EXPOSING SIDING TREATMENTS AND WALLS FITTED WITH EAVES TO FIREBRAND SHOWERS

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ABSTRACT

An experimental campaign was undertaken to determine vulnerabilities of siding treatments and walls fitted with eaves to firebrand bombardment using the NIST Dragon installed in the Building Research Institute's Fire Research Wind Tunnel Facility (FRWTF). Experiments were conducted using two different siding treatments; vinyl siding and polypropylene siding. The siding treatments were installed in an inside corner configuration and the moisture content of the sheathing material (oriented strand board – OSB) was varied. An inside corner configuration was used since it is believed that firebrands may become trapped within the corner post and under the siding itself. In addition to exposing siding treatments to firebrand showers, a parametric study was also undertaken to determine eave vulnerability to firebrand showers. A very important, long standing question is whether firebrands may become lodged within joints between walls and the eave overhang. Walls fitted with eaves were constructed and exposed to firebrand showers. Since the open eave construction is thought to the worst possible situation, this configuration was used. Experiments were completed by varying the wind speed as well as investigating the influence of vent openings on firebrand accumulation and penetration into an open eave configuration. The results of these experimental findings are presented.

INTRODUCTION

Fires in the Wildland-Urban Interface (WUI) have resulted in large property loss and destruction throughout the world. Post-fire studies suggest that the firebrands are a major cause of structural ignition of WUI fires in USA and Australia [1-3].

In order to develop scientifically based mitigation strategies, it is necessary to understand the vulnerabilities of structures to firebrand showers. While firebrands have been studied for some time, most of these studies have been focused on how far firebrands fly or spotting distance [4-14]. Unfortunately, very few studies have been performed regarding firebrand generation [15-17] and the ultimate ignition of materials by firebrands [18-21].

Recently, Manzello *et al.* [17, 22-26] developed an experimental apparatus, known as the NIST Firebrand Generator (NIST Dragon), to investigate ignition vulnerabilities of structures to firebrand showers. The NIST Firebrand Generator is able to generate a controlled and repeatable size and mass distribution of glowing firebrands. The experimental results generated from the marriage of the NIST Dragon to the Building Research Institute's (BRI) Fire Research Wind Tunnel Facility (FRWTF) have uncovered the vulnerabilities that structures possess to firebrand showers for the first time [23-26]. These detailed experimental findings are being considered as a basis for performance-based building standards with the intent of making structures more resistant to firebrand attack. An experimental database is also being created to support NIST's Wildland Fire Dynamics Simulator (WFDS) [27].

The present investigation is focused on exposing two different siding treatments; vinyl siding and polypropylene siding to firebrand showers. The siding treatments were installed in an inside corner configuration and the moisture content of the sheathing material was varied. Two different wind tunnel speeds were used to ascertain the influence of wind speed on siding vulnerability to firebrand showers. A corner configuration was used since it is believed that firebrands may become trapped within the corner post and under the siding itself.

In addition to exposing siding treatments to firebrand showers, a parametric study was also undertaken to determine eave vulnerability to firebrand showers. A very important, long standing question is whether firebrands may become lodged within joints between walls and the eave overhang. There are essentially two types of eave construction commonly used in California and the USA [28]. In open eave construction, the roof rafter tails extend beyond the exterior wall and are readily visible. In the second type of eave construction, known as boxed in eave construction, the eaves are essentially enclosed and the rafter tails are no longer exposed. Since the open eave configuration is believed to be the most vulnerable to firebrand showers, some jurisdictions prone to intense WUI fires have required eaves be boxed in. In both construction types, vents may be installed [28]. As a result, walls fitted with eaves were constructed and exposed to firebrand showers. Since the open eave construction is thought to the worst possible situation, this configuration was used. Experiments were completed by varying the wind speed as well as investigating the influence of vent openings on firebrand accumulation and penetration into open eave configurations. A key issue is if vulnerabilities would be observed to actually justify the costly process of boxing in eaves.

