under radiant heat exposures. The research evaluated bronze, aluminum and fiberglass with polyvinyl chloride coated screens and all were noted to improve glass performance. Results from the study however showed that of the materials evaluated, bronze screens were the most effective and aluminum were least effective. The research also concluded that screens did not add any protection from direct flame contact (University of California, 2023).

Fire Shutters offer a physical barrier between radiant heat and flying embers and windows and doors. Products on the market include non-rated and fire-rated products. Shutters can be retrofitted over existing windows and doors. Shutters can be mounted on the interior or exterior, but to protect the window or door from damage, an exterior installation would be required. Typically, they are roll-down products that are stored inside a box above an opening and can be activated manually or connected to an automated system. The following is a look at one rolling shutter manufacturer as an example of products on the market.

1. Enviroblind Rolling Shutters (Environblind, 2021)

These exterior rolling shutters are installed over a building's windows and doors, but do not have an official fire-rating. The shutters provide a physical barrier to reduce radiant and convective heat from entering the building and igniting objects. They also offer a barrier to flying debris or falling objects that might break through windows and doors. The shutters can be operated manually by a push button or on an automated system with an electric motor and hard-wired switch.



Figure 16: Enviroblind shutter in open position. Image credit: enviroblind.com, accessed March 21, 2023



Figure 17: Enviroblind shutter in closed position. Image credit: enviroblind.com, accessed March 21, 2023



Figure 18: Enviroblind shutters on various sized windows and doors in closed position. Image credit: enviroblind.com, accessed March 21, 2023

Evaluation:

Cost:

Pricing for a typical door size of 36" x 84", Electric Motor and Hard-Wired Installation = \$1,650

Pricing for a typical window size of 36" x 48", Electric Motor and Hard-Wired Installation = \$1,390 (priced on March 22, 2023, and does not include packaging, shipping or installation).

Pros: Technically could be considered reversible by SOI Standards, depending on method of installation. Once installed, closing the shutters is user-friendly and quick.

Cons: High visual impact at exterior. The shutters are stored in a metal box mounted above the window or door opening that protrudes from the face of the building. There are also fixed guide rail tracks mounted on each side of the opening for the shutters. If utilized as a single mitigation solution, the risk of ignition remains at key building locations/elements like vents, rafters, eaves, siding, etc. It is not uncommon to find wood-framed historic buildings that were constructed without headers above window and door openings. Therefore, consideration would need to be given to the product weight and forces on the historic structure and evaluation by a structural

engineer prior to installation would be required. Shutters operated by an automated system could be at risk of not working and those without automation would require manual closure by someone on-site. The smallest unit size is 24 inches when using the electric motor and the largest unit size is 19 feet. The manufacturer has a limited color selection, therefore matching the historic building might be additional cost and aftermarket custom painting may affect the performance of the product.

Conclusion: The visual impact of exterior rolling shutters is significant for a historic building. An interior installation would resolve the visual impact from the exterior but would expose the window or door to damage from a fire. The structural implications for installation would also need to be considered. Without having a cohesive non-combustible exterior envelope (siding, trim, vents, decking, roofing, etc.) the installation of rolling shutters may be superfluous and highly alter the historic aesthetic of a historic building. Consideration could be given to installation of shutters on secondary (rear or side elevations), if those elevations are also at high risk for wildfire exposure. However, this concession would need strong justification and would likely need to be combined with a cohesive non-combustible exterior envelope design (See [Cohesive envelope system](#) narrative in

AREAS OF FURTHER STUDY).

F. REPLACEMENT MATERIALS

A major question that has arisen regarding existing buildings constructed in high-risk wildfire areas, is should the existing building materials be replaced with fire resistant materials? This question is a complicated one for historic buildings, where the materials and visual appearance are key aspects to its historic integrity. Loss of historic integrity typically results in the loss of designation as a historic structure.

Opportunities may present themselves with historic buildings, where materials are missing, highly deteriorated, or beyond repair. In these cases, consideration could and should be given to replacement with a more durable product, but the qualification for replacement always centers on answering the question of “does the replacement product match the historic material in size, scale and profile?” and if the answer is no, “how close or far off is it?” Concessions have been made in historic buildings where modern materials are slightly different, but the difference to the untrained eye is negligible.

Whereas, for a historic building where the materials are highly intact, the argument for removal and replacement would be more difficult to justify and obtain approvals. The following is a review and discussion of a selection of available building products and materials that aim to “harden” a building against wildfire.

As discussed previously, ignition of structures is typically the result of flying embers, radiant heat, and/or direct flame. With each material reviewed, the goal was to provide insight on how resistant each product might be to the various ignition sources. Discussion, consultation, and feedback would likely be necessary beyond this point to determine if others agree with these findings and whether replacement of historic materials (except in the case of missing/deteriorated conditions) is beneficial and justifiable.

Additional questions arose when evaluating the following products. Noted in each section are the tests that manufacturers have conducted and certifications that products have achieved. To temper these results, our team must point out that laboratory testing is not always commensurate with real-life conditions and variables. And our Team is not necessarily able to answer questions that arose from looking at these products, such as: Are results from laboratory testing, like the ASTM Surface Burning Testing and Fire Tests, where direct flame via a torch is applied to a small section of building material, comparable to saying a product has Wildfire Resistance? Unfortunately, we cannot find data to inform this answer.

Therefore, from this perspective, it would be difficult for anyone to recommend removal of historic material and replacement without knowing with confidence that it would result in resistance to wildfire. Is the cost of replacement of all historic elements a benefit when comparing the cost, level of intervention (i.e., not reversible) and actual fire resistance that results from this replacement product?

Without all the answers to questions that arose, the following attempts to merely present what is available for consideration and if possible, conclusions that can be drawn. As mentioned elsewhere, an exhaustive evaluation of every product on the market was not included, but the following captures materials that the authors found and those that partners involved in this report suggested.

1. Roofing

A building's roof is the most vulnerable surface to wildfire. It is a large relatively horizontal surface where embers can land. If the roof material is made of a combustible material or if debris (leaves, pine needles, etc.) has accumulated, they can ignite quickly. A building may only be at risk from the flaming front of a wildfire for a few minutes, but blowing embers can be risky for longer periods of time and can travel significant distances.

The performance of a roof during a wildfire depends on several factors including the roof material and its fire resistance rating, the age and condition of the roof, the edge of roof materials (eaves, rafters, gutters, intersections, etc.), vents and penetrations (skylights, chimneys, etc.) (University of California, 2023).

A Class A fire rated roof is recommended for maximum performance and protection. However, it should be noted that old and weathered roofs lose their performance over time. Therefore, it is also recommended that regular inspection and maintenance of the roof is critical.

Class A is the highest rating achievable through rigorous testing and provides the highest resistance to fire. The fire rating system also has Class B, Class C or Unrated designations. An Unrated roof would be the worst/lowest protection available. Fire testing evaluates performance based on flame penetration through the roof covering into the attic space; flame spread over the surface of the roof covering; and the propensity for the roof covering to become dislodged and generate embers.

Some roof coverings must be installed as part of a "by assembly" to achieve their fire rating, meaning they may require a specific underlayment or installation technique to achieve their fire rating. If the roof covering achieves the fire rating alone it is referred to as a "stand-alone" system.

There are several Class A rated roof materials available on the market. Stand-alone systems include clay tiles, slate, concrete tiles, asphalt glass fiber composition shingles, PVC membrane, and TPO membranes.

There are acrylic and silicone roof coating roof systems that have a Class A fire rating, however, these are "by assemblies" and require a commercial roofing system to achieve their rating.

There are also metal roofs and fire retardant treated wooden shingle / shake roof coverings that require a "by assembly" to achieve a Class A fire rating (Quarles, 2017). While metal roofs are

non-combustible, they require underlayment to achieve a Class A rating. For example, if a metal roof is installed directly on a wood deck, the heat transfer can ignite the deck. The underlayment prevents this direct transfer.

A fire-retardant treated wood shingle/shake has a stand-alone Class B rating, but with the installation of a particular underlayment, it can meet the requirements for a Class A rating. Common underlying materials include 72 pound felt or cap sheet and a panelized gypsum product called DensDeck. For fire retardant treated wooden shakes, it should also be noted that reapplication of the fire retardant is required. The duration for reapplication will differ based on the manufacturer's recommendations but is around 5 years. Another challenge with treated wood shingle/shake roofs is that there is no visible marking/indication that it is treated. Discussions with emergency response personnel have indicated that if they see a structure with a wood shingle/shake roof, they deprioritize it and move on to the next structure. Many jurisdictions do not allow wood shingle/shake roofs, even if they are fire treated. Some historic preservation projects can be "grandfathered" in to retain their historic wood shingle roofs, however, consultation with local building authorities and historic preservation authorities is recommended to obtain all approvals.

There are synthetic materials, such as CeDUR (CeDUR , 2022), that have stand-alone Class A fire ratings that were specifically developed in order to replace wood shingle/shake roofs, but closely match the visual appearance. There are other synthetic material options on the market. Consideration and consultation are recommended with historic preservation authorities, as the dimensions and profiles of these products are not an exact match for historic wood shingles/shakes, but the tradeoff for fire resistance warrants consideration.

Beyond the roof material and rating itself, the next fire ignition risk at the roof level is related to combustible areas at soffits, such as wood fascia trim, exposed wood rafter tails, exposed wood sheathing, and gutters. Although sheet metal gutters and downspouts are non-combustible, ignition materials such as pine needles and leaves gathered in the gutters pose a threat to exposed wood at the roof level of the buildings. If embers fall into the gutters, ignite the fuels in the gutters adjacent to exposed wood rafters / eaves / soffits and trims, this offers an ignition path. The following is a review and evaluation of potential treatments / alterations:

1. Sheet Metal Enclosures of Open Rafters / Wood Soffits

One potential solution to respond to the ignition risk of wood soffits and trims is to enclose them with sheet metal. There are companies that do this sort of treatment, made more common in California due to their wildfires. A Plus Gutter Systems of Los Angeles and Orange County (A Plus Gutter Systems, Undated) has several photos of work they have completed, see Figure 19 and Figure 20.



Figure 19: A Plus Gutter Systems of Los Angeles and Orange County, Photo of soffit and fascia retrofitting with sheet metal, Accessed May 17, 2023



Figure 20: A Plus Gutter Systems of Los Angeles and Orange County, Photo of soffit and fascia retrofitting with sheet metal, Accessed May 17, 2023

Evaluation:

Cost: Enclosing soffits and fascia can range from \$6-30 per linear foot, depending on the size and complexity of the project. This is a very rough range gathered from multiple online sources based on 2023 information.

Pros: According to installers that offer this type of treatment, the benefits include that it can help satisfy insurance requirements living in fire prone areas, offers protection of your wood from UV rays, provides an additional barrier from wind driven rain, requires no painting, and helps to minimize areas that insects can normally penetrate wood. This treatment would protect wood elements from ignition from flying embers, assuming any venting in the soffits is able to prevent embers from entering.

Cons: This treatment does not protect the exterior wood soffits and trim from direct flames or high radiant heat. As mentioned, if the radiant heat is great enough, wood elements will combust.

Conclusion: This treatment is highly visible and alters the appearance of the building, changing the feeling, materials, design and workmanship associated with historic integrity. Technically this would be nearly reversible from the perspective that the enclosures could be removed, mounting penetrations repaired, and the historic materials remain below. As a standalone treatment, enclosing soffits and fascias would be nearly useless, but as part of a cohesive non-combustible exterior envelope (which would include siding, trim, vents, decking, roofing, etc.) it might warrant further consideration, for the entire structure or for specific elevations at high risk for wildfire exposure. However, this concession would need strong justification and consultation with historic preservation authorities for approval.

2. Consideration for Removal of or Not Installing Gutters on Historic Buildings

Gutters are a consideration for historic buildings as a means of collecting and directing water away from a building's foundation. Water infiltration poses risks of undermining the structure, decay of materials, etc. Ignition of organic materials that build-up in gutters poses a high structural risk during a wildfire. Although there are solutions such as gutter covers, these products do not guarantee that debris will not find its way and build-up in the gutters. Therefore, for historic buildings at high risk of wildfire exposure additional discussion and consideration should be given to either elimination of gutters entirely or if gutters do not currently exist on the building, not installing them. This treatment would trigger the need for an alternative drainage design at the ground level surrounding the buildings to ensure that protection from water infiltration can still be achieved. Many historic buildings lack continuous foundations, therefore eliminating gutters and downspouts would likely result in increased risk to the integrity and longevity of the historic structures. A holistic approach to preservation of a historic building needs to be considered beyond just wildfire risk reduction and consultation is recommended with historic preservation authorities prior to making a decision.

2. Windows & Glazing

See OPENING PROTECTION: COVERS, INSECT SCREENS, FIRE SHUTTERS for additional discussions for Window and Glazing protection. The National Park Service Technical Preservation Brief 9 addresses the repair of historic wood windows. As described in the brief:

The windows on many historic buildings are an important aspect of the architectural character of those buildings. Their design, craftsmanship, or other qualities may make them worthy of preservation....The Secretary of the Interior's Standards for Rehabilitation and the accompanying guidelines, call for respecting the significance of original materials and features, repairing and retaining them wherever possible, and when necessary, replacing them in kind.

