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Laboratory Investigation of Fire Transfer from Exterior Wood Decks to Buildings in the Wildland–Urban Interface

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Abstract. In the wildland-urban interface, wood decks are a target for wildfire and may be ignited by firebrands or flaming debris. Wood decks also present a potential source for ignition of structures in the wildland-urban interface. However, their role in ignition of the adjacent structure is unclear and current regulation is based in part on anecdotal evidence. This paper examines the results of a set of preliminary laboratory experiments used to determine how experimental variables affect the thermal exposure from a burning wood deck to an attached structure. The experimental setup consists of a test deck of 609 mm by 711 mm (24 inches by 28 inches) on a stand with an attached back wall equipped with two heat flux sensors and twelve thermocouples. Two ignition sources were considered: a below deck flame test using a propane burner and an above deck test using a Class A burning brand. The initial tests study the effect of wind and burner size and were all conducted on redwood decking. The experimental data from these tests showed that wind speeds of 2.9 m/s (6.5 mph) and 5.4 m/s (12 mph) had the highest temperature and heat flux on the wall. These winds were then further tested on three different species; redwood and inert deck boards. The test methods developed herein and the data obtained can be used to gain insight into how a burning wood deck contributes to structural ignition.

Keywords: Wood decking, Wildland–urban interface (WUI), Flame spread, Ignition

1. Introduction

Wildland Urban Interface (WUI) fires affect both new and existing construction throughout the country [1]. Property loss from these potentially large fires has been steadily increasing over the past two decades in the United States. In the 1990s, an average of nine hundred homes were lost per year and beginning in 2000, this number grew to over three thousand homes per year. For example, in

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2012, the Waldo Canyon Fire in Colorado had an estimated property loss of \$453,700,000 with 346 homes destroyed [2]. Under prolonged drought conditions and more drastic weather fluctuations as a result of global climate change, it is projected that this pattern will continue, if not worsen [3]. WUI fires spread to structures through three possible mechanisms: flame contact, radiative exposure, and ember exposure [4]. Flame contact occurs when flames directly impinge on a structure from smaller fires, such as those from litter or wood piles near a structure. Flame exposure can be lessened by clearing debris and creating a defensible space around structures. Radiative exposure occurs when a large fire, either from nearby vegetation or neighboring structures, is close enough to an exposed structure that radiative heat transfer can ignite the structure. This exposure can be minimized by maintaining a defensible space and choosing appropriate vegetation [5]. Firebrands, also known as burning embers, are the third exposure type and typically develop in the main fire front or from burning structures and consist of burning pieces of material that are small enough to be carried by the wind to ignite other structures(e.g. conflagrations) [6, 7]. Transfer of fires from firebrands can be minimized by using ignition resistant materials and fire-resistant designs (i.e., the geometry of a structure).

Decks and other housing appendages present a unique problem related structural ignition in WUI fires because they may transition from a target fuel to a source of ignition. This transition is dependent on several variables from the physical properties of the firebrands and proximity of the wildfire to the materials used and ambient weather conditions [4]. As a target fuel, a wood deck may react in numerous ways. First it may ignite, support glowing combustion and then self-extinguish. A wood deck could also smolder and then transition from smoldering to flaming and grow into a larger fire. After the Waldo Canyon Fire, it was hypothesized that attached wood decks were the cause for property loss [8, 9]. The two main sources for ignition of wood decks are firebrands that accumulate on top of the deck and the ignition of unmaintained debris below the deck. Firebrands can also accumulate both in the gaps between the deck boards and in the space between the first deck board and an exterior wall [9]. Additionally, firebrands or high-levels of radiant heat from a wildfire can cause debris, such as woodpiles and leaves, to ignite and cause the underside of a deck to ignite. Once ignition of a wood deck occurs and the fire grows, combustible siding and soffits can ignite and glass doors or windows can break from high heat exposure allowing fire to enter the structure [10].