It is very important to realize that to date there has been no experimental methods to generate and visualize wind driven firebrand bombardment to eave construction or various siding treatments in a controlled laboratory setting. These experiments are the first to investigate these vulnerabilities in a parametric fashion. Prior to conducting these experiments, input was collected from interested parties in California (*e.g.* building officials, OSFM, code consultants, industry) since large Wildland-Urban Interface (WUI) fires have occurred in this state recently [29]. Consequently, the type of siding treatments used as well as details about the construction of the eave assemblies was obtained from this workshop [29].

EXPERIMENTAL DESCRIPTION

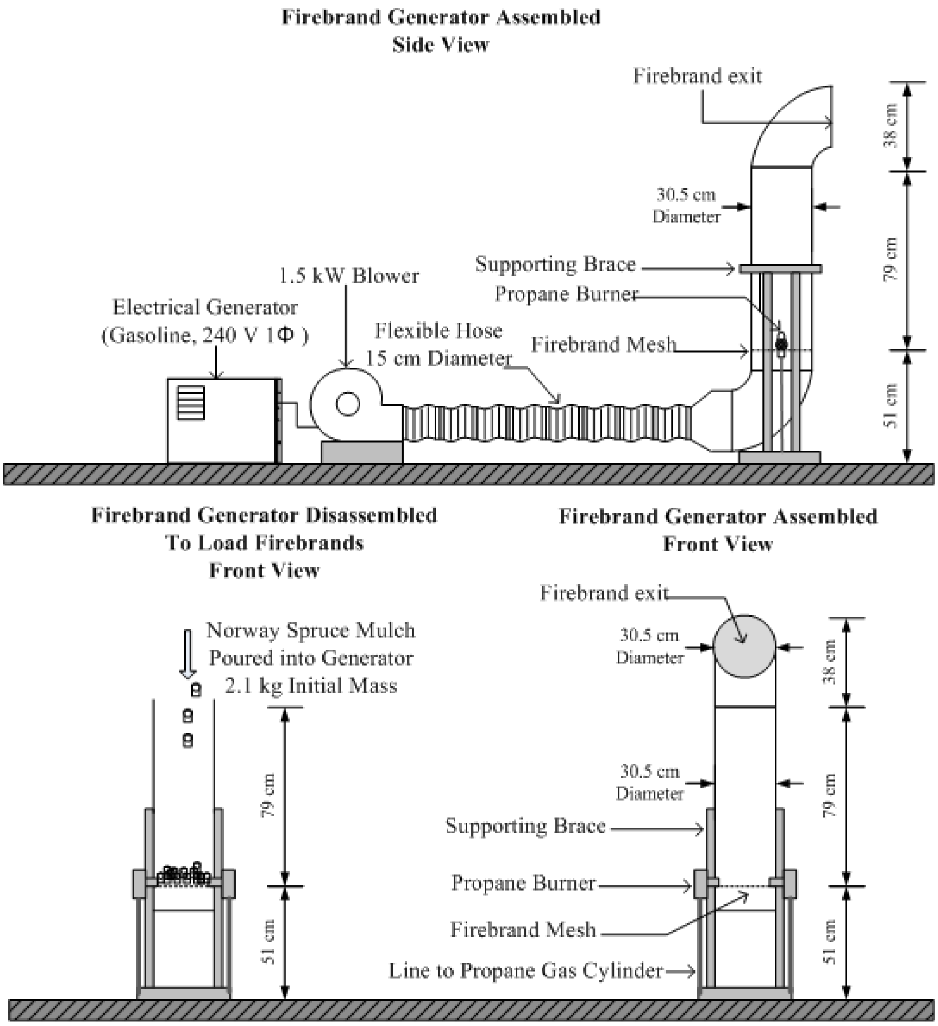
Figure 1 is a drawing of the NIST Firebrand Generator. A brief description of the device is provided here for completeness and follows prior descriptions very closely [25]. This version of the device was scaled up from a first-generation, proof-of-concept Firebrand Generator [25]. The bottom panel displays the procedure for loading the Norway Spruce (*picea abies Karst)* tree mulch into the apparatus. Norway Spruce (*picea abies Karst)* was chosen since it belongs to the *Pinaceae* family, which includes such species as Ponderosa Pine (*Pinus Ponderosa)* and Douglas-Fir *(Pseudotsuga menziesii)*; common conifer species dominant in the USA. In addition, Norwegian Spruce is found in more than 20 states in the USA. These trees were used as a source for mulch for the Firebrand Generator since they were quite easy to locate in Japan.