Following the sections of the brief that discuss repair of historic windows, there is a section in Window Replacement. The following is discussed in the brief:

Although the retention of original or existing windows is always desirable and this Brief is intended to encourage that goal, there is a point when the condition of a window may clearly indicate replacement. The decision process for selecting replacement windows should not begin with a survey of contemporary window products which are available as replacements but should begin with a look at the windows which are being replaced. Attempt to understand the contribution of the window(s) to the appearance of the façade including: the pattern of the openings and their size; proportions of the frame and sash; configuration of window panes; muntin profiles; type of wood; paint color; characteristics of the glass; and associated details such as arched tops, hoods, or other decorative elements.....Armed with an awareness of the significance of the existing window, begin to search for a replacement which retains as much of the character of the historic window as possible.....Consider energy efficiency as one of the factors for replacements, but do not let it dominate the issue. Energy conservation is no excuse for the wholesale destruction of historic windows which can be made thermally efficient by historically and aesthetically acceptable means. In fact, a historic wooden window with a high quality storm window added should thermally outperform a new double-glazed metal window which does not have thermal breaks.... (Preservation Briefs 9 The Repair of Historic Wooden Windows, 2023)

Like other discussions in this report, there are no provisions for adaptations to the SOI Standards with regards to wildfire prone areas. As mentioned in Brief 9, adaptations for increased energy efficiency include adding high quality storm windows. Projects have received approval for both wood-framed and aluminum-framed exterior storm windows. An aluminum-framed exterior storm window would provide the added benefit of a non-combustible exterior barrier to protect the historic wood window from flying embers. Exposure to direct flame is less likely to offer a considerable benefit, since historic wood siding and trim would remain in place below and around the storm window. There are many exterior aluminum storm window manufacturers on the market. Products utilized and approved for historic projects include, but are not limited to:

- Allied Windows, Inc. Storm Windows (Allied Window, Inc. , 2023)
- St. Cloud Window Secondary Glazing Products (St. Cloud Window, 2023)

There are fire-rated windows on the market that were evaluated as part of this report:

a. Fyre-Tec (Fyre-Tec, 2023), Fire-Rated Windows

This is a manufactured fire-rated steel window. The rolled steel sections have welded corners for strength and durability. The window frames have been listed by Underwriters Laboratories. Styles of windows include horizontal slider, single hung, fixed lite, awning, and casement. UL rated factory glazing options include clear ceramic 1 hour rated glass or ¼ inch wire glass with a

45-minute rating. These rated glazing types can be combined with Low-E glazing (to reduce UV and infrared light) in an insulated glass unit (IGU). Heat activated fusible links are standard on all operating windows which close the windows in the presence of fire. Horizontal sliding windows may also be equipped with a resettable device which may be activated by a fire or smoke alarm, computer, or another electrical signal.

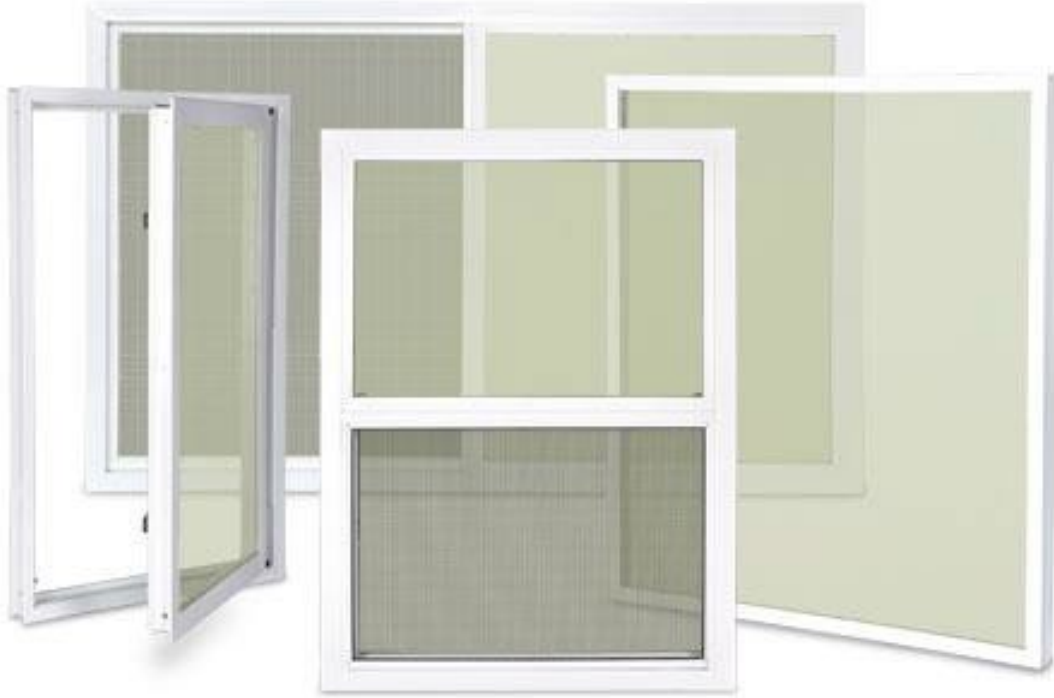


Figure 21: Fyre-Tec Fire Rated Window Styles. Image credit: fyre-tec.com, accessed March 21, 2023



Figure 22: Fyre-Tec Fire Rated Window Sections Compared to Typical Rated Window Frame Construction. Image credit: fyre-tec.com, accessed March 21, 2023

Evaluation:

Cost: Price for a single hung window typical size 36" x 48" = \$3,945

Pros: Fyre-Tec windows have been tested by Underwriters Laboratories and have an official fire rating.

Cons: Replacement windows are rarely a good visual match for historic wood windows and these steel windows would be drastically different from the historic. This product does not come in a double-hung configuration and there is not an ability to match historic muntins for divided light windows.

Conclusion: Without having a cohesive non-combustible exterior envelope (siding, trim, vents, decking, roofing, etc.) the installation of fire-rated windows would be superfluous and highly alter the historic aesthetic of a historic building, especially those with simple single-pane wood windows. Consideration could be given where historic wood windows were previously replaced / are not extant on building elevations that are secondary (rear or side elevations), if those elevations are also at high risk for wildfire exposure. However, this concession would need strong justification and would need to be combined with a cohesive non-combustible exterior envelope design (See

AREAS OF FURTHER STUDY for [Cohesive envelope system](#) discussion).

3. Cladding & Trim

Historic wood cladding and trim that require repair or replacement should be, in accordance with the SOI Standards, the same species, the same cut of wood (flat sawn vs. vertical grain), the same grade, the same defects (a few large knots, many small knots, no knots, etc.) and similar technical requirements. At a minimum, the same wood species and same cut of wood should be required under the umbrella of "in-kind".

Wood products that provide fire resistance may be able to satisfy those requirements, but some cannot. Chemical treatment to provide fire resistance is not possible with all species due to the anatomical and chemical properties of the wood. Non-wood cladding and trim products face the additional hurdle of not being wood, thus, not satisfying a basic requirement of the SOI Standards. Additionally, the appearance can be very difficult to match based on the type of cut or weathered texture of the historic wood.

Nonetheless, in some cases where the materials (in this case, the fire-resistant wood products), might be considered if replacement of the existing cladding and trim is warranted due to reaching the end of its service life. Without the need for replacement, the cost of replacing the cladding and trim should be evaluated based on the benefit of changing to a product that has satisfied the specific tests to provide a degree of fire resistance. As was discussed in the Fire Chemicals section, such tests are intended to provide fire resistance but are not fireproof. Replacement of existing cladding that is in good condition may not be economically viable from a cost/benefit analysis. The following is a look at some products marketed towards fire resistance:

a. Cedar Valley (Cedar Valley, 2023)

Cedar Valley, a California Company, manufactures western red cedar shingle and shake siding panels for exterior walls. Their panelized system consists of shingles mounted to a fiberglass mat laminated onto a strong plywood backing. The system includes specialty customization options including matching corners and radius flares. Their products are CAL FIRE State Fire Marshal Wildland Urban Interface (WUI) approved for siding after undergoing the California SFM 12-7a-1 Fire Test. This test protocol involves a direct flame exposure at the base of a 4 foot by 8-foot wall sample at a heat output of 8535 BTU/min for a period of 10 minutes. The assembly is then observed for a period of 60 minutes for flaming or glowing on the unexposed side (Chapter 12-7A Materials and Construction Methods for Exterior Wildfire Exposure, 2023).



Figure 23: Cedar Valley Website Photo, Custom Massachusetts Home Installation, Accessed May 22, 2023



Figure 24: Cedar Valley Website Photo, Radius Panel Photo, Accessed May 22, 2023



Figure 25: Cedar Valley Website Photo, Custom Combed (Striated) Texture, Accessed May 22, 2023

Evaluation:

Cost: \$7.00 to 8.00 per square foot for material cost only

Pros: A fire-resistant replacement for wood shingle or shake siding is intriguing. Some customization options for this product do exist including radius installation and combed/striated texture.

Cons: Cedar Valley is a manufactured system with a different thickness, size and profile to historic wood shingle or shake siding. Their standard exposures are 7.125-inch, 5.3-inch, and 4.25-inch. Consideration would need to be given to the detailing of this product, especially where it interfaces with trim and other building elements.

Conclusion: This product would be most successful with wholesale removal of historic shake or shingle siding down to the exterior substrate. Installation of a panel system over existing shakes or shingles would likely create a non-uniform result. Wholesale removal of historic siding would be a considerable alteration to the historic fabric. If the exterior siding of a historic building was very deteriorated or predominantly missing, replacement with a product such as this would be opportune, however consultation with historic authorities would be required and consideration would be needed as to how compatible it is with the historic siding in design, color, texture, and materials.

b. Chemco SaferWood (Chemco, Undated)

SaferWood by Chemco, Inc. in Washington, provides fire resistant treatment wood products including cedar roofing, soffits, fascia, siding, decking and interior lumber and plywood building products. Their SaferWood siding has passed ASTM E-84 (Standard Test Method for Surface Burning Characteristics of Building Materials) and D2898 (Fire Tests for Pressure Fire Retardant Treated Wood) testing and is ICC compliant. The fire-retardant treatment product is Thermex-FR which is listed as safe and environmentally friendly that renders wood resistant to fire. According to the website, beyond the independent laboratory and quality-control testing, the effectiveness has been verified by real-world stories in which applied SaferWood products have been subjected to both structural and wildland fires. The manufacturer provided the following information on testing and the treatment process:

PRESSURE TREATMENT

We offer fire retardant treatment of wood (mostly softwoods but a few hardwoods as well as thermally modified wood, however, treatment is required by IBC and IWUIC to be done under a pressure process, per IBC 2303.2.1. Our “SaferWood” treatment is performed in a pressure-vessel, at our facility. Additionally, once treated, wood is required to be KDAT-Kiln Dried After Treatment, per IBC 2303.2.8.

FLAME & WEATHER TESTING

Further, to meet IWUIC-International Wildland Urban Interface Code compliance, which SaferWood does and is currently the only exterior fire-retardant to currently do so (ref. ICC-ES ESR-1159), as ignition-resistant per IWUIC Section 503.2, Item 3, FRTW. Compliance with IWUIC requires Fire-Testing per ASTM E84/UL 723 extended 30 minutes after undergoing ASTM D2898 accelerated weathering.

PERMANENT PROTECTION

Fire retardant treatment of wood, per IBC 2303.2.2, must provide permanent protection to all surfaces of the wood products. The use of paints, coatings, stains or other surface treatments is not an approved method of protection as required. Our treatment is permanent and backed by a limited lifetime guarantee.



Figure 26: SaferWood Website Project Photo, Accessed May 22, 2023

Evaluation:

Cost: Inquiry to the manufacturer was sent to determine rough cost information for this report. The response from the manufacturer was that a rough cost per square foot depends on the species of wood selected and quantity. SaferWood does not sell or distribute the wood elements, they are a treatment service only where the wood species and estimated quantity must be submitted to the manufacturer to obtain a price per square foot cost.

Pros: From preliminary evaluation, the SaferWood treatment appears to offer customization, flexibility and longevity for new wood materials. The treatment does not need to be reapplied; the process makes it inherent in the treated wood.

Cons: The testing, similarly, explained elsewhere in this report, is based on laboratory testing, but is difficult to translate into wildfire effectiveness. The cost of this treatment is unknown. Utilization of this treatment would be applicable for new wood materials that might be installed on a new building or on a historic building where previous materials are missing or deteriorated. But it seems it would be highly cost prohibitive and infeasible to consider such a treatment for existing historic materials where elements would need to be removed from a structure, stripped if painted, and transported to SaferWood's facilities for treatment. If such a process were feasible, it would be irreversible.

Evaluation: With the information available, it is difficult to evaluate this product, especially as it relates to a historic building. For replacement of historic wood features that are missing or deteriorated, it would seem to offer some protection against flying embers and some protection against ignition, although the temperature of ignition is not known. Without greater understanding of costs, it is difficult to evaluate. Further consideration is warranted.

c. Hewn Fire-Resistant Products (Hewn, 2022)

Hewn, a company in Oregon, manufactures a Class A Exterior Pressure Treated Fire Resistant Siding Product. The product aims to maintain the visual look and feel of exterior cedar siding that resists the spread of fire. An added benefit of their fire-resistant treatment process that they discuss is the aging process is slower and there is protection against ultraviolet degradation, providing for a longer lasting product. The testing they have undergone includes ASTM D-2898 (Standard Practice for Accelerated Weather of Fire-Retardant-Treated Wood for Fire Testing), ASTM D-84 (Standard Test Method for Surface Burning Characteristics of Building Materials) and their product has been verified by International Code Council (ICC ESR-1159 and ESL-1021, which are evaluations on multiple fire-retardant treated wood products, including SaferWood, Mataverde, etc.). Their products are available in standard nominal widths (1x4, 1x6, 1x8, 1x10 and 1x12) and have a thickness of 13/16 inches. The milling profiles available are Tongue and Groove or Shiplap. They have a Flame Spread Index of 25 or less, and a Smoke Developed Index of 45 or less. They have eleven standard finish options ranging from white, red, brown, and grey. There is the option of custom colors. The siding can be installed with the boards oriented vertically and horizontally. Following correspondence with the manufacturer, it became clear that their products are impregnated with Thermex FR, potentially by Chemco SaferWood although this is unclear, similar to other products included in this report.