Structure fires in the WUI may also occur through several pathways such as eaves, vents or soffits [5, 6, 11]. While wood decks are a target fuel, little is known about their exact contribution to structural ignition and property damage. Traditionally, the fire performance properties of exterior deck materials have been characterized by their flame spread index (FSI) as determined the extended UL 723/ASTM E84, *Standard Test Method for Surface Burning Characteristics of Building Materials* [12, 13]. However, in 1993, the California Office of the State Fire Marshal initiated a research project with the Forest Products Laboratory at the University of California to develop new test methods for evaluating building products used in the WUI. The resulting test protocols were adopted as the California Wildland–Urban Interface Building Standards (WUIBS) [14]. As a part of California WUIBS, SFM Standard 12-7A-4 Parts A and B [15] describe the test protocols and conditions of acceptance for decking materials in California. This standard expands the flammability requirements for deck boards from a material property (i.e., flame-spread) to include fire performance tests on deck systems that include multiple deck boards, the joists and ledger board [14]. In response to the development of SFM 12-7A-4, ASTM International created two standards to address the fire performance of decking materials; ASTM E2632, *Standard Test Method for Evaluating the Under-Deck Fire Test Response of Deck Materials* and E2726, *Standard Test Method for Evaluating the Fire-Test-Response of Deck Structures to Burning Brands* [16, 17]. These two standards are very similar to the SFM 12-7A-4 test protocols, however, they have not yet been adopted into regulation and do not provide acceptance criteria.

SFM 12-7A-4 Part A and ASTM E2632 are under-deck flame tests that simulate the situation where combustible material is located beneath a deck and becomes involved in a wildland fire event. During the under deck flame test, a deck is exposed to an 80 kW fire that is provided by a diffusion flame from a 305 mm (12 inches) square burner for 3 min. There is a noncombustible 2.4 m (8 feet) back wall and ceramic fiberboard to simulate a ledger board, but no wind is simulated. The heat release rate (HRR) of is calculated using the oxygen consumption method. In SFM 12-7A-4 Part A, the conditions of acceptance state that the effective net peak HRR, which is the peak HRR divided by the area of the deck, may not be greater than 269 kW/m^2 (25 kW/ft^2) and there may not be any flaming or glowing combustion or falling particles that are still burning when hitting the floor at 40 min. SFM 12-7A-4 Part B and ASTM E2726 are the above deck burning brand test that simulate a flaming combustible material in contact with the top of a deck surface. For this test method, a burning Class A brand is set on top of the deck while a wind tunnel supplies airflow at 5.4 m/s (12 mph) over the deck. The HRR is not measured and there is not a back wall. In SFM 12-7A-4 Part B, the conditions of acceptance again include that there may not be any flaming or glowing combustion or falling particles that are still burning when hitting the floor at 40 min [15–17]. The acceptance criteria for SFM 12-7A-4 Parts A and B are not related to the ignition or contribution to a wall fire.

Presented here is a preliminary investigation of how and under what conditions an already flaming deck may contribute to ignition and support combustion of an adjacent structure. The test set up was based on the SFM 12-7A-4 protocol and ignition conditions to begin determining the thermal exposure to an adjacent wall as well as under what conditions the flames may spread to a wall. The standard ignition conditions do not represent firebrand exposure, but rather are representative of combustible items on or under the deck ignited from ember ignition or fire moving through the property igniting something other than the deck. Determining the thermal exposure of an attached wall was accomplished using thermocouples and heat flux sensors installed in a wall segment and the experimental variables included under deck fire sizes, wind speeds and deck geometry.

2. Experimental Methods

The deck geometry was based on SFM 12-7A-4. Five 38 mm by 133 mm (2 inches by 6 inches, nominal) redwood deck boards cut 609 mm (24 inches) in length were

Figure 1. Wind generator designed at FPL with a continuously variable velocity from 0.1 m/s to 6 m/s.

used to construct the deck surface for a total surface of 609 mm by 711 mm (24 inches by 28 inches). Gaps between deck boards are necessary to prevent standing water and to allow a deck to properly ventilate; the test decks were constructed with a typical between-board spacing of 5 mm (0.19 inches). The joists were constructed of 50 mm by 152 mm (2 inches by 6 inches) Douglas fir spaced 406 mm (16 inches) on center. The redwood deck boards were attached to the joists with 63.5 mm (2.5 inches) deck screws. The decks were conditioned in a 21°C (70°F)/ 50% relative humidity room for more than 30 days prior to testing to allow the wood to reach equilibrium with the environment [17].

The angle iron test frame used to hold the deck and back wall was high enough so that the bottom of the deck was 730 mm (28.75 inches) above a 305 mm by 305 mm (12 inches by 12 inches) propane burner that was used for the below deck flame tests (Figure 1). In accordance with ASTM E2726, the frame was attached to a noncombustible cement board wall.