The mulch pieces were deposited into the firebrand generator by removing the top portion. The mulch pieces were supported using a stainless steel mesh screen (0.35 cm spacing). Two different screens were used to filter the mulch pieces prior to loading into the firebrand generator. The first screen blocked all mulch pieces larger than 25 mm in diameter. A second screen was then used to remove all needles from the mulch pieces. The justification for this filtering methodology is provided below. The mulch loading was fixed at 2.8 kg. The mulch was produced from 6.0 m tall Norway Spruce trees. The firebrand generator was driven by a 1.5 kW blower that was powered by a gasoline electrical generator. The gasoline electric generator provided the blower with the necessary power requirements (see Figure 1). These power requirements were not available at the FRWTF, necessitating the use of a portable power source.

After the Norway Spruce tree mulch was loaded, the top section of the firebrand generator was coupled to the main body of the apparatus (see Figure 1). With the exception of the flexible hose, all components of the apparatus were constructed from stainless steel (0.8 mm in thickness). The blower was then switched to provide a low flow for ignition (1.0 m/s flow inside the duct measured upstream of the wood pieces). The two propane burners were then ignited individually and simultaneously inserted into the side of the generator. Each burner was connected to a 0.635 cm diameter copper tube with the propane regulator pressure set to 344 kPa at the burner inlet; this configuration allowed for a 1.3 cm flame length from each burner [25]. The Norway Spruce mulch was ignited for a total time of 45 seconds. After 45 seconds of ignition, the fan speed of the blower was increased (2.0 m/s flow inside the duct measured upstream of the wood pieces). This sequence of events was selected in order to generate a continuous flow of glowing firebrands for approximately six minutes duration.

The Firebrand Generator was installed inside the test section of the FRWTF at BRI. The facility was equipped with a 4.0 m diameter fan used to produce the wind field and was capable of producing up to a 10 m/s wind flow. The wind flow velocity distribution was verified using a hot wire anemometer array. To track the evolution of the size and mass distribution of firebrands produced, a series of water pans was placed downstream of the Firebrand Generator. Details of the size and mass distribution of firebrands produced from the Firebrand Generator are presented below.

Figure 1 Schematic of NIST Firebrand Generator.