Figure 27: Hewn Website Project Photo, Accessed May 22, 2023

Evaluation:

Cost: starting at \$17 / square foot, not including shipping, taxes, etc. Per feedback from the manufacturer, this cost is based on “...an order that would clad a reasonable size home. *Smaller orders can get more expensive due to logistics*”

Pros: From preliminary evaluation, the Hewn Class A Exterior Pressure Treated Fire Resistant Siding Product appears to offer some level of fire resistance. See similar discussions for other products.

Cons: The manufacturer does not offer much data or testing to assist in evaluating this product as it relates specifically to wildfire. Flame spread is low and Smoke development index is low, but it is unclear at this time how these factors can be correlated with wildfire conditions. See similar discussions for other products.

Conclusion: Customization with color is available, however sizes and profiles are limited. With the limited information available, it is difficult to evaluate this product. In theory it would offer some protection against flying embers and some protection against ignition, although the temperature of ignition is not known. Similar to other discussions wholesale replacement seems to be necessary to offer some level of protection (and to what level when considering active wildfire exposure versus laboratory testing is also needing further consideration), however,

wholesale replacement does not currently meet the Secretary of the Interior Standards and would not be approved. Selective replacement of missing or deteriorated wood elements with Hewn products seems futile.

d. Metaverde Fire Retardant Treated Hem Fir Wood Siding (Nolan, 2021)

Metaverde, a company with locations in Connecticut and California, produces a Fire-Retardant Treated Hem Fir Wood Siding to closely match the natural look of Western Red Cedar Siding. The siding is thermally modified and utilizes Thermex pressure treatment, similar to the other wood siding manufactured products. The standard profile manufactured is a 1x6 Tongue and Groove profile with 1/8-inch joint. Thermally modified wood, as compared to standard kiln dried lumber, is saturated with moisture and the wood is heated to higher temperatures. The moisture keeps the wood more uniform during the drying process and the higher heat “cook the sugars out”. This process is reported to make wood more dimensionally stable, uniform, resistant to insect damage and decay. One downside of thermally modified wood is that it is more brittle. Thermally modified hem fir is 70% less brittle than red cedar and measured on a Janka Hardness Test, is nearly twice as hard as red cedar.

An inquiry to the manufacturer was submitted asking the following questions: Does it have a standalone fire rating? (Like Class A, B or C). Or is there a manner you’ve found to detail the exterior assembly to achieve a rating? Like installing a particular substrate, underlayment and your siding? It appears that you can install it as vertical siding, horizontal siding or as a soffit material, is that correct? The Blog post about the product listed that it only comes in 1x6 Tongue and Groove profile. But I noticed that was from 2021, so I wasn’t sure if any additional sizes and profiles are achievable (even if that would be a custom item)? For example, a lot of historic wood buildings have a clapboard siding profile, so I wanted to see if there were custom options like that? Does the fire-retardant treatment need to be reapplied after a certain period of time? If so, what is the timeframe and what is the process for reapplication? Have you conducted any ignition tests related to temperature? Is there a temperature at which this material will ignite / is resistant up to based on testing? However, a response from the manufacturer was not received. Therefore, evaluation of this product is limited.

Evaluation:

Cost: No response from manufacturer inquiry.

Pros: From preliminary evaluation, the Metaverde ThermaWood FR Hem Fir Siding Product appears to offer some level of fire resistance.

Cons: The manufacturer appears to only offer one siding profile / configuration

Conclusion: See similar material conclusions sections. For replacement of missing or deteriorated wood elements in high-risk wildfire areas, a solution like this could be considered if it matches the material and profile it is replacing.

e. Montana Timber Products (Fire Treatment for Wood: Defensive Solutions for Fire, Undated)

Montana Timber Products, a manufacturer of wood building materials including wood siding and trim. They offer fire treatment options to their products including a spray-applied fire treatment and their Fireline pressure-treated fire treatment. These treatments can be applied to siding, soffits, fascia, trim, timbers, posts, beams and decking.

Their spray-applied fire retreatment is advertised as a Class A Rated fire retardant that reduces flame spread and smoke development. It has a UL Greenguard Gold Certification and is non-toxic, with low VOC content and emissions. The installation process is to coat, dry and cure onto the wood substrate at their facility and they report that it is permanent and never needs to be reapplied. Although it is a formulated Class A retardant it is not currently Wildland Urban Interface compliant. The Wildland Urban Interface Approved Products listing was established under the California Building Code to offer resources for approved products. The categories include decking materials, exterior windows, exterior siding and sheathing, exterior doors and under eaves (Wildland-Urban Interfaces, 2023). This treatment does not perceptibly change the color of the wood when combined with their stains. Although the spray-applied treatment has a Class A rating, it does not meet the requirements to be listed as a CAL FIRE Wildland Urban Interface (WUI) Product. When evaluating spray-applied treatment versus the Fireline pressure-treated treatment, some considerations are that the topical treatment is generally less expensive.

Their Fireline treatment involves a vacuum pressure impregnation process to remove moisture and air from the wood cells and replace it with a safe, environmentally friendly additive. It is then thermally cured, to lock the additives into the wood cells. This process alters the cellular structure of the wood to provide enhanced fire-resistance. Due to the Fireline product penetrating and bonding to the interior structure of the wood, there is no need for retreatment/reapplication. There will be variations in colors as a result of the Fireline treatment and it cannot be controlled. The process adds approximately 6-8 weeks to the lead time of a wood order. The Fireline products have passed a series of fire and weathering testing and credentials, including ASTM E-84, ASTM D-2898, ICC ESR 1159, ICC ESR 1410, and it is listed on the CAL FIRE WUI Product Handbook. The WUI compliance, combined with the Class A rating, makes it the higher level of fire-resistant treatment of the two.

An inquiry to the manufacturer was submitted asking the following questions: Is there an additional lead time for the spray-applied treatment? Are both treatment options available for any wood product? Are there any dimensional and profile limitations? It seems like you offer a variety of sizes and configurations of wood products. And you likely realize historic buildings would have specific profiles and sizes, so I was just curious if there were any issues/limitations for wood. However, a response from the manufacturer was not received. Therefore, evaluation of this product is limited.



Figure 28: Montana Timber Products Website Project Photo, Accessed May 23, 2023

Evaluation:

Cost: No response from manufacturer inquiry.

Pros: From information available at this point, both the Fireline and the Spray-Applied Fire treatment offered by Montana Timber Products appear to provide some fire-resistant benefits. The company appears to offer treatment to any type, size and application of wood. The spray-applied treatment reports to have no perceivable change in color to the wood.

Cons: There appears to be additional lead time to these treatment options. Consideration and planning will be needed to account for this if utilized for a project. The Fireline treatment reports uncontrollable changes in color of the wood (according to their materials it is approximately a shade or two darker in color). However, for a painted wood application, this doesn't seem like a problem.

Conclusion: For replacement of missing or deteriorated wood elements in high-risk wildfire areas, a solution like this could be considered. In theory it would offer some protection against

flying embers and some protection against ignition, although the temperature of ignition is not known. Similar to other discussions wholesale replacement seems to be necessary to offer some level of protection (and to what level when considering active wildfire exposure versus laboratory testing is also needing further consideration), however, wholesale replacement does not currently meet the Secretary of the Interior Standards and would not be approved.

f. Fiber Cement Cladding

Fiber cement is a manufactured product made of cement, sand, cellulose, and other additives. It is advertised as a durable low-cost alternative to more expensive cladding options like wood, brick, or stone. There are various manufacturers on the market including: James Hardie. Nichiha Architectural Wall Panels, Equitone Panels, etc. Some manufacturers offer products that aim to mimic wood siding materials found on historic buildings like wood shakes, shingles, and horizontal clapboards.



Figure 29: Nichiha Website Photo, Nichiboard Cedar (Nichiha, 2023)



Figure 30: Nichiha Website Photo, Sierra Premium Shake (Nichiha, 2023)



Figure 31: James Hardie Website Photo, Hardie Pank Lap Siding (James Hardie, 2023)



Figure 32: James Hardie Website Photo, Hardie Shingle Siding (James Hardie, 2023)

Direct comparison of fiber cement siding is extremely difficult as the quality of each product line and manufacturer is not easily decipherable, especially when attempting to contrast it with historic wood siding. Fiber cement siding manufacturer's list benefits of their products such as "does not require regular repainting", "does not rot", "is insect resistant", "fireproof" and "performs exceptionally well in natural disasters". Manufacturer's recommendations on maintenance schedules also vary, however generally they recommend annual cleaning and then repainting every 10-15 years. Similarly, maintenance of wood siding is recommended to be cleaned annually with soapy water and a brush. In contrast, if painted, wood siding may require repainting in as little as 3 years and up to 15 years. The maintenance schedule for wood siding is highly dependent on the color (darker colors fade more quickly than lighter colors) and the quality of paint (higher quality paint performs better for a longer duration). It would be prudent to consider that a dark paint on fiber cement siding would degrade at a fairly similar rate as it would on wood siding, considering they would be exposed to identical sun and weather patterns. Moisture performance of fiber cement siding is questionable. Fiber cement siding has been known to hold moisture and even mold, although higher quality manufactured products may have addressed some of these problems. Wood siding does swell when exposed to moisture, and extended duration of exposure results in rot, but wood itself is typically a breathable material that will, in most cases - if the moisture is mitigated/managed - dry back out and reset to its original profile. The biggest consideration for fiber cement siding in comparison to wood siding is the visual and material compatibility. Although manufacturers advertise their ability to mimic historic wood profiles and dimensions, the smallest exposure available at the time of this report is 4 inches (from HardiePlank) and all board lengths are 12 feet. A manufacturer stamped wood texture on a fiber cement siding board also visually differs from a real wood product. Consideration would be needed based on specific building design features on whether a visual match is achievable with a fiber cement product.

Regarding material compatibility, in a wood-framed building with wood siding, the framing and siding are moving (swelling and shrinking with temperature and moisture changes) at a similar rate. Fiber cement is a more rigid material therefore when installed as a siding on a wood-framed building, consideration should be given to building and material movement and how that might differ. On fiber cement siding installations observed in west and south facing elevations in Colorado, siding nails have been observed working themselves out on fiber cement siding, a potential sign of differential movement of the siding and the wall framing, see Figure 33. For historic preservation professionals considerations such as changing how a building moves and performs is critical to ensuring no harm is introduced that would potentially impact its longevity.



Figure 33: West Wall of 1957 Ranch in Colorado, Nails Visibly Working Their Way Out of Fiber Cement Siding (Lord, 2023)

As mentioned elsewhere in this report, when evaluating fiber cement siding as a replacement to wood siding based on performance during a wildfire, an ASTM or similar laboratory test is difficult to translate to actual application. The fiber cement siding would have more resistance to embers and perhaps resist higher temperatures than wood siding. However, with existing wood framing directly below, it is questionable in high temperature fires where materials will combust, that fiber cement siding will make much of a difference. Specific laboratory testing to this effect is not available at this time.

Evaluation:

Cost: The cost of fiber cement siding, trim, etc. varies from between \$5 and \$14 per square foot and is highly dependent on brand, quality, size, and complexity of the structure. For a more direct comparison, wood siding cost per square foot ranges anywhere from \$4 and \$16 depending on similar considerations plus species and whether it is going to be painted, stained or will remain natural.

Pros: Costs are similar. The protection against fire, similar to other products evaluated, does appear to offer some fire resistance to flying embers. Although, as mentioned elsewhere, consideration needs to include laboratory testing versus direct wildfire exposure.

Cons: When evaluating against the Secretary of the Interior Standards, the replacement of wood siding with fiber cement siding on a historic structure does not satisfy the requirements. Wholesale replacement of wood siding with fiber cement siding would be required to achieve some semblance of fire resistance, selective replacement in certain areas would leave wood directly exposed to ignite the remainder of the structure. The SOI Standards require historic materials to be retained where condition allows and required replacement “in kind” where missing, rotten, or deteriorated. “In kind” means same material, profile, spacing, and in the case of wood, it also means matching the species and grain as closely as is feasible.

Conclusion: Further development and customization of fiber cement siding in the marketplace will likely continue to expand and perhaps at some point, more information, testing and options will be available to warrant the re-evaluation of this material as a potential wildfire mitigation resource for historic wood buildings. Similarly, if the SOI Standards are updated to respond to Wildfire risks, like “The Secretary of The Interior’s Standards for Rehabilitation & Guidelines on Flood Adaptation for Rehabilitating Historic Buildings”, perhaps this update could further evaluate and consider the replacement of wood siding with alternative materials that offer fire resistance, such as fiber cement siding. However, at this time, fiber cement siding is not a recommended treatment based on the current information, testing data, and inability to meet the SOI Standards as they currently exist.