Two different ignition scenarios were tested; below-deck and above-deck. The below-deck tests utilized a 305 mm by 305 mm (12 inches by 12 inches) propane burner similar to ASTM E2632 and SFM 12-7A-4 Part A. However, in addition to the 80 kW fire specified in ASTM and SFM, other fire sizes were examined. The fire size ranged from 40 kW up to 80 kW with a typical exposure time of 3 min. Class A brands were used for the above-deck tests, similar to ASTM E2726 and SFM 12-7A-4 Part B. However, various wind speeds between 0 m/s and 5.4 m/s (12 mph) were examined. As specified in ASTM E2726, the brands were oven-dried at 38°C (100°F) for 24 h prior to testing. The Class A brand ignition sequence per ASTM E2726 was followed with exposure for 30 s on each 305 mm by 305 mm (12 inches by 12 inches) face, 45 s on each 57 mm by 305 mm (2.25 inches by 12 inches) face, and again for 30 s on each 305 mm by 305 mm (12 inches by 12 inches) face for a total of 5 min [17]. Once the ignition routine was complete, the brands were immediately placed on the deck surface in the center of the deck and even with the front of the deck with both the upper and lower brand strips parallel with the direction of airflow and, if used, the fan was turned on. The tests were terminated when flaming combustion stopped or 40 min elapsed.

In preliminary experiments, a 1 m (3 feet) diameter axial fan was used to simulate wind at a set speed per test from zero up to 5.4 m/s (12 mph). For the below-deck tests, a fan, set to the same wind speed for each test, was turned on after the propane burner was turned off. Including wind in the below deck flame test is different than the current standard tests, which require no simulated wind. For the above deck burning brand tests, the fan was turned on when the brand was placed on the deck surface. The above deck tests examined wind speed as an experimental variable.

In later tests, a wind generator was constructed to provide more uniform flow over the deck specimen. The wind generator, shown in Figure 1, was constructed using a 0.6 m (24 inches) vane axial fan, honeycomb flow straightener, screen frames, and an outlet duct. The axial fan had fixed vanes mounted downstream to counteract the swirl introduced by the moving propeller. The outlet of the generator was 0.9 m by 0.6 m (36 inches by 24 inches). The ductwork contains an aluminum honeycomb flow straightener with 6.35 mm (0.25 inch) diameter cells that are 76 mm (3 inches) long to lower the Reynold's number of the air flow and greatly reduce the turbulence. Additionally, breaking the flow into many small diameter chambers that are long (relative to their diameter) helps to reduce any swirl in the duct. After the honeycomb straightener, the flow goes through three screens that are designed to further reduce turbulence as well as giving the flow a more uniform velocity profile and a progression from coarse screen to fine screen is designed to help remove turbulent eddies of different scales. The first screen frame has openings that are 11 mm (0.44 inch) followed by a screen with 5 mm (0.2 inch) openings and finally a screen with 3 mm (0.13 inch) openings. The screen design was based on empirical formulas for wind tunnel design. The fan, feet and outlet are isolated from the rest of the system by rubber mounts and connectors to prevent vibration in the duct that will disrupt the flow. The wind generator provides a more laminar airflow across the deck than the axial fan and produces a flow velocity profile that is within 0.22 m/s (0.49 mph) over the 24″ wide test deck, from the deck to 0.3 m (12 inches) above the deck. The velocity is continuously variable from approximately 0.1 m/s to 6 m/s (0.22 mph to 13 mph). The wind generator was used for a more careful examination of the effect of the Class A brand on above-deck test with a wind speed of 2.9 m/s (6.5 mph) and 5.4 m/s (12 mph).

The whole test stand was placed under the large HRR hood at the Forest Products Laboratory (FPL). Exhaust gas composition was determined using three gas analyzers from Sable Systems (www.sablesys.com). Oxygen was measured using a PA-10 paramagnetic analyzer capable of resolution to 0.0001% O_2 and modified by reducing internal volume of the filters to provide a faster response. Exhaust gas to the sensor was dried using the Sable ND-2, a permeable-membrane dryer. Carbon dioxide was measured using the CA-10, a dual wavelength infrared sensor capable of resolution to 1 ppm. The same technology was used in the CM-10A for carbon monoxide detection. The exhaust fan was run at a volumetric flow rate of approximately 4 m^3/s (8475.5 cfm) for all tests and the gas samples were delivered to the analyzers using two pumps. The first pump pulls exhaust quickly to the location of the gas analyzers through a pre-filter and a 50°C (122°F) water-bath controlled water-to-air heat exchanger to provide consistent incoming air conditions. Then a sub-sample pump pulls exhaust smoothly through the dryer and analyzers. The Sable components provide analog signals, including the barometric pressure. These signals along with the type K thermocouple and heat flux sensors were captured by the data acquisition system (Measurement Computing USB-1616HS) at 4 Hz. The exhaust flow rate calculations were based on ISO 9705 formula using pressure drop across the bidirectional probe, temperature of the exhaust, and concentrations of CO, CO_2 and O_2 [18].