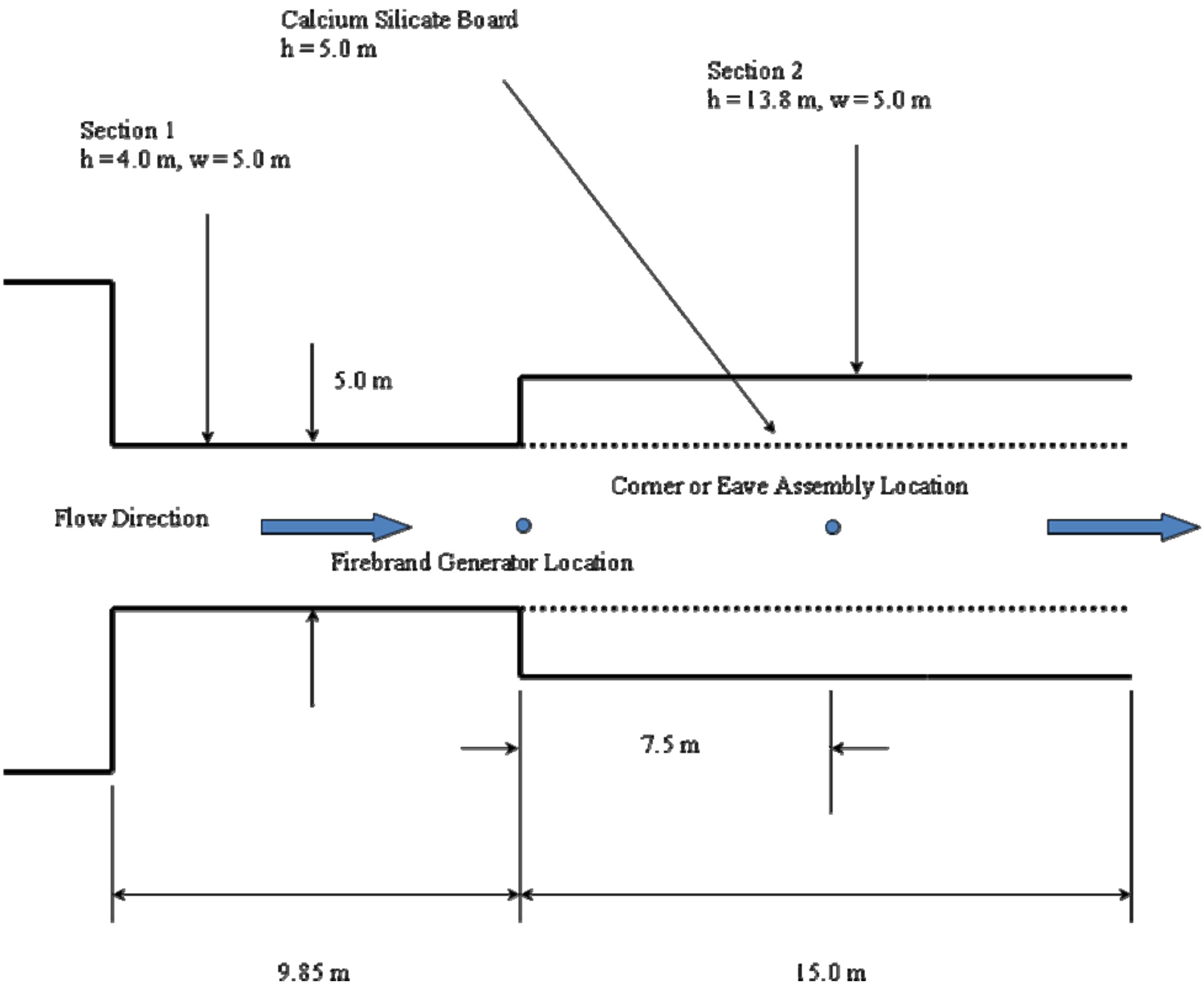


RESULTS AND DISCUSSION

Similar to past studies, the input conditions for the Firebrand Generator were intentionally selected to produce firebrands with mass up to 0.2 g. This was accomplished by sorting the Norway Spruce tree mulch using a series of filters prior to being loaded into the firebrand generator. The same filtering procedure was used as in past studies. Since the procedure for determining the size and mass distribution was identical to prior work, it is not presented here.

After the size and mass distribution of firebrands produced from the Firebrand Generator was determined, full scale corner assemblies and walls fitted with eaves were installed inside the FRWTF. For all the tests conducted, the Firebrand Generator was located 7.5 m from the assemblies (see Figure 2). With respect to corner tests, a distance of 7.5 was measured from Firebrand Generator to corner post.

Figure 2 Schematic of Fire Research Wind Tunnel Facility (FRWTF).



CORNER TESTS FITTED WITH SIDING TREATMENTS

A full scale corner section (each side was 122 cm wide by 244 cm high) assembly was constructed for testing (shown in Figure 3). To be able to control the moisture content of the sheathing (OSB) base layer, the experiments were designed in a modular fashion. Specifically, each side of the 122 cm by 244 cm full section was comprised of 12 separate OSB pieces. This allowed each section to be oven dried and simply reassembled inside the custom mounting frame. For each assembly, a moisture barrier was applied (Tyvek; a registered product of DuPont) and then the siding treatments were applied. The frame was constructed using wood studs with a stud spacing of 400 mm (16”) on center. Two different types of siding treatments were used. Vinyl siding and polypropylene siding. Polypropylene siding is newer to the market as compared to vinyl and is used since it has the look and feel of cedar siding. The American Vinyl Siding Institute was contacted for proper installation and construction was performed in accordance with their installation manual [30].