4. Decking & Walkways

A handful of the products discussed in [CLADDING & TRIM](#) included replacement options for wood decking with fire-retardant treatment products. See that section for more information. The following is a review of a couple of products on the market for decking and walkways.

a. HardieDeck (HardieDeck, 2023)

Although currently only available in Australia, HardieDeck is a product developed in reaction to the Bushfires. The material is manufactured by James Hardie but does not appear to be available in the United States. It is made from premium fiber cement, making it non-combustible and has been approved to be installed in Bushfire Attack Level (BAL) rating zones up to BAL-

FZ, meaning “direct flame contact from fire front & radiant heat exposure is greater than 40kW/m² (Kilowatt per square meter)”, which is the highest level recognized by the Australian Rural Fire Service (What Are Bal FZ and Bal 40 Requirements?, 2023).



Figure 34: HardiDeck Website Project Photo, Accessed May 23, 2023

Evaluation:

Cost: Unavailable in the United States

Pros: Although the fire resistance rating comparison between the United States and Australia is unknown, this appears to be a highly resistant product with the ability for outdoor horizontal installations.

Cons: There is a lot of unknown information at this time. It appears this product is a solid sheathing product. The “gaps” between “deck boards” appear to be solid material. From the photos on the website, the installation at raised deck areas appears to require fully enclosed construction around the sides and bases of the structure, see Figure 34.

Conclusion: This product has some exciting potential as a new construction product in wildfire prone areas. However, with no availability in the United States it is not currently an option for Owners to consider. It also does not mimic wood decking, so from a historic preservation perspective does not seem to be a consideration related to this report. However, with more

information about the installation details and methodology it is possible further consideration in the future is warranted. Can this system be installed over and around an existing deck, maintaining the historic materials in place below (similar to the discussions of sheet metal enclosure of eaves and soffits), and provide fire resistance? The question there would be, are wood railings and other elements still exposed, negating the success of this alteration?

b. TREX (Trex Composite Decking Boards & Products, 2023)

Trex composite decking advertises their product in comparison to wood with benefits that it “won’t rot, warp or splinter; doesn’t require seasonal painting, sealing, or staining; doesn’t fade or stain; and won’t become food for termites.” Their products have 25–50-year limited warranties. When it comes to fire resistance, their decking product lines of Transcend and Select have a Class B fire rating. The Enhance decking line has a Class C fire rating.



Figure 35: Trex Website Installation Photo, Accessed May 23, 2023

Evaluation:

Cost: Range between \$5-12 per square feet, depending on product line and color (material cost only)

Pros: Advertised to be low-maintenance and durable. With Class B and Class C rated products, there would be some ignition resistance.

Cons: In areas of large temperature swings (like Colorado) composite decking can expand and contract. The structural framing below the decking is typically wood, and the two materials move at different rates during thermal swings. This can cause warping and cracking of the decking. Composite decking is also less strong than wood decking requiring closer spaced wood framing below, which makes the deck structure more expensive in addition to the decking material being a bit more expensive than a typical wood deck.

Conclusion: Trex's rated products would provide some resistance to ignition. For an existing wood framed deck, removing the wood deck and replacing it with a Trex deck does not seem to be a worthy alteration. The combustibility of the wood framing/structure below would be the same and the dissimilar material behavior is a concern. A similar concern that is not addressed in the marketing material is that with high heat, Trex products will melt.

5. Vents

RETROFITTING VENTS: Vents on buildings such as those located in walls, soffits, eaves, foundations, etc. provide a pathway for flying embers to enter a structure and ignite exposed framing or finishes. California websites such as readyforwildfire.org (CAL FIRE, 2019) and firesafemarin.org (Fire Safe Marin, 2023) suggest two hardening options for open vents in buildings, the first is to retrofit all vent openings with metal mesh with spacing between 1/16 inch to 1/8 inch. They warn that fiberglass or plastic mesh should not be utilized as these can melt and burn, providing an additional ignition source.

Evaluation:

Cost: The material cost of 1/16 to 1/8 inch wire mesh is around \$0.40 - \$1.00 per square foot. Most products are sold in rolls (ranging from 10-100 feet long).

Pros: This solution has a relatively inexpensive material cost. Installation cost would primarily be dependent on labor, but a building Owner could choose to self-perform the install. For vertical installation this would be a minimally invasive solution to adding protection to open vents.

Cons: This solution requires regular inspection to ensure that elements, such as wind, snow or pests, haven't shifted or torn up the wire mesh. As a solution for covering roof vents, the wire mesh retrofitting method is likely not the best. As seen in Figure 36, a fabricated wire mesh cage around a roof vent requires screws to penetrate through the roof material, adding a new path for water to enter the building. Additionally, in Colorado climates with snow it would be questionable how durable this solution would be to sliding snow on the roof.



Figure 36: Roof Vent with Retrofitted Wire Mesh Cover (Roof Vent Screens Installation, 2023)

Conclusion: From a SOI Standards perspective, retrofitting existing vents in historic buildings with metal mesh would be a reversible solution that would minimally change the visual appearance of the building. In all likelihood most onlookers would not notice this alteration. The mesh could be removed with minor repairs required to the historic fabric, like filling holes and repainting. This solution would not be recommended for roof vents, but would be a good solution for vents on vertical surfaces or soffit vents in overhangs, etc.

REPLACEMENT OF VENTS: The second hardening recommendation is to replace open vents with those manufactured specifically for ember and flame resistance. The following is a look at two manufactured options:

a. EMBERSOUT (Embers Out, 2023)

Embers Out is a company in California that developed protective vent filters that can be installed over existing vents in order to stop embers from entering the building and restricting access to direct flames. Additional benefits the manufacturer advertises are that their vents restrict insects and rodents, dust and debris, wind driven rain, snowpack penetration, and wind. Their company lists the following features: they are CAL FIRE approved, made in America, have a lifetime guarantee, and are impervious to corrosion. Their products are paintable, so once installed they can be painted to match a building's exterior. They meet the ASTM EE2886/E2286M-14 standard, which is the American Society for Testing and Materials (ASTM) Standard Test for Evaluating the Ability of Exterior Vents to Resist the Entry of Embers and Direct Flame Impingement. A video on the Embers Out Website shows the testing with flying embers and direct flames with cotton pads on the opposite side of the vent. In both cases, the cotton pads did not ignite.



Figure 37: Photo from Embers Out Website of Retrofitted Vent Applications, Accessed May 22, 2023



Figure 38: Photo from Embers Out Website of Gable Vent Filter, Accessed May 22, 2023

Evaluation:

Cost:

5.5 inch by 15.5 inch retrofit vent = \$54

14 inch by 24 inch retrofit vent = \$84

This is the vent product cost only and does not include taxes, shipping, installation and other products necessary (fasteners and sealant) to install (Source Lowes.com, Accessed May 22, 2023).

Pros: Based on the information available, these products provide protection from flying embers and restrict direct flames based on their ASTM testing results. According to the manufacturer's website, this product can be installed over an existing vent, in which case the historic material would remain below the new vent. However, detailed installation details or photos depicting the existing vent in place were not available from the manufacturer. The manufacturer confirmed that custom sizes are available and that direct order from the manufacturer is available.

Cons: Pending review and approval of installation detailing, the downsides of this mitigation solution were not identified.

Conclusion: From a Secretary of the Interior's Standards perspective, if this product is able to be installed with the historic vent retained below, it would be a reversible solution, with the historic fabric retained in place. The visual change to the building would be different from the historic look, but this trade-off may be worth the added protection from flying embers and direct flames. If custom sizes are available, this would be a viable and fairly minimal cost alteration to a historic building to provide resistance to flying embers. It would not be successful at resisting direct wildfire flames as a standalone treatment, but as part of a cohesive non-combustible exterior envelope (siding, trim, decking, roofing, etc.) it might be worth further consideration, especially for specific elevations at high risk for wildfire exposure. However, this concession would need strong justification and consultation with historic preservation authorities for approval.

b. Vulcan vents (A Home's First Line of Defense from Embers and Wildfire Flames, 2023)

Vulcan Technologies, located in California, manufactures the Vulcan Vent, a line of products that stop embers and restrict fire for residential structures, without sacrificing air flow into attics or crawl spaces. They are CAL FIRE approved and pass ASTM E2886 testing to block ember entry. They have also been tested by the International Code Council Listings for 1 Hour Burn Testing (ICC-ESL: 1299, 1455 and 1300). In addition to their manufactured vent types, which include dormer, eave, foundation, gable, and soffit vents, they also offer retrofit options such as mesh screening and honeycomb intumescent coating products that can be installed on any existing vent. Vulcan Vents can be painted to match a building's exterior, however proper care and protection is required to ensure that the paint does not clog the steel mesh or the

honeycomb matrix in order not to reduce/prevent airflow. Vulcan Vents have a patented honeycomb matrix with intumescent coatings on the interior that begin to react when temperatures reach approximately 450 degrees Fahrenheit. There are standard sized manufactured vents available as well as custom order for specific sizes available from the manufacturer. In addition, you can purchase the honeycomb matrix and stainless-steel ember mesh as a set to be customized in retrofitting of existing vent locations.

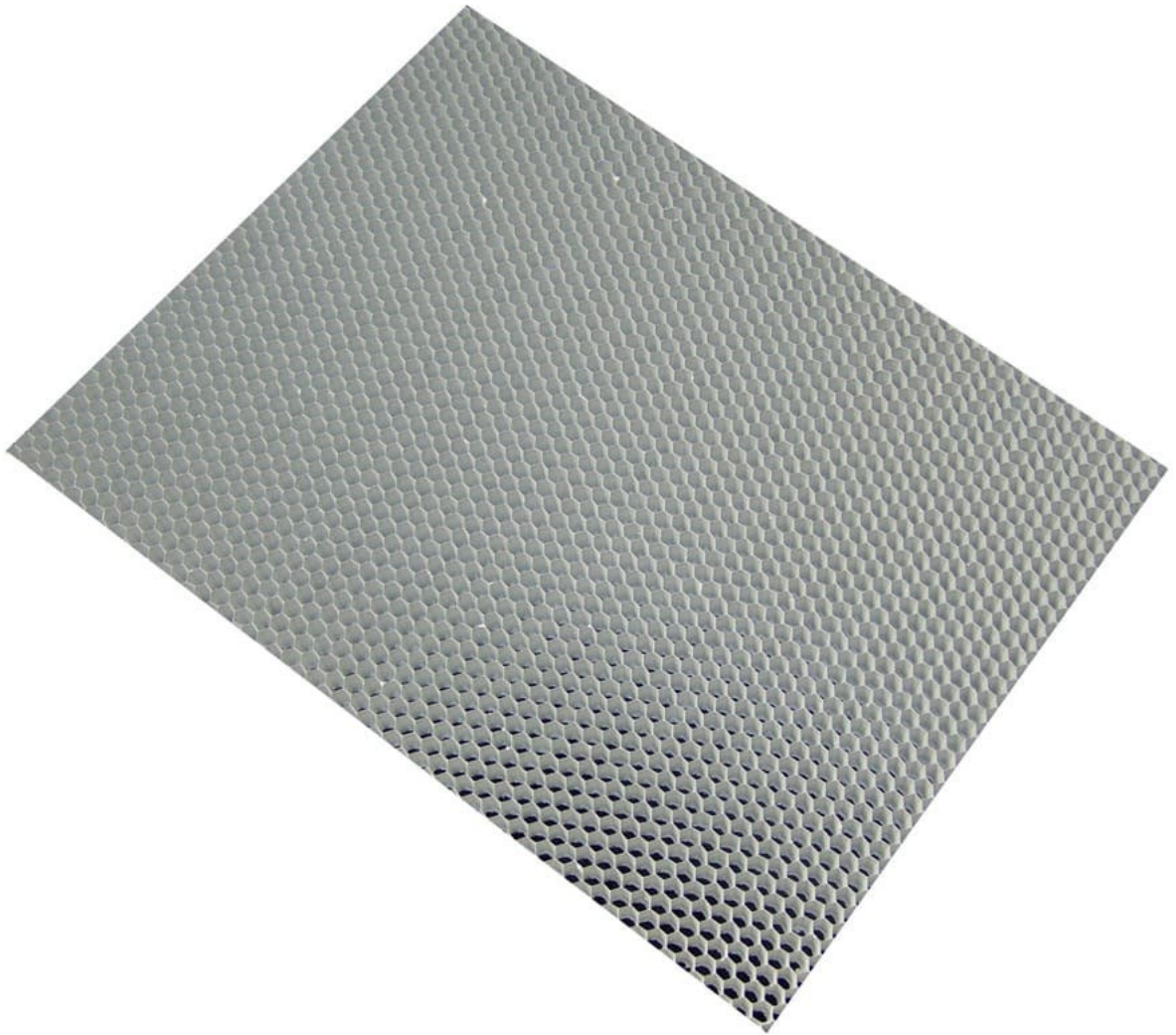


Figure 39: Vulcan Vent Honeycomb Matrix, Accessed May 22, 2023



Figure 40: Vulcan Vent Foundation Vent, Accessed May 22, 2023



Figure 41: Vulcan Vent Gable Vent, Accessed May 22, 2023



Figure 42: Vulcan Vent Soffit Vent, Accessed May 22, 2023

Evaluation:

Cost: No response from manufacturer inquiry.

Pros: Based on the information available, these products provide protection from flying embers based on their ASTM testing results. According to the manufacturer's website, their retrofit honeycomb and metal mesh products can be installed to the interior of existing vents, in which case the historic vent would remain in place and the visual impact would be minimal. Custom sizes are available, giving ultimate flexibility for historic vent sizes and configuration.

Cons: Pending review and approval of installation detailing, the downsides of this mitigation solution were not identified.