Data was collected from 14 thermocouples for every test (Figure 2). Two thermocouples were placed on the deck; one at the center point and one in the gap between the center board and the next board closest to the wall. Twelve thermocouples were spaced on the noncombustible cement board wall. The first eight thermocouples started at 50 mm (2 inches) above the deck surface and were spaced 76 mm (3 in.) apart and the next four thermocouples were spaced at 254 mm (10 inches) each. The signals from these thermocouples were captured by the data acquisition system (Measurement Computing USB-1616HS) at 4 Hz. Water-cooled, 25.4 mm (1 inch) diameter heat flux sensors (Medtherm 64-10SB-18) were also placed in the noncombustible cement board wall so that the surface of the heat flux sensor was even with the surface of the wall. The first heat flux sensor was placed 152 mm (6 inches) above the deck surface and the second was 508 mm (20 inches) above the deck surface. Both the thermocouples and the heat flux sensors were aligned with the centerline of the deck.

The under deck tests subjected the decks to five different fire sizes; 40 kW, 50 kW, 60 kW, 70 kW and 80 kW. The propane burner was turned off after 3 min and, in the cases with wind, the fan was turned on at 3 min. Where ignition did not occur in 3 min, the burner was allowed to run until ignition occurred. All of the under deck flame tests were performed at 5.4 m/s (12 mph) with the deck boards perpendicular to the wind direction.

The above deck burning brand tests performed had four different wind speeds: 0 m/s, 1.4 m/s, 2.9 m/s, and 5.4 m/s (0 mph, 3.1 mph, 6.5 mph, and 12 mph). Two tests were conducted at 2.9 m/s (6.5 mph); one with the deck boards perpendicular to the wind direction and one with the deck boards parallel to the wind direction.

3. Results

3.1. Below Deck Flame Test Results

The HRR from the below deck flame tests are shown in Figure 3. During the initial time, the heat from the propane burner was recorded and a spike occurs when the deck ignites. For the 60 kW, 70 kW, and 80 kW tests, the propane burner was turned off around 200 s and a significant drop in the HRR occurs at that time. The HRR from the deck alone is then recorded for the remainder of the tests. When the propane burner was set at 40 kW and 50 kW the decks did not ignite in the 3 min time period so the burner was allowed to run until ignition of the deck occurred and then it was turned off. For the 40 kW fire, the propane burner was turned off around 530 s and, for the 50 kW fire, the propane burner was turned