A parametric study was performed in an effort to quantify the range of conditions that these assemblies are vulnerable to ignition from firebrand showers. Table I displays the parameters that were varied in these experiments. A starting velocity of 7 m/s was selected since most of the firebrands produced from the Firebrand Generator were observed to be lofted under these conditions. The velocity was subsequently increased to 9 m/s to ascertain if any the results were velocity dependent. Three replicate experiments were conducted for each wind speed.

Table I Summary of corner test results for vinyl and polypropylene.
NI = No Ignition; SI = Smoldering Ignition

U_∞ (m/s)	Vinyl Siding OSB Sheathing Dried	Vinyl Siding OSB Sheathing Not Dried	Polyproplylene Siding OSB Sheathing Dried	Polyproplylene Siding OSB Sheathing Not Dried
7	Siding melted/holes Burns on Tyvek OSB NI	Siding melted/holes Burns on Tyvek OSB NI	Siding melted Burns on Tyvek OSB NI	Siding melted Burns on Tyvek OSB NI
9	Siding melted/holes Burns on Tyvek OSB SI	Siding melted/holes Burns on Tyvek OSB NI	Siding melted Burns on Tyvek OSB NI	Siding melted Burns on Tyvek OSB NI

Figure 3 Picture of vinyl siding corner assembly under firebrand bombardment.

For experiments with vinyl siding conducted at 7 m/s and 9 m/s, the firebrands were observed to melt the siding to the point where holes developed through the material. A picture of this is shown in Figure 4. While burns were observed in the moisture barrier at both wind speeds (Tyvek), ignition of the OSB sheathing was only observed for vinyl siding tests at 9 m/s and when the sheathing was dried. It is important to point out that the OSB sheathing burned completely through and ignition was observed within the framing members as well (2 x 4).

For polypropylene siding, firebrands produced melting within the material but no holes were formed within the siding itself. Firebrands were observed to penetrate the corner post and burn holes into the moisture barrier (Tyvek) but ignition was never observed in the OSB sheathing for any wind speed of moisture content considered.

Figure 4 Image of vinyl siding (from bottom) after firebrand exposure at 7 m/s.

WALLS FITTED WITH EAVES

Since the open eave construction is thought to the worst possible situation, this configuration was used. A 244 cm by 244 cm wall fitted with an open eave was constructed for testing. An eave with a total length of 122 cm overhang was constructed and mounted to the wall assembly. While the eave was 122 cm long, the actual overhang used was 61 cm. Since the purpose of these experiments was to determine if any accumulation of firebrands was observed within the eave assembly, the wall was simply fitted with OSB sheathing and it was not dried. Specifically, two OSB sheets of 122 cm by 244 cm were screwed to framing members. The wall was constructed using wood framing members spaced 400 mm (16") on center.

Figure 5 Construction of common open eave assembly in California. Top image is most typical (vents not shown) [29]; bottom image is approved fire resistant construction in San Diego County (vents shown) [31].