Conclusion: From a SOI Standards perspective, the retrofit honeycomb and metal mesh product installed to the interior of historic vents would be a reversible solution, with the historic fabric retained in place. The visual change to the building would be minimal and only observable up close. This would be a viable and fairly minimal cost alteration to a historic building to provide resistance to flying embers.

6. Other Building Products:

- a. Armortex Bullet Resistant and Fire Rated Wall Panels (Armortex Bullet Resistant and Fire Rated Wall Panels, 2023)

A product shared for consideration is the Armortex Bullet Resistant and Fire Rated Wall Panel. This appears to predominantly be a bullet resistant product for government and high security applications, that also achieves a 1-hour fire rating. The panel is installed directly onto the interior face of the wall framing and then interior gypsum board or other finishes are installed on top of it. The fire resistance would appear to be for interior furnishings and life safety applications only. As demonstrated by the manufacturer's diagram, the wall framing, and exterior siding would burn completely.

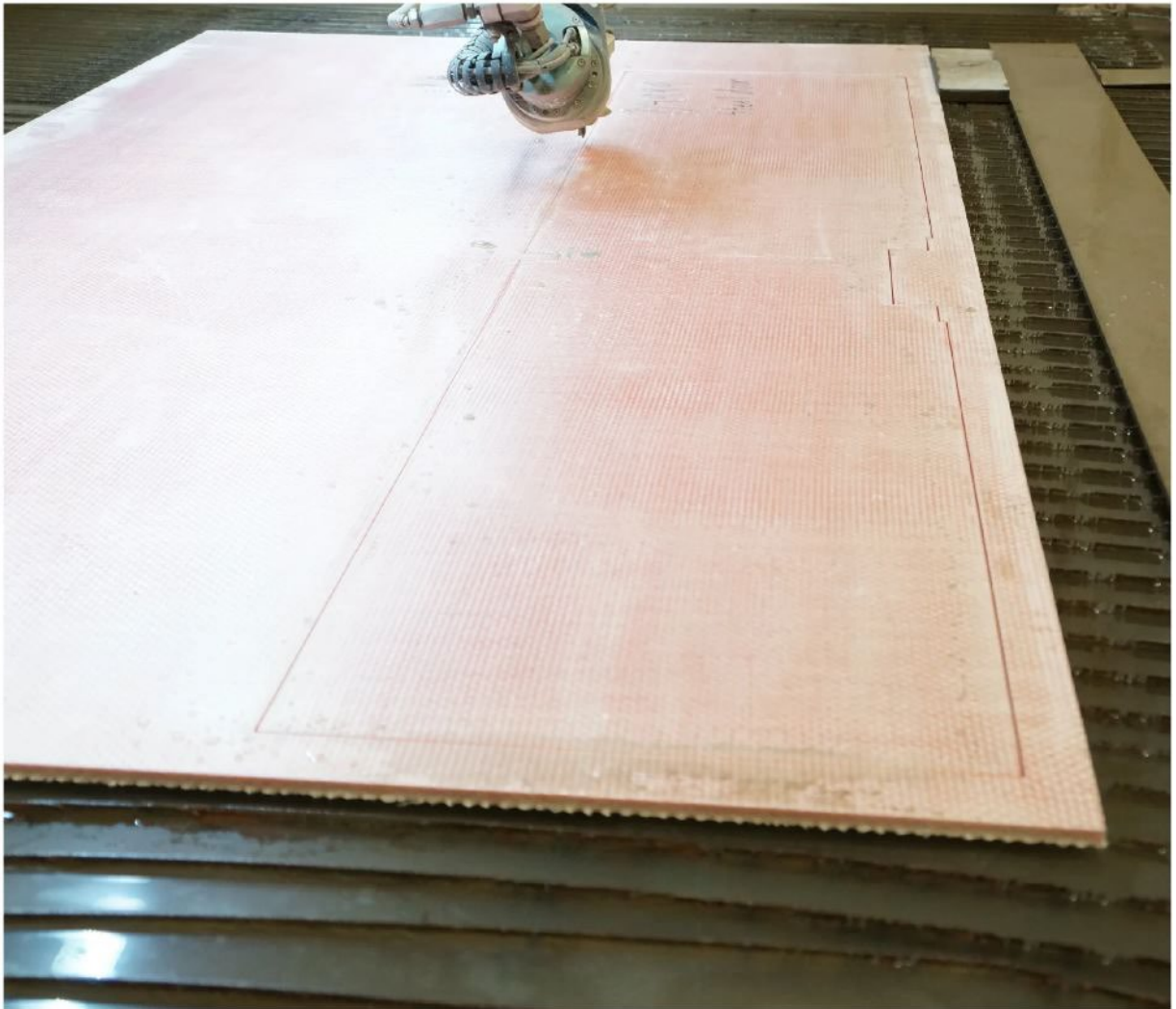


Figure 43: Armortex Panel Being Custom Cut with CNC Machine, Accessed May 23, 2023

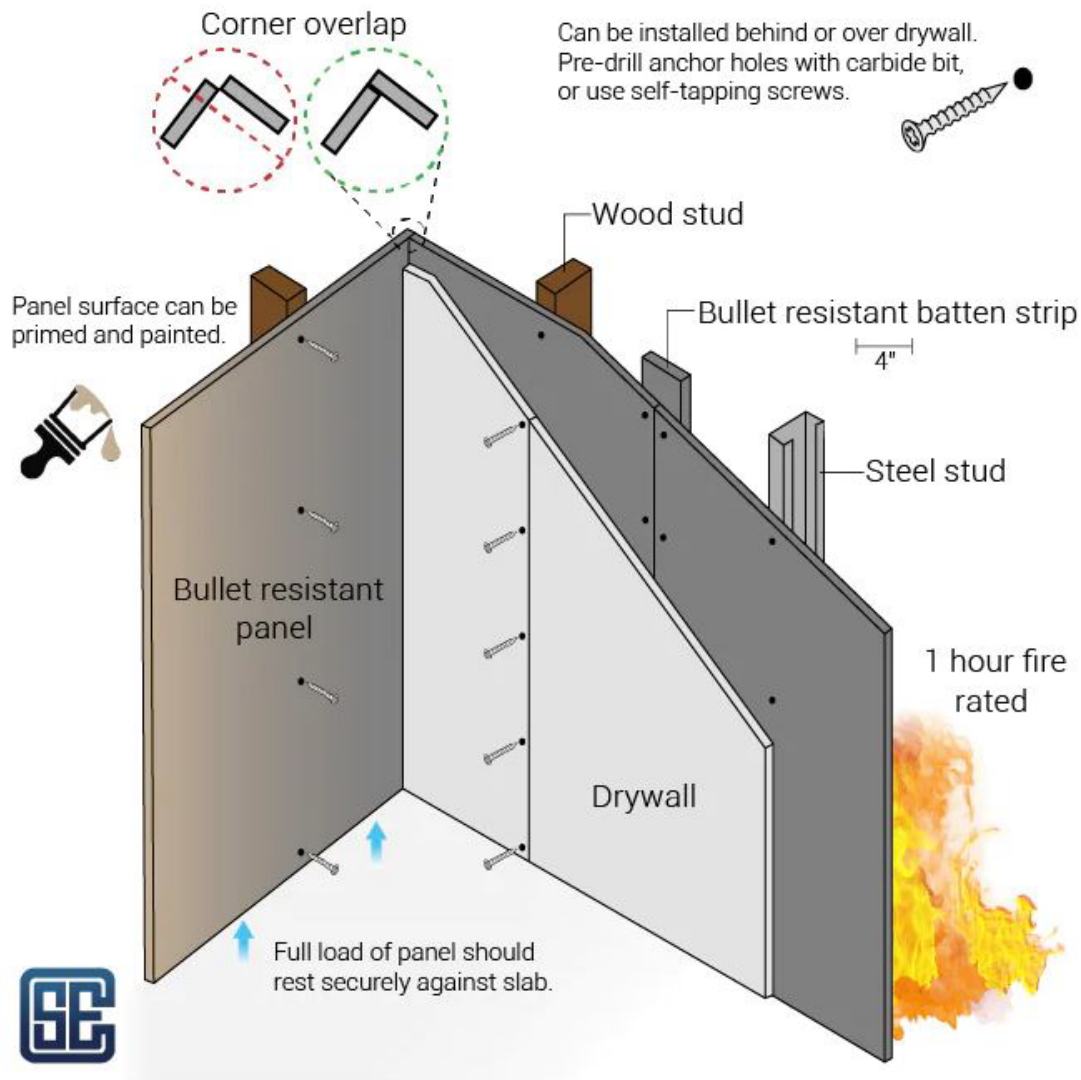


Figure 44: Armortex Installation Diagram, Accessed May 23, 2023

Evaluation:

Cost: \$800 for a 4 foot by 8 foot panel with 1 hour fire rating and Level 1 bullet resistance (their lowest resistance level offered)

Pros: No notable pros.

Cons: Extremely high cost, for unknown benefit. Would require removal of interior finishes to apply directly to the wood stud framing.

Conclusion: This product does not appear to be a viable consideration for historic building applications. A 1-hour fire rating is achievable with a single layer of Type X 5/8 gypsum board, and comparatively the cost would be approximately \$20 for a 4 foot by 8 foot board. If a fire-rating is desired, another less expensive method seems more appropriate.

IV. PHYSICAL INTERVENTION SUMMARY MATRIX

Product Type	Name	Meet SOI	Relative Cost to Implement	Notes
Fire-fighting Foams	Various Manufacturers: Chemguard, PHOS-CHEK WD881, etc.	MAYBE	\$	Short-term effectiveness, difficult to apply at large, multi-building complexes due to the number of structures and close proximity
Fire-fighting Gels	Various Manufacturers: Thermo-Gel, PHOS-CHEK INSUL-8, Firelce Pro, etc.	MAYBE	\$\$	Short-term effectiveness, difficult to apply at large, multi-building complexes due to the number of structures and close proximity
Fire Retardants Coatings	Various Manufacturers: Flamecheck M-111PA, Flame Control No. 10, etc.	MAYBE	\$\$	Not a remedial treatment for existing structures except for repairs that can be pressure treated (e.g., structural lumber)
Fire Retardants	Various Manufacturers: PHOS-CHEK LC95W	MAYBE	\$\$	Short-term effectiveness, difficult to apply at large, multi-building complexes due to the number of structures and close proximity
Intumescent Paints	Various Manufacturers	NO	\$\$	Does not appear to be effective for protecting the exterior of the structure
Building Wrap	Various Manufacturers: FireGuard, Firezat, etc.	YES	\$\$	Can be effective, requires training and deployment plan and consideration to install method
Sprinkler System: Portable Systems	Various Manufacturers: MARK-3, Code2, etc.	YES	\$\$\$	Can be effective, needs monitoring during fire operations

Sprinkler System: Installed System	Various Manufacturers: Colorado Fire Break, Defense System 2	MAYBE	\$\$\$\$	Consideration to visibility, impact to structure, and performance during freeze/thaw cycles
Opening Protection	Fabricated Covers: Plywood or Other	YES	\$\$	Consideration of deployment and storage.
Opening Protection	Metal Insect Screens	YES	\$\$	Replacing existing screening material would have minimal visual impact with increased ember protection benefit.
Opening Protection	Enviroblind Rolling Shutters	MAYBE	\$\$\$	Would require negotiation and approval by historic authorities.
Roofing	Class A Roofing: Various Types	MAYBE	\$\$\$\$	Depends on historic roofing material, if it is in place and can be retained / repaired. Consideration of fire risk and negotiation with historic authorities is needed.
Windows	Fyre-Tec Fire-Rated Windows	NO	\$\$\$\$	
Cladding & Trim	Fire-retardant Treated Wood Products Various Manufacturers: Cedar Valley, Hewn, Metaverde, Montana Timber Products, Etc.	MAYBE	\$\$\$\$	Consideration to matching historic profiles / configurations. Would require negotiation and approval by historic authorities.
Cladding & Trim	Fiber Cement Siding. Various Manufacturers: James Hardie, Nichiha Architectural Wall Panels, Equitone Panels, etc	NO	\$\$\$\$	Incompatible material, question of resistance in active wildfire conditions

Decking & Walkways	HardieDeck	NO	N/A	Not available in the US. Incompatible material, question of resistance in active wildfire conditions
Decking & Walkways	TREX	NO	\$\$	Incompatible material, question of resistance in active wildfire conditions
Vents	Retrofitting vents with metal wire mesh	YES	\$	Reversible and historic material can be retained in place.
Vents	Manufactured Fire-Rated Vents. Various Manufacturers: Embers Out, Vulcan Vents, etc.	YES	\$\$	Reversible. Consideration of detailing would be needed to retain historic material in place.
Other	Armortex Bullet Resistant and Fire Rated Wall Panels	NO	\$\$\$\$	

V. AREAS OF FURTHER STUDY

This research concluded that there are areas of further study warranted as it relates to the built environment and Wildfire hazards.

UPDATE TO THE SECRETARY OF THE INTERIOR STANDARDS FOR WILDFIRE RELATED RISKS

As discussed in the SOI STANDARDS section of this document, there is need for further consideration at the federal level for wildfire risks to historic buildings and sites, similar to the *Guidelines on Flood Adaptation for Rehabilitating Historic Buildings*. This is a recommended area of further study / discussion.

EFFECTS OF FIRE CHEMICALS FROM FOAM, GEL, AND RETARDANTS ON HISTORIC WOOD

Based on the lack of data on the effects of fire chemicals on historic wood, this would be a recommended area of further study.