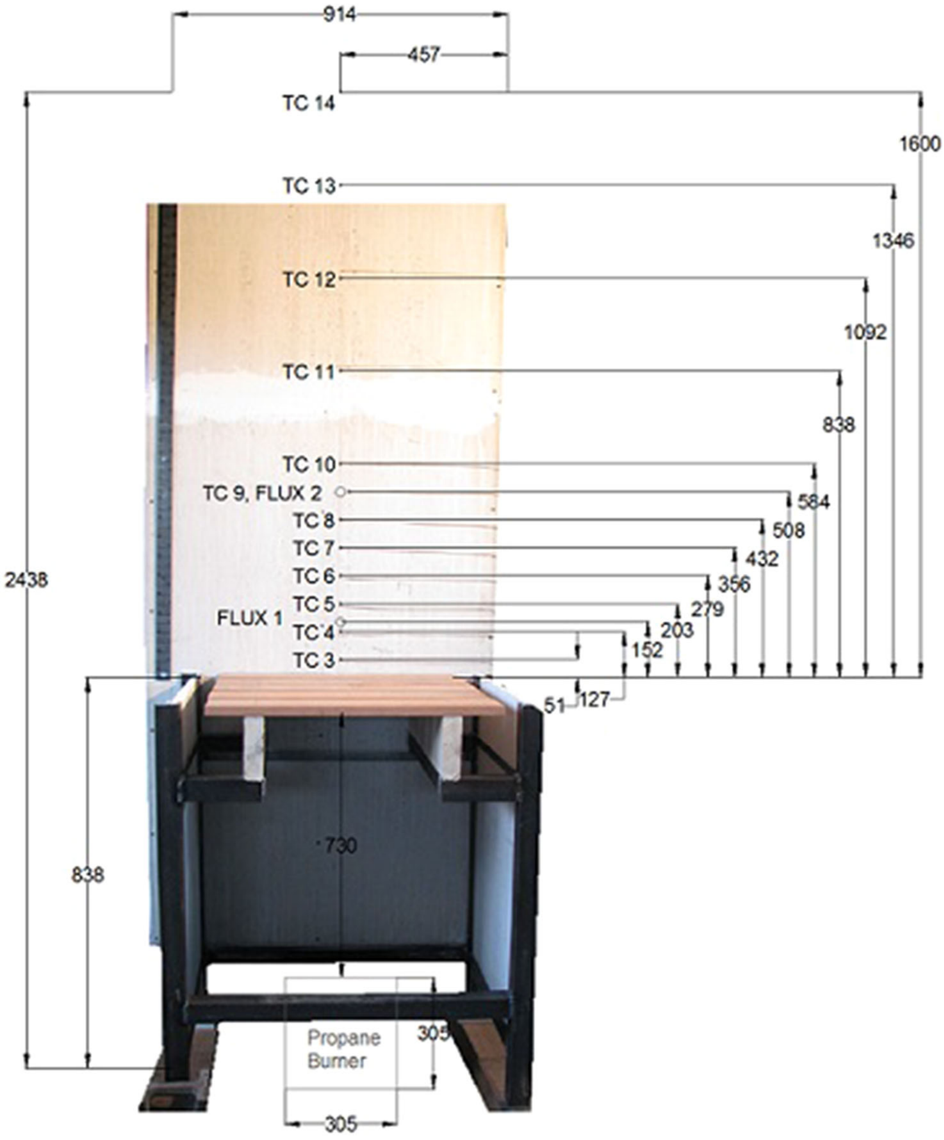

Figure 2. Thermocouple and heat flux sensor locations; dimensions given in mm.

off around 460 s. For all tests, after the burner was turned off, the effective net peak HRR for the deck remained under 70 kW/m^2 (6.5 kW/ft^2). The effective net peak HRR of the test assembly after the burner is turned off is calculated as: pk HRR = (peak HRR in kW)/(deck surface area). The tests were terminated at various times based on when flaming combustion stopped or at 2400 s. For clarity of