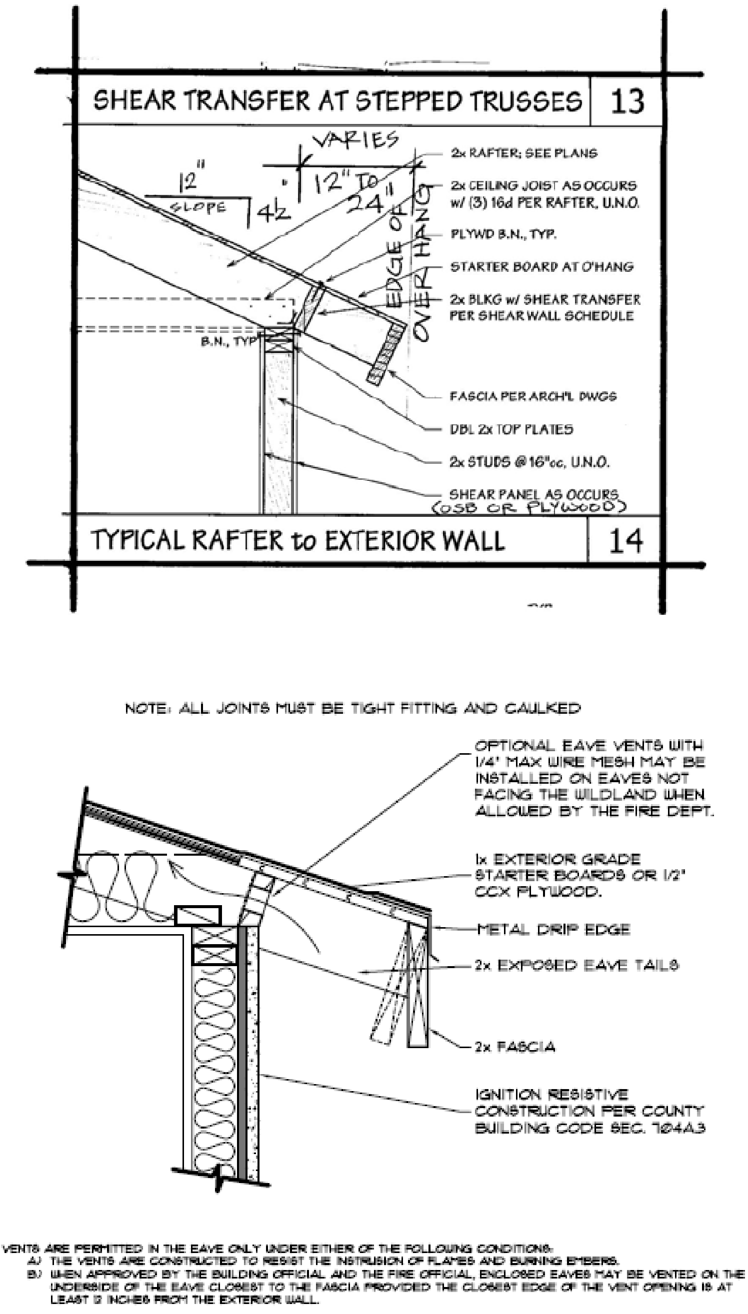


Figure 5 displays common open eave constructions used in California. The construction found in top panel of Figure 5 was followed for testing [29]. In half of the experiments, no vent opening was used to simply observe if firebrands actually accumulated within the exposed rafters and subsequent joints (see Figure 6). In the remaining experiments, vents were installed (see bottom panel) and a mesh was placed within the vent opening (see Figure 6). For the vent openings, 50 mm holes were drilled into the blocking material and an 8 x 8 mesh (2.75 mm opening) was secured, as recommended in the new, 2010 California WUI code [32]. As in the corner tests described above, three replicate experiments were performed. Table II is a summary of the range of parameters used.

Table II Summary of eave experiments; the firebrand exposure time was six minutes.

U_∞ (m/s)	Open Eave With No Vents	Open Eave with Vents
7	No Accumulation	11 Firebrands Arrived at Vents
9	No Accumulation	28 Firebrands Arrived at Vents

Figure 6 Images of open eave construction with no vents (top) and vents (bottom).

Figure 7 displays a typical experiment showing a wall fitted with an eave exposed to firebrand showers from the NIST Dragon inside the FRWTF. For the experiments that used no vent opening, firebrands were not observed to accumulate under the eave over the range of wind speeds considered.

Figure 7 Image of wall fitted with eave under firebrand bombardment.