The after-effects when fire chemicals are applied can be quite varied but may include color changes, changes in texture, or damage to the historic fabric, among other detrimental effects. What is typically unknown are the effects on the material itself - whether the application of a chemical (foam, gel, retardant, coatings, or intumescent paints) alters the fundamental properties of the wood in ways that reduce the service life of the wood. For virtually all of the fire chemicals discussed in this report, technical data does not exist that answers the question of whether the wood is altered (harmed) by applying the chemical such that the historic nature of the wood and the structure is negatively impacted. There is limited information that the chemicals act only on the surface of the wood but whether it is truly reversible requires that technical research be conducted to determine whether that is the case. Once this is firmly determined, then consideration for Wildfire Adaptation should be considered. Is slight alteration to the appearance of historic wood preferable to full structure loss? If application results in reducing the service life of historic wood by a few or many years, is this preferable to full structure loss? These questions can be further considered once the technical testing information is known on the effects of chemicals on historic wood.

COHESIVE ENVELOPE SYSTEM ON NON-PRIMARY BUILDING ELEVATIONS

Following the review and evaluation of various materials and products available on the market to “harden” a building against Wildfires, potentially the only viable solution to providing resistance would involve a cohesive envelope system which would need to encapsulate roofing, siding, trim, vents, windows, doors, etc. Wholesale replacement or encapsulation of historic materials via a new exterior envelope would drastically alter the visual character and experience of the building and would likely result in the loss of designation as a National Historic Landmark. Even on a National Register designated building, the argument for this treatment would be difficult to justify to historic authorities. That being said, as illustrated by the November 2019 SOI

“Standards for Rehabilitation & Guidelines on Flood Adaptation for Rehabilitating Historic Buildings”, historic authorities recognize that increased climate and weather risks can necessitate a deeper look at treatment for historic properties. A similar update could be considered for historic buildings at high risk of wildfire and that update could perhaps take into consideration secondary elevations on historic buildings that face the greatest threat from wildfire.

For example, on buildings with secondary elevations (back and side) that face open space / landscapes with the highest risk of wildfire approach, i.e., abutting high ladder fuel landscapes. Whereas the primary elevations (front facades) of these buildings face into the district. Design and evaluation of an envelope system that would encapsulate historic materials with fire-rated or fire-resistant materials, in conjunction with installing fire-rated windows and doors, and/or installing operable fire shutters could perhaps be evaluated. Additional strategies such as enclosure of open soffits and removal of gutters could be considered as well. The goal being a cohesive envelope system that would provide optimal protection to these high-risk elevations on a building. The consideration of this treatment would not only need strong justification and careful detailing with review and approval from historic authorities, but consideration would also be needed as to the success of such an alteration.

While something like this would likely assist with increasing the resistance of a building from flying embers, direct flames would not be resisted by this alteration and wildfires with high radiant heat would ignite combustible materials from the inside of the building outward without direct contact from flames. Therefore, the evaluation of whether this level of alteration and the cost of doing so would be unjustifiable for fairly limited overall resistance.

APPENDIX A:

BIBLIOGRAPHY

- 17 Structures at Old Faithful Catch Fire.* (1988, September 8). From Los Angeles Times: <https://www.latimes.com/archives/la-xpm-1988-09-08-mn-2145-story.html>
- (2023). From Embers Out: <https://www.embersout.com/>
- (2023, July 7). From Nichiha: <https://www.nichiha.com>
- (2023, July 7). From James Hardie: <https://www.jameshardie.com/>
- (2023). From FlameOFF: https://flameoffcoatings.com/intumescent-fire-resistant-paint?utm_source=Adwords&utm_medium=cpc&utm_campaign=MountainTime&utm_term=fire%20resistant%20paint&gclid=CjwKCAjwzY2bBhB6EiwAPpUpZqlrq9TDYwhQzTVYGwimrZoUWyO02nhHuA1DrZpUAeFoXdjbUrjthoCsg0QAvD_BwE
- (2023). From St. Cloud Window: https://stcloudwindow.com/our-products/?_sft_applications=secondary-glazing-systems
- (2023). From Allied Window, Inc. : <https://www.alliedwindow.com/>
- A Home's First Line of Defense from Embers and Wildfire Flames.* (2023). From Vulcan Vent: <https://www.vulcanvents.com/>
- A Plus Gutter Systems. (Undated). *Seamless Rain Gutters and Sheet Metal.* From Gutter 4 U: <https://www.gutter4u.com/index.html>
- After the Fire: Cleaning Up Fire Retardant and Fire Suppressants.* (Undated). From State of Oregon Department of Environmental Quality: <https://www.oregon.gov/deq/wildfires/Documents/FireChemlCUpWQ.pdf>
- Armortex Bullet Resistant and Fire Rated Wall Panels.* (2023). From Covenant Security Equipment: <https://covenantsecurityequipment.com/products/armortex-bullet-resistant-and-fire-rated-wall-panels?currency=USD&variant=38004736884922>
- ASTM 119-20 Standard Test Methods for Fire Tests of Building Construction and Materials.* (2023). From ASTM : <https://www.astm.org/e0119-20.html>
- ASTM E84-21a Standard Test Method for Surface Burning Characteristics of Building Materials.* (2023). From ASTM: <https://www.astm.org/e0084-21a.html>
- Barricade Fire Blocking Gel.* (2023). From Primo Supply: https://www.primosupply.com/Fire-Protection-Gel/products/29/?gclid=CjwKCAjwzY2bBhB6EiwAPpUpZtxwarfC9FMYYuKY8kLWVfWkGqrmx8GDPU_CqGwc73Jkn7O69ZVEbxoCGaAQAvD_BwE
- Big Bend National Park Texas: Wildland Fire Management Plan.* (2005, June). From National Park Service: <http://npshistory.com/publications/bibe/fmp-2005.pdf>
- Brewer, W., Brown, C., Hawks, S., Link, E., Maranghides, A., Mell, W., . . . Walton, W. (2021, January). *NIST Technical Note 2135 A Case Study of the Camp Fire - Fire Progression Timeline.* From <https://nvlpubs.nist.gov/nistpubs/TechnicalNotes/NIST.TN.2135.pdf>
- CAL FIRE. (2019). *Prepare for Wildfire: Hardening Your Home.* From Ready for Wildfire.
- Campbell, H. (2020, December). *Firescaping: Wildfire-Resistant Landscaping in Georgia.* From University of Georgia Warnell School of Forestry & Natural Resources: <https://bugwoodcloud.org/resource/files/18516.pdf>

Catelli, E. B. (2016). Salt efflorescence in historic wooden buildings. *Heritage Science*, p. 4.

Cedar Valley. (2023). *Real Cedar Siding Panels*. From Cedar Valley: <https://cedar-valley.com/>

CeDUR . (2022). *Home Fire Safety & Fire Resistant Roofing For Your Home*. From CeDUR Synthetic Roofing Products: <https://www.cedur.com/fire-safety>

Chapter 12-7A Materials and Construction Methods for Exterior Wildfire Exposure. (2023). From Up Codes: <https://up.codes/viewer/california/ca-referenced-standards-code-2016/chapter/12-7A/materials-and-construction-methods-for-exterior-wildfire-exposure#12-7A>

Chemco. (Undated). *SaferWood in Siding*. From <https://www.chemco.org/saferwood/products/siding/>

Chemguard. (2005). *Specialty Chemicals & Equipment: General Foam Information*.

Chemguard. (2005). *Specialty Chemicals & Equipment: Use and Benefit of Class "A" Foam Concentrate in Water*.

Class A Foam Concentrates. (2023). From Chemguard: <https://www.chemguard.com/fire-suppression/catalog/foam-concentrates/class-a-foam/>

Code 3 Water. (2023). *Portable Wildfire Fire Pump System*. From Code 3 Water: <https://code3water.com/>

Colorado Firebreak. (2023). *Customized Wildfire Protection to Defend Your Home*. From Colorado Firebreak: <https://www.coloradofirebreak.com/>

Eggleston, J., Parker, J., & Wellock, J. (2019, November). *Guidelines on Flood Adaptation for Rehabilitating Historic Buildings*. From National Park Service: <https://www.nps.gov/orgs/1739/upload/flood-adaptation-guidelines-2021.pdf>

Eldredge, K. (2022). *Fire Suppressants and Cultural Resources*. National Center for Preservation Technology and Training.

Envioblind. (2021). *Envioblind Shutters*. From Envioblind: <https://www.envioblind.com/rolling-shutters/>

FBL-100 . (2023). From International Coatings Group: <https://internationalcoatingsgroup.com/fbl-100-fire-protection/>

Fighting, K. F. (n.d.). *Section 1 Basics to Foam*. National Foam.

Fire Retardant - Thermo Gel and Phos Check Foam. (2023). From Fire Pump & Hose Packages: <https://fire-pump-packages.com/fire-retardants-thermo-gel-and-phos-check-foam/>

Fire Retardant Paints. (2023). From FlameControl: <https://www.flamecontrolcoatings.com/product-catalog/frpaints>

Fire Safe Marin. (2023). *Harden Your Home: Fire Resistant Vents*. From Fire Safe Marin: <https://firesafemarin.org/harden-your-home/fire-resistant-vents/#gsc.tab=0>

Fire Treatment for Wood: Defensive Solutions for Fire. (Undated). From Montana Timber Products: <https://www.montanatimberproducts.com/product-applications/wood-fire-treatment/>

Firefree products provide high performance fire protection. (2023). From Firefree Coatings, Inc. : https://www.firefree.com/?matchtype=e&network=g&device=c&adposition=&keyword=intumescent%20paint&campaign=1486987657&adgroup=63021042608&gclid=CjwKCAjwzY2bBhB6EiwAPpUpZpuefDQzIWlp2sCqBzk9Vq0dAixWkbiHelugfNM-Cgxhjpw8urNANhoCnTEQAvD_BwE

FireGuard. (2021). *Aluminized Fiberglass Fabric (AFF) Wildfire Protection*. From SEITec FireGuard: <https://www.fireguard.us/>

FireIce Pro (Dry Concentrate). (2023). From FireIce A GelTech Solution: <https://geltechsolutions.com/fireice/>

Firewise USA. (2022). *Exterior Sprinkler Systems*. From National Fire Protection Association: <https://www.nfpa.org/-/media/Files/Firewise/Fact-sheets/FirewiseFactSheetsExteriorSprinklers.ashx>

Firezat. (2023). *Fire Resistant Fire Shields*. From Firezat Inc: <https://www.firezat.com/>

Flamecheck M-111PA. (2023). From Flamecheck: https://flamecheck.com/fire-retardant-paint/?gclid=CjwKCAjwzY2bBhB6EiwAPpUpZng4UMtyqhC-Vv9gfvmjuh4VEnjp16h9C72gx6jUAFpZjwgdcrLH8hoC56EQAvD_BwE

Foam-Gel-Fire Retardant Comparison Chart. (2010). From Consumer Fire Products, Inc.: <http://www.consumerfireproducts.com/foam-gels-and-fire-retardant.html>

Fol-Da-Tank Collapsible Fire Department Frameless Water Tank. (2023). From Tank Retailer: <https://tankretailer.com/products/fol-da-tank-self-supporting-fire-department-tank-vinyl?currency=USD&variant=44731390263616>

Fornell, D. (1991). *Fire stream management handbook*. Saddle Brook, NJ: Fire Engineering.

Frontline Wildfire Defense. (2023). *Wildfire Protection for Homes & Businesses*. From Frontline Wildfire Defense: <https://www.frontlinewildfire.com/>

Fyre-Tec. (2023). *Fire-Tec Fire Rated Windows*. From Fyre-Tec: <https://fyre-tec.com/fyre-tec-fire-rated-windows.php>

Green, D. (2021, October 28). *USDA Forest Service Help Protect Reagan Ranch from Alisal Fire with Phos-Chek Fortify Long-Term Fire Retardant*. From Perimeter Solutions: <https://www.perimeter-solutions.com/en/2021/10/28/reagan-ranch-usda-forest-service-help-protect-reagan-ranch-from-alisal-fire-with-phos-chek-fortify/>

Griggs, M. B. (2014, August 8). *It's a Wrap! The Forest Service Is Wrapping Historic Structures to Protect Them From Wildfires*. From Smithsonian Magazine: <https://www.smithsonianmag.com/smart-news/its-wrap-forest-service-wrapping-historic-structures-protect-them-wildfires-2-180952289/>

Group, N. W. (1993, October). *United States Department of Agriculture*. From FOAM VS FIRE: Class A Foam for Wildland Fires: https://www.fs.usda.gov/t-d/pubs/pdf/hi_res/93511208hi.pdf

Harden Your Home. (2023, March 15). From Fire Safe Marin: Adapting to Wildfire: <https://firesafemarin.org/harden-your-home/#gsc.tab=0>

HardieDeck. (2023). *4 Reasons Why You Need HardieDeck in the Australian Summer*. From HardieDeck: <https://hardiedeck.com.au/case-studies/4-reasons-why-you-need-HardieDeck-in-the-Australian-summer>

Hewn. (2022). *Fire Resistant Exterior Cedar*. From Hewn: <https://hewn.com/fire-resistant-products/>

Husky Portable Folding Frame Water Tanks. (2023). From Husky Portable Containment: <https://www.huskyportable.com/standard-portable-folding-frame-tanks>

Inc, F. (2023). *Fire Resistant Fire Shields*. From Firezat Inc: <https://www.firezat.com/>

Insurance Institute for Business & Home Safety. (Undated). *California Edition: Protect Your Property from Wildfire*. From Disaster Safety: https://disastersafety.org/wp-content/uploads/2019/03/Wildfire-Retrofit-Guide-California_IBHS.pdf

Kim DW, K. C. (2014). Flame Retardant Treatment's Effects and Detection Method on Wooden Buildings' Pigment Layer. *Journal of the Korean Wood Science and Technology*, pp. 393-406.