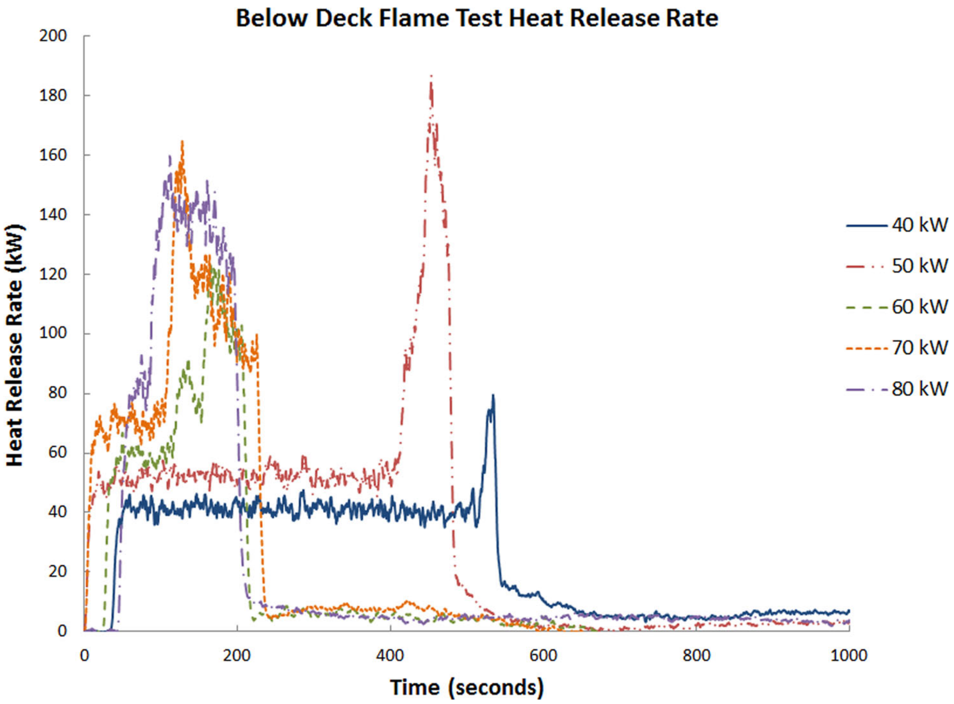

Figure 3. Below deck flame test heat release rate in kW as a function of time.

the data at the beginning of the tests, Figure 3 is only shown until 1000 s as the HRR continues towards 0 kW for all tests after this time.

The heat flux was measured on the wall at both 152 mm (6 inches) and 508 mm (20 inches) above the deck. At both locations, the spikes in heat flux in both Figures 4 and 5 correspond with the initial spike in HRR when ignition of the deck occurs. The heat flux and temperature data presented have been exponentially smoothed with a damping factor (alpha) of 0.1 to remove noise. The uncertainty of the temperature measurements is ±2.3°C and the uncertainty of the heat flux being ±2 kW/m^2. The error in the HRR data is ±10% of readings with a portion of that contributed to the noise in flow rate and the remainder to absolute uncertainty of C factor.

Images of the extent of damage to each deck after the tests were terminated provide qualitative information. Figure 6 compares the extent of charring for each test, which shows a correlation to the exposure fire size. The extent of damage for the 50 kW fire appears greater than that for the 60 kW burner fire. This is most likely due to pre-heating that occurred because the 50 kW did not ignite the deck in 3 min and the deck was exposed the burner flame for approximately 6 min until ignition occurred and the burner was turned off.

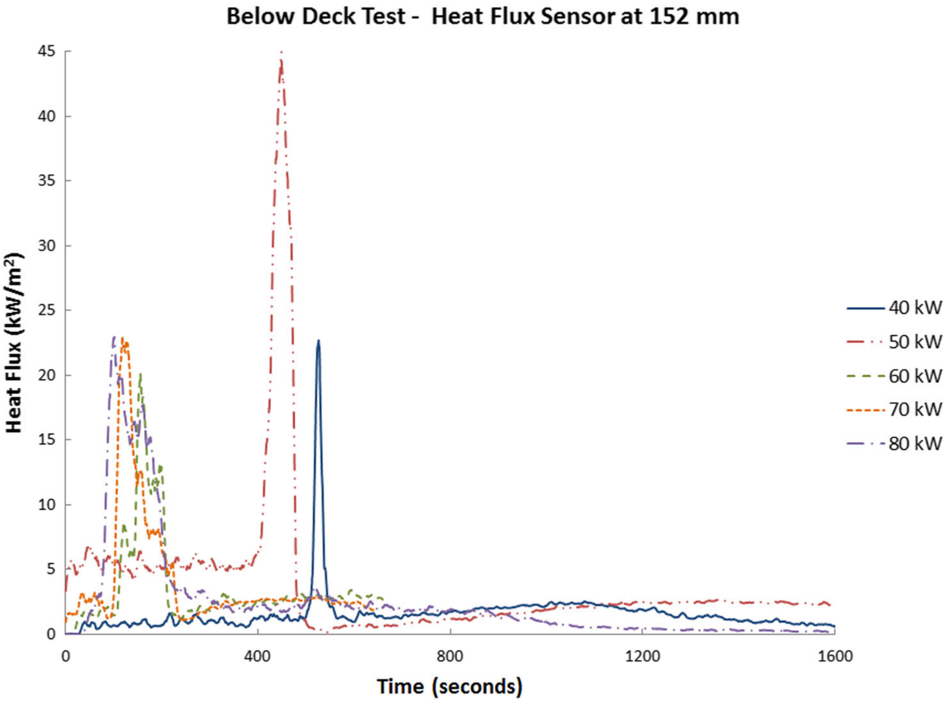

Figure 4. Below deck flame test heat flux on wall at 152 mm (6 inches) above the deck.