When vents were installed, cameras were placed both in front and behind of the eave assembly in order to quantify the number of firebrands arriving at the vent locations. At 7 m/s, the number of firebrands arriving at the vent location was 10 ± 1 (average ± standard deviation). As the velocity was increased to 9 m/s, the total number of firebrands arriving at the vent location increased to 28 ± 2 (average ± standard deviation). While the number of firebrands arriving at the vent locations increased as the wind speed increased, it was very small as compared to the number of firebrands that bombarded the wall/eave assembly (see Figure 7).

Firebrand entry into vents has long been thought to be important. Based on input garnered from the NIST workshop in California [29], for the present experiments using vents, it was desired to construct the wall from a combustible material to determine whether the wall itself could be ignited by firebrands within the time of the firebrand exposure (six minutes). Prior work by Manzello *et al.* [26] used non-combustible construction to investigate only vent penetration and ignition of materials inside the structure. During the experiments conducted at 9 m/s, the base of the wall actually ignited due to the accumulation of firebrands. These experiments demonstrate that it was very easy to produce ignition outside the structure since many firebrands were observed to accumulate in front of the structure during the tests. Although some firebrands were observed to enter the vents, the ignition of the wall assembly itself demonstrates the dangers of wind driven firebrand showers. It must be noted that the base of wall assembly ignited without the presence of other combustibles that may be found near real structures (*e.g*. mulch, vegetation).

SUMMARY

An experimental campaign was undertaken to determine vulnerabilities of siding treatments and walls fitted with eaves to firebrand bombardment using the NIST Dragon installed in the Building Research Institute's Fire Research Wind Tunnel Facility (FRWTF). Experiments were conducted using two different siding treatments; vinyl siding and polypropylene siding. The siding treatments were installed in a corner configuration and the moisture content of the sheathing material (oriented strand board – OSB) was varied. For experiments with vinyl siding conducted at 7 m/s and 9 m/s, the firebrands were observed to melt the siding to the point where holes developed through the material. While burns were observed in the moisture barrier at both wind speeds (Tyvek), ignition of the OSB sheathing was only observed for vinyl siding tests at 9 m/s and when the sheathing was dried. It is important to point out that the OSB sheathing burned completely through and ignition was observed within the framing members as well (2 x 4). For polypropylene siding, firebrands produced melting within the material but no holes were formed within the siding itself. Firebrands were observed to penetrate the corner post and burn holes into the moisture barrier (Tyvek) but ignition was never observed in the OSB sheathing for any wind speed of moisture content considered.

In addition to exposing siding treatments to firebrand showers, a parametric study was also undertaken to determine eave vulnerability to firebrand showers. For the experiments that used no vent opening, firebrands were not observed to accumulate under the eave over the range of wind speeds considered. When vents were installed, at 7 m/s, the number of firebrands arriving at the vent location was 10 ± 1 (average ± standard deviation). As the velocity was increased to 9 m/s, the total number of firebrands arriving at the vent location increased to 28 ± 2 (average ± standard deviation). While the number arriving at the vent locations increased as the wind speed increased, it was very small as compared to the number of firebrands that bombarded the wall/eave assembly. To illustrate this issue, during the experiments conducted at 9 m/s, the base of the wall actually ignited due to the accumulation of firebrands. While vents have long been thought to be important, these experiments actually show that is was easy to produce ignition outside the structure since many firebrands were observed to accumulate in front of the structure itself.

It must be stated that in real WUI fires, firebrand showers have been observed for several hours and with winds in excess of 20 m/s [33]. It was not possible to conduct experiments using higher wind speeds since the FRWTF was not designed to generate a wind field in excess of 10 m/s. In any event, these experiments are the first to investigate these vulnerabilities in a parametric fashion. It is hoped that future work can consider exposures under higher wind speed as well as different firebrand size/mass distributions tied to various WUI exposures. In this study, the firebrand size distribution used was commensurate with sizes measured from full scale burning trees as well as a distribution obtained from a post-fire survey of actual WUI fire (Angora) [34].

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