Lebow, S., Kirker, G., White, R., Amburgey, T., Barnes, H., Sanders, M., & Morrell, J. (n.d.). Guide for In-Place Treatment of Wood in Historic Covered and Modern Bridges. *U.S. Department of Agriculture, Forest Service, Forest Products Laboratory*, 43.

Liebson, J. (n.d.). *Introduction to Class A Foams and Compressed Air Foam Systems for the Structural Fire Service*. Ashland, Massachusetts.

Lord, N. (2023, July 25). Personal Photo. Denver, Colorado.

Miller-Carl, M. (2008, July 18). *Fire spares historic structure thanks to protective wrap*. From Gold Country Media: <https://goldcountrymedia.com/news/1029/fire-spares-historic-structure-thanks-to-protective-wrap/>

National Historic Landmarks Glossary of Terms. (2023). From National Park Service: <https://www.nps.gov/subjects/nationalhistoriclandmarks/glossary.htm>

Nolan, C. (2021, August 24). *Metaverde Introduces Fire Retardant Treated Hem Fir Wood Siding*. From Metaverde: <https://www.mataverdedecking.com/blog/mataverde-introduces-fire-retardant-treated-hem-fir-wood-siding>

O'Shaughnessy, T. (2022, November 19). *Industrial Paint and Protection Magazine*. From Fire Rating Classifications Explained: <https://www.ippmagazine.com/fireproof-paint/fire-rating-classification/>

Part 68 The Secretary of the Interior's Standard for the Treatment of Historic Properties. (2023, February 7). From National Archives: Code of Federal Regulations: <https://www.ecfr.gov/current/title-36/chapter-I/part-68>

Pedrogão Grande Fire Timeline. (2018, April 13). From Portugal Wildfires: <https://www.portugalwildfires.com/pedrogao-grande-fire-timeline/>

Phos-Check WD881. (2023). From Perimeter Solutions: <https://www.perimeter-solutions.com/en/class-a-foam/phos-chek-wd881/>

Phos-Chek Fortify: Season-Long Preventive Protection Against Wildfires. (2023). From Perimeter Solutions: <https://www.perimeter-solutions.com/en/fire-safety-fire-retardants/phos-chek-fortify/>

Phos-Chek Insul-8. (2020). From Perimeter Solutions: <https://www.perimeter-solutions.com/wp-content/uploads/2021/02/PC-INSUL-8-PCC-2019047-0-A4.pdf>

Phos-Chek LC95W. (2023). From Perimeter Solutions: <https://www.perimeter-solutions.com/en/fire-safety-fire-retardants/phos-chek-lc95-259-fx/>

Portable Water Tank - Steel Frame. (2023). From Feldfire: https://www.feldfire.com/Portable-Water-Tank--Steel-Frame_p_869.html?msclkid=dae58abaaae71a7857e0ee0005f4df25&utm_source=bing&utm_medium=cpc&utm_campaign=Hardware%20%7C%20Shopping%20%7C%20Bing&utm_term=4579534652266232&utm_content=Storage%20Tanks

Preservation Briefs 9 The Repair of Historic Wooden Windows. (2023). From National Park Service Technical Preservation Services: <https://home1.nps.gov/tps/how-to-preserve/briefs/9-wooden-windows.htm#replacement>

Puri, R., & Khanna, A. (2017). Intumescent coatings: A review on recent progress. *J. Coat. Technol. Res.* , 14 (1) 1-20.

Quarles, S. L. (2017, August 27). *Fire Ratings for Roofing Material*. From Surviving Wildfire: <https://surviving-wildfire.extension.org/fire-ratings-for-roofing-material/#:~:text=%20Class%20A%20is%20the%20highest,an%20untreated%20wood%20shake%20roof.>

Richter-Ryerson, S. (2023, April 12). *Nebraska Game Parks*. From Rock Creek Station state parks temporarily closed: <https://outdoornebraska.gov/about/press-events/news/rock-creek-station-state-parks-temporarily-closed/>

Roof Vent Screens Installation. (2023, May 22). From Animal Control Specialists, Inc.: <https://animalcontrolspecialists.com/roof-vent-screens/>

Ross, R. J. (2010). *Wood handbook: wood as an engineering material*. From United States Department of Agriculture: <https://www.fs.usda.gov/research/treesearch/37440>

Shirley, B. (2015, June 30). *Understanding heat energy*. From Building Design + Construction: <https://www.bdcnetwork.com/blog/understanding-heat-energy>

Takahashi, F. (2019, October 15). *Whole-House Fire Blanket Protection from Wildland-Urban Interface Fires*. From Frontiers in Mechanical Engineering: <https://www.frontiersin.org/articles/10.3389/fmech.2019.00060/full>

The use of PFAS and fluorine-free alternatives in fire-fighting foams. (2020, June). From European Commission DG Environmental / Euprean Chemicals Agency (ECHA): https://echa.europa.eu/documents/10162/28801697/pfas_flourine-free_alternatives_fire_fighting_en.pdf/d5b24e2a-d027-0168-cdd8-f723c675fa98

Trex Composite Decking Boards & Products. (2023). From Trex: <https://www.trex.com/>

U.S. Fire Administration. (2022, August 22). From <https://www.usfa.fema.gov/wui/what-is-the-wui.html>.

University of California. (2023). *Top of the House*. From Homeowner's Wildfire Mitigation Guide: <https://ucanr.edu/sites/Wildfire/Roof/>

University of California. (2023). *Windows*. From Homeowner's Wildfire Mitigation Guide: https://ucanr.edu/sites/Wildfire/Side_of_House/Windows/

Wagner, P. (1944). Conflagration-Retardative Curtain. *U.S. Patent and Trademark Office U.S. Patent*, U.S. Patent, No. 2365127.

Walls, R. (2023). From Research Gate: https://www.researchgate.net/figure/Firebrand-ember-attack-from-lofted-burning-material-being-carried-onto-homes-and_fig3_333670782

Water Enhancers Fact Sheet. (2017, March). From United States Department of Agriculture: https://www.fs.usda.gov/rm/fire/wfcs/documents/WE_FactSheet_2017-0328.pdf

Waterax. (2023). *Mark-3 Portable High-Pressure Fire Pump*. From Waterax Fire Pumps: <https://www.waterax.com/en/product-category/mark-3-portable-high-pressure-fire-pump>

What Are Bal FZ and Bal 40 Requirements? (2023). From Bushfire Control: <https://www.bushfirecontrol.com.au/what-are-bal-fz-and-bal-40-requirements/>

Wildfire Mitigation and Preparedness. (2023). From Summit County Colorado: <https://www.summitcountyco.gov/1244/Wildfire-Programs>

- Wildland Fire Shelter*. (Undated). From National Wildfire Coordinating Group:
<https://www.nwcg.gov/sites/default/files/committee/docs/fsppes-fire-shelter-history.pdf>
- Wildland-Urban Interfaces*. (2023). From California Department of Housing and Community Development: <https://www.hcd.ca.gov/building-standards/manufactured-and-factory-built/wildland-urban-interfaces>
- Young Jr., R. (2023). *Solvable: Wildfire Ignition is Solvable*. From Pushkin FM:
<https://www.pushkin.fm/podcasts/solvable/wildfire-ignition-is-solvable>
- Yu, A., Hernandez, H., Kim, A., Stapleton, L., Brand, R., Mellor, E., . . . Appel, E. (2019). Wildfire prevention through prophylactic treatment of high-risk landscapes using viscoelastic retardant fluids. *The Proceedings of the National Academy of Sciences*, 116.

APPENDIX B:

LIST OF FIGURES

Figure 1: The Fire Triangle	5
Figure 2: Diagram Horizontal Fuel and Vertical/Ladder Fuels (Campbell, 2020).....	7
Figure 3: Idealized defensible space that is recommended around a single residential structure. This approach is often not feasible for cultural resource sites due to proximity of other structures, heritage trees, or other features that are significant to the cultural landscape.....	8
Figure 4: Defensible space as recommended by removing or trimming vegetation to eliminate horizontal and vertical fuel continuity to reduce the risk of the fire spreading and making fire operations more challenging and less safe. As is the case for Figure 3, this approach is often not feasible for cultural resource sites due to proximity of other structures, heritage trees, or other features that are significant to the cultural landscape. (Wildfire Mitigation and Preparedness, 2023)	8
Figure 5: Diagram of Convection, Conduction, and Radiation Heat (Shirley, 2015).....	9
Figure 6: Illustration of Firebrand / Embers Traveling from Fire to Structure (Walls, 2023).....	10
Figure 7: Diagram of a convective column (Pedrógão Grande Fire Timeline, 2018).....	11
Figure 8: Deteriorated fascia board that provides an entry for wind-blown embers can result in an ignition on the interior of the structure.....	11
Figure 9: Image of stack of Firezat rolls. Could be stockpiled on-site for use. Image credit: firezat.com, accessed March 21, 2023	31
Figure 10: Firezat installation with chicken wire and staples. Building has an existing metal roof eliminating the need to wrap the roof. Image credit: firezat.com, accessed March 21, 2023	32
Figure 11: Image of a Husky Portable Water Tank (Husky Portable Folding Frame Water Tanks, 2023).....	34
Figure 12: Waterax MARK-3 Website Photo, Accessed May 23, 2023	35
Figure 13: Code3 Website Photo, Accessed May 23, 2023	37
Figure 14: Defense System 2 Website Photo Control System and Surface-Run Piping, Accessed May 23, 2023.....	40
Figure 15: Defense System 2 Website Photo Soffit Sprinklers and Foam, Accessed May 23, 2023	41
Figure 16: Enviroblind shutter in open position. Image credit: enviroblind.com, accessed March 21, 2023	43
Figure 17: Enviroblind shutter in closed position. Image credit: enviroblind.com, accessed March 21, 2023	44
Figure 18: Enviroblind shutters on various sized windows and doors in closed position. Image credit: enviroblind.com, accessed March 21, 2023	45
Figure 19: A Plus Gutter Systems of Los Angeles and Orange County, Photo of soffit and fascia retrofitting with sheet metal, Accessed May 17, 2023.....	50
Figure 20: A Plus Gutter Systems of Los Angeles and Orange County, Photo of soffit and fascia retrofitting with sheet metal, Accessed May 17, 2023.....	51
Figure 21: Fyre-Tec Fire Rated Window Styles. Image credit: fyre-tec.com, accessed March 21, 2023	54

Figure 22: Fyre-Tec Fire Rated Window Sections Compared to Typical Rated Window Frame Construction. Image credit: fyre-tec.com, accessed March 21, 2023	55
Figure 23: Cedar Valley Website Photo, Custom Massachusetts Home Installation, Accessed May 22, 2023	57
Figure 24: Cedar Valley Website Photo, Radius Panel Photo, Accessed May 22, 2023.....	57
Figure 25: Cedar Valley Website Photo, Custom Combed (Striated) Texture, Accessed May 22, 2023	58
Figure 26: SaferWood Website Project Photo, Accessed May 22, 2023	60
Figure 27: Hewn Website Project Photo, Accessed May 22, 2023.....	62
Figure 28: Montana Timber Products Website Project Photo, Accessed May 23, 2023.....	65
Figure 29: Nichiha Website Photo, Nichiboard Cedar (Nichiha, 2023)	66
Figure 30: Nichiha Website Photo, Sierra Premium Shake (Nichiha, 2023)	67
Figure 31: James Hardie Website Photo, Hardie Pank Lap Siding (James Hardie, 2023)	67
Figure 32: James Hardie Website Photo, Hardie Shingle Siding (James Hardie, 2023)	68
Figure 33: West Wall of 1957 Ranch in Colorado, Nails Visibly Working Their Way Out of Fiber Cement Siding (Lord, 2023).....	69
Figure 34: HardiDeck Website Project Photo, Accessed May 23, 2023	71
Figure 35: Trex Website Installation Photo, Accessed May 23, 2023.....	72
Figure 36: Roof Vent with Retrofitted Wire Mesh Cover (Roof Vent Screens Installation, 2023)74	
Figure 37: Photo from Embers Out Website of Retrofitted Vent Applications, Accessed May 22, 2023	75
Figure 38: Photo from Embers Out Website of Gable Vent Filter, Accessed May 22, 2023.....	75
Figure 39: Vulcan Vent Honeycomb Matrix, Accessed May 22, 2023	77
Figure 40: Vulcan Vent Foundation Vent, Accessed May 22, 2023.....	78
Figure 41: Vulcan Vent Gable Vent, Accessed May 22, 2023	79
Figure 42: Vulcan Vent Soffit Vent, Accessed May 22, 2023	80
Figure 43: Armortex Panel Being Custom Cut with CNC Machine, Accessed May 23, 2023.....	81
Figure 44: Armortex Installation Diagram, Accessed May 23, 2023	82

APPENDIX C: SHF DELIVERABLE #3

List of Research Stakeholders & Resources

Colorado Chautauqua Association

Wildfire Mitigation Plan (Phase 2)

Deliverable #3 List of Research Stakeholders & Resources

SHF Project: #2022-M2-001

1. Research physical wildfire mitigation interventions for historic wood-framed buildings in relationship to the Secretary of Interior's (SOI) Standards

This task consists primarily of a literature review and discussions regarding fire behavior, fire mitigation practices, and fire-protection products or strategies for reducing the risks to historic resources. Key considerations when assessing the appropriateness of any product or strategy are conformance to the SOI Standards, including ease of application, feasibility and reversibility, relative cost and efficacy. It is not sufficient that a product or strategy be effective for modern structures but it must be effective when used on historic structures, such as the cottages at Chautauqua.