3.2. Above Deck Burning Brand Test Results

For the above deck burning brand tests, the heat flux to the wall and temperature profile on the wall were affected by the different wind speeds. The first 400 s include set up and the brand ignition sequence. A spike occurs when the brand is placed on the deck and the fan is turned on. As the brand is consumed, the heat flux and temperature profile on the wall steadily decreases. For these tests, 2.9 m/s and 5.4 m/s (6.5 mph and 12 mph) resulted in the highest heat flux at 152 mm (6 inches) above the deck boards. The highest heat flux for the burning brand tests was 24 kW/m^2 (2.2 kW/ft^2) at 152 mm (6 inches) above the deck with a wind speed of 5.4 m/s (12 mph). The second highest heat flux for the burning brand tests was 21.6 kW/m^2 (2.0 kW/ft^2) at 152 mm (6 inches) above the deck with a wind speed of 2.9 m/s (6.5 mph). At 508 mm (20 inches) above the deck, wind speeds of 1.4 m/s and 2.9 m/s (3.1 mph and 6.5 mph) resulted in the highest heat fluxes of 12.7 kW/m^2 and 10.1 kW/m^2 (1.2 kW/ft^2 and 0.9 kW/ft^2), respectively.

Figure 9 shows the temperature distribution on the wall at 508 mm (20 inches) above the deck. Wind speeds of 1.4 m/s and 2.9 m/s (3.2 mph and 6.5 mph) resulted in the highest temperature on the wall surface at this height. The highest temperature to the wall for a wind speed of 5.4 m/s (12 mph) was 230°C at 279 mm (11 inches) above the deck. The overall highest recorded temperature among all

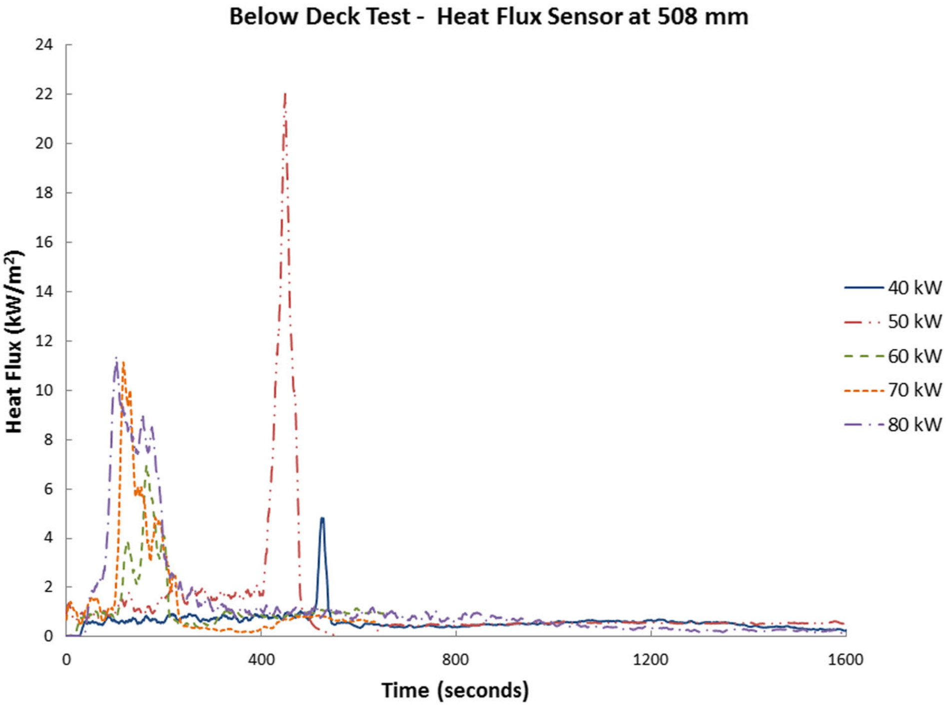

Figure 5. Below deck flame test heat flux on wall at 508 mm (20 inches) above the deck.

burning brand tests was 270°C (518°F) which occurred at 127 mm (5 inches) above the deck with a wind speed of 2.9 m/s (6.5 mph).

To examine the effect of deck board orientation, two burning brands tests were conducted at 2.9 m/s (6.5 mph); one with the boards positioned perpendicular to the direction of the wind and one with the boards parallel to the direction of the wind. Figure 10 shows a comparison of these two tests. The perpendicular test had a total burned area of approximately 0.25 m^2 (399.8 in^2) and the maximum distance from the leading edge was 558 mm (22.0 inches). The parallel test had a total burned area of approximately 0.23 m^2 (357.2 in^2) and the maximum distance from the leading edge was 561 mm (22.1 inches). There was very little difference in both the total area charred and the distance from the leading edge. However, there is a noticeable difference in the remaining structure with less decking material present at the end of the parallel test. For the parallel test, approximately twice as much of the structure is missing when compared to the perpendicular test at 0.036 m^2 and 0.016 m^2, respectively. There is also a difference evident when comparing the temperature and heat flux curves. In Figures 7, 8, and 9 the curves associated with the parallel and perpendicular cases are very similar up to approximately 700 s, after which point the parallel case shows a higher thermal exposure to the wall (Fig. 10).

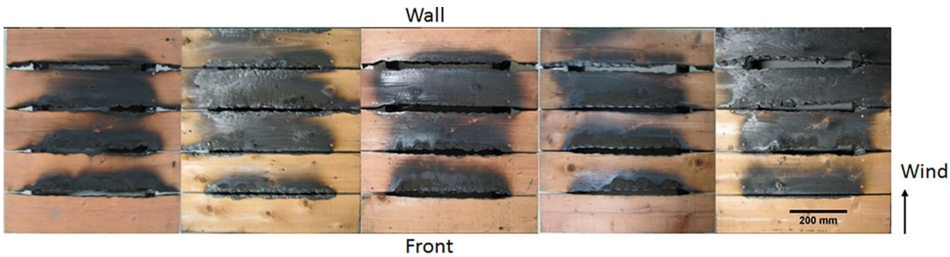

Figure 6. *Top view* of decks after below deck flame tests. From *left* to *right*—40 kW, 50 kW, 60 kW, 70 kW, 80 kW.

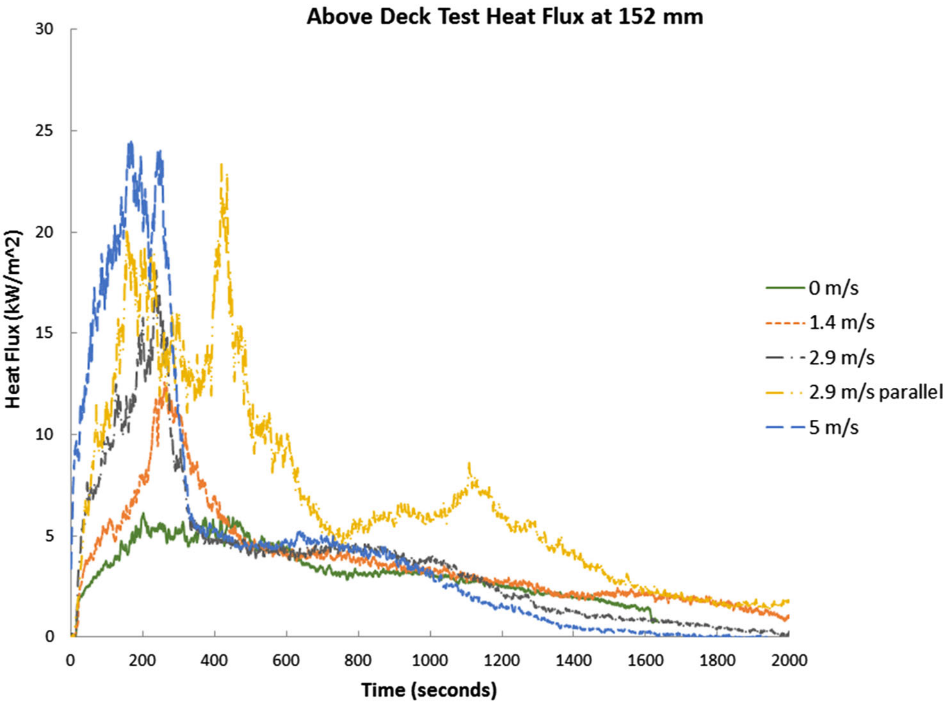

Figure 7. Burning brand test heat flux at 152 mm (6 inches) above deck for different wind speeds.

For the burning brand tests, ignition of the deck occurred within the first 3 min for all wind speeds. From the screenshots in Figure 11a and b, there is a noticeable difference in the flame spread on the deck boards at 5 min and the amount of brand consumed by 30 min. As with the below deck tests, the initial ignition of the deck boards occurred in the gaps and the fire was sustained via re-radiation