Examples of products that may be reviewed include various foams, paints, and coatings:

Perimeter Solutions Phos-Chek Fortify

<https://www.perimeter-solutions.com/en/fire-safety-fire-retardants/phos-chek-fortify/>

FireIce Pro (Dry Concentrate)

<https://geltechsolutions.com/fireice/>

Pierce Fire-Fighting Foam

<https://www.piercemfg.com/pierce/blog/fire-fighting-foam-systems>

Consumer Fire Products Foam

<http://www.consumerfireproducts.com/why-foam.html>

<http://www.consumerfireproducts.com/foam-gels-and-fire-retardant.html>

Primo Supply Fire Protection Gel

[https://www.primosupply.com/Fire-Protection-](https://www.primosupply.com/Fire-Protection-Gel/products/29/?qclid=CjwKCAjwzY2bBhB6EiwAPpUpZtxwarfC9FMYYuKY8kLWVfWkGqrmx8GDPU_CqGwc73Jkn7O69ZVEbxoCGaAQAvD_BwE)

[Gel/products/29/?qclid=CjwKCAjwzY2bBhB6EiwAPpUpZtxwarfC9FMYYuKY8kLWVfWkGqrmx8GDPU_CqGwc73Jkn7O69ZVEbxoCGaAQAvD_BwE](https://www.primosupply.com/Fire-Protection-Gel/products/29/?qclid=CjwKCAjwzY2bBhB6EiwAPpUpZtxwarfC9FMYYuKY8kLWVfWkGqrmx8GDPU_CqGwc73Jkn7O69ZVEbxoCGaAQAvD_BwE)

International Coatings Group - Intumescent Paint

https://internationalcoatingsgroup.com/?qclid=CjwKCAjwzY2bBhB6EiwAPpUpZk29B6A5G-FgAe7Fd_qvt0Ea_6g23j9RgjKJBggAwUH7TGQmdLdKNBoCVOEQAvD_BwE

Firefree Coatings, Inc.

https://www.firefree.com/?matchtype=e&network=g&device=c&adposition=&keyword=intumescent%20paint&campaign=1486987657&adgroup=63021042608&gclid=CjwKCAjwzY2bBhB6EiwAPpUpZpuefDQzIWlp2sCgBzk9Vq0dAixWkbiHelugfNM-CgxhjpW8urNANhoCnTEQAvD_BwE

Flamecheck

https://flamecheck.com/fire-retardant-paint/?gclid=CjwKCAjwzY2bBhB6EiwAPpUpZng4UMtyghC-Vv9gfvnmjuh4VEnjp16h9C72gx6jUAFpZjwgdcrlH8hoC56EQAvD_BwE

FlameOFF

https://flameoffcoatings.com/intumescent-fire-resistant-paint?utm_source=Adwords&utm_medium=cpc&utm_campaign=MountainTime&utm_term=fire%20resistant%20paint&gclid=CjwKCAjwzY2bBhB6EiwAPpUpZqlrq9TDYwhQzTVYGwimrZoUWyO02nhHuA1DrZpUAeFoXdjbUjrthoCsg0QAvD_BwE

FlameControl Fire Retardant Coatings

<https://www.flamecontrolcoatings.com/product-catalog/frpaints>

ISOLATEK International Intumescent Coatings

https://www.isolatek.com/construction/commercial-products/intumescent-coatings/?gclid=CjwKCAjwzY2bBhB6EiwAPpUpZmEtcICttfJZN5x0nTSEuUFq3zMk_PA9gjbF7HEpXMyXrbkKf72EvBoClrUQAvD_BwE

International Fireproof Technology Inc. Intumescent coating

<https://painttoprotect.com/>

No-Burn Coatings

<https://www.noburn.com/>

Benjamin Moore Insl-X

<https://www.benjaminmoore.com/en-us/interior-exterior-paints-stains/insl-x>

JLS Chemical Coatings

<https://en.jlschemical.com/>

FX Lumber Guard XT Retardant for Exterior Wood

<https://shop.rdrtechnologies.com/Lumber-Guard-fire-retardant-for-Exterior-Wood-p/lqxt5g.htm>

Flame Stop Inc. Fire Retardant Spray for Wood

<https://www.flamestop.com/shop/fire-retardants/fire-retardant-spray-for-wood/>

Zeroflame Fire Retardant Treatment for Wood
<https://www.zeroflame.co/Fire-Retardant-Treatment>

Other types of fire protections:

Foil building wrap

Firezat Inc. <https://www.firezat.com/>

Sprinklers (on building and on site)

Code 3 Water
<https://code3water.com/vineyards-and-wineries>

Colorado Fire Break
[Coloradofirebreak.com](https://coloradofirebreak.com)

Frontline Wildfire Defense
<https://www.frontlinewildfire.com/protect-home-with-roof-wildfire-sprinkler-system/>
WASP
<https://waspwildfire.com/>

Fire Safe Marin
<https://firesafemarin.org/harden-your-home/exterior-sprinklers-and-coatings/>

Ember Wildfire Defense Solutions
<https://emberdefensellc.com/sprinklers/>

Determining conformance to the SOI Standards and effectiveness on historic structures will not be based on laboratory research conducted during this project but rather on a review of published technical literature (as opposed to marketing information). An example of technical literature to be reviewed would be:

Zabb-Parmley, Samuel. 2021. *Considering Modern Fire Codes in Replacing Wood-Shingle and Wood-Shake Roofing*. APT Bulletin: The Journal of Preservation Technology, Vol. 52, No. 4, Special Issue: Wood (2021), pp. 33-40.

SFPE Task Group on Fire Risk Assessment, 2022. *Risk, Fire Risk, and Fire Risk Assessment*. In SFPE Guide to Fire Risk Assessment.

Other replacement materials suggested for protecting structures during wildland fire (but need to be vetted for conformance to SOI Standards) include:

Replacement Materials (Roofing, Windows, Cladding, Decking and Walkways, etc.) - Natalie

Montana Timber Products Fire Treatment for Wood

https://www.montanatimberproducts.com/product-applications/wood-fire-treatment/?gclid=CjwKCAjwzY2bBhB6EiwAPpUpZmyWatyzOkWLprZvTc34UdFF-foDHJMs75P7Hu39nlcep70RF4OKSxoCRP0QAvD_BwE

Cedar Valley

https://cedar-valley.com/quality-cedar-shingles/?&keyword=fire%20resistant%20wood%20siding&gclid=CjwKCAjwzY2bBhB6EiwAPpUpZuJsGrMXtu-5s_7BGIQ99pq5qHoJrulbMje6WxAZfti5QkvsgpXzlxoCm7sQAvD_BwE

Chemco SaferWood Siding

<https://www.chemco.org/saferwood/products/siding/>

Hewn Fire Resistant Products

<https://hewn.com/fire-resistant-products/>

Mataverde Fire Retardant Treated Hem Fir Wood Siding

<https://www.mataverdedecking.com/blog/mataverde-introduces-fire-retardant-treated-hem-fir-wood-siding>

https://covenantsecurityequipment.com/products/armotex-bullet-resistant-and-fire-rated-wall-panels?currency=USD&variant=38004736884922&gclid=CjwKCAjwzY2bBhB6EiwAPpUpZt2xExYphbILKp6lqS6JOYV12f8CYUhA2zDB9yrt43hWMTgXGbZ7xhoCPq0QAvD_BwE

Decking / Walkway Replacement Materials:

Trex/ Composite Decking / Ipe / Tropical Hardwood / Grappa / Tigerwood / Spanish Cedar

- Low intensity grass fire, tropical hardwoods are very resistant versus lower-density north American species
- Steps

[Vulcan Vents](https://www.vulcanvents.com/)

<https://www.vulcanvents.com/>

<https://firesafemarin.org/harden-your-home/fire-resistant-soffits-eaves/#gsc.tab=0>

2. Contact other institutions and agencies, testing labs, manufacturers, wildfire managers, cost estimators, etc., to gather data.

This task involves gathering information from a wide range of organizations that have considered, discussed, or written policies regarding wildland fire and cultural resource protection.

- Colorado State Forest Service
 - Ben Pfohl, Supervisory Forester, Fort Collins Office
- Association for Preservation Technology
- National Center for Preservation Technology and Training (Ron Anthony has a project with them on wildland fire and cultural resources)
 - Simeon Warren, Chief of Architecture and Engineering, simeon_warren@nps.gov, 318-652-7969
 - Jason Church, Material Conservation, Jason_Church@contractor.nps.gov,
 - Covered Bridge Security Manual
 - Guide for In-Place Treatment of Wood in Historic Covered and Modern Bridges
- National Park Service
 - Brian Goeken, Chief, Technical Preservation Services – Brian_Goeken@nps.gov, 202-354-2033
 - Justin Henderson – NPS Program Coordinator for NHL in the Intermountain Region in Denver – Justin_Henderson@nps.gov,
 - Morris (Marty) Hylton, CR Climate Change Architect morris_hylton@nps.gov
 -
- US Forest Service
 - Fire-Retardant Treatments for Wood (Multiple Articles)
 - Effect of Fire-Retardant Treatments on Performance Properties of Wood
 - <https://www.fpl.fs.usda.gov/documnts/pdf1977/holme77a.pdf>
 - Fire-retardant-treated strandboard: properties and fire performance
 - Forest Products Laboratory – USDA Forest Service <https://www.fpl.fs.usda.gov/>
 - Long-term fire retardants
 - <https://www.fs.usda.gov/rm/fire/wfcs/long-term-fire-retardants.php>
 - Development of Field Inspection Practices for Wood Structures on Fire-Prone Lands: Application of State-of-the-Art Condition Assessment Techniques
 - <https://www.srs.fs.usda.gov/pubs/63482>
 -
- Denver Mountain Parks and affiliated local responding fire departments
- Boulder Fire – Rescue, Wildland Fire Division
 - Brian Oliver (Chief)
 - Erin Doyle
 - Jamie Carpenter
- Boulder County Emergency Services
- Open Space and Mountain Parks – Boulder County
 - Chris Wanner, Vegetation Stewardship Supervisor
- City of Fort Collins Historic Preservation

- City of Fort Collins Emergency Services
- Larimer County Emergency Manager
- Mountain community – possibly Leadville or Aspen
- Western Slope community – possible Grand Junction or Silverton
- University of Colorado Boulder
 - Hannah Brenkert-Smith, Research Associate Professor at the Institute of Behavioral Science <https://ibs.colorado.edu/people/hannah-brenkert-smith/>
 - Karen Hollweg, Director of Community Collaboration on Forest Health, Center for Sustainable Landscapes and Communities <https://cslc.colorado.edu/community-collaboration-on-forest-health>
- Missoula Fire Science Laboratory <https://www.firelab.org>
- Council of Western State Foresters <https://www.westernforesters.org>
- Colorado Division of Fire Prevention and Control <https://dfpc.colorado.gov/home/about-us/executive-team>

<https://ncptt.nps.gov/articles/disasters/wildland-structural-fire/fire-and-cultural-resource-management-fire-preparedness-3/bare-bones-guide-to-fire-effects-on-cultural-resources-for-cultural-resource-specialists/>

Info from Firezat

Dan Hirning

Firezat Inc.

San Diego, CA 92130

www.firezat.com/info.html

www.firezat.com/productpage5x200.html

<https://www.facebook.com/cabinwrap>

dan.h@firezat.com

www.firezat.com

619-324-9025 off

619-847-7556 cell

https://www.getguardianlegal.com/firefighting-foam-gtm-step-1/?intakesource=BP_GLN_FireFightingFoamLegal-AD-WEB&asid=106249980864&aid=648130170460&keyword=fire%20foam%20lawsuit&qclid=CjwKCAjwq-WgBhBMEiwAzKSH6KWgNIRJuglO98hExENDQMl8saTGr-yihCL9ITD2IMLncMtSvI0XBoC9QcQAvD_BwE

<https://www.usatoday.com/story/news/nation/2013/08/18/idaho-wildfire-hailey-ketchum/2668431/>

[Wildfire Hazard Areas - Residential Structures and Landscaping | Portland.gov](#)

[CSU Fire Landscaping List](#)

APPENDIX D: ADDITIONAL INFORMATION

HISTORY OF PERSONAL FIRE SHELTERS

In 1958 Australians began working on the development of a fire shelter. The earliest shelter was made of a laminate of aluminum foil and glass cloth and was bell-shaped. In 1959 the Australians created an A-frame design for the fire shelter and that same year the Missoula Equipment Development Center (MEDC), part of the Forest Service and now known as the Missoula Technology and Development Center (MTDC) began development of a fire shelter. MEDC and the Australians exchanged information and ideas and in 1967 the first large purchase and deployment of fire shelters for the Forest Service was implemented. These shelters were made of aluminum foil and glass cloth laminate with a kraft paper barrier inner liner, this liner was eliminated in 1974. In 1977, carrying a fire shelter became mandatory after three firefighters were killed on the Battlement Creek Fire in Colorado. Starting in 1998 through 2005 redesign and testing was completed to determine the most optimal design and material for personal fire shelters. The finalized design was made with an outer layer of woven silica and foil and the inner layer of fiberglass and foil (Wildland Fire Shelter, Undated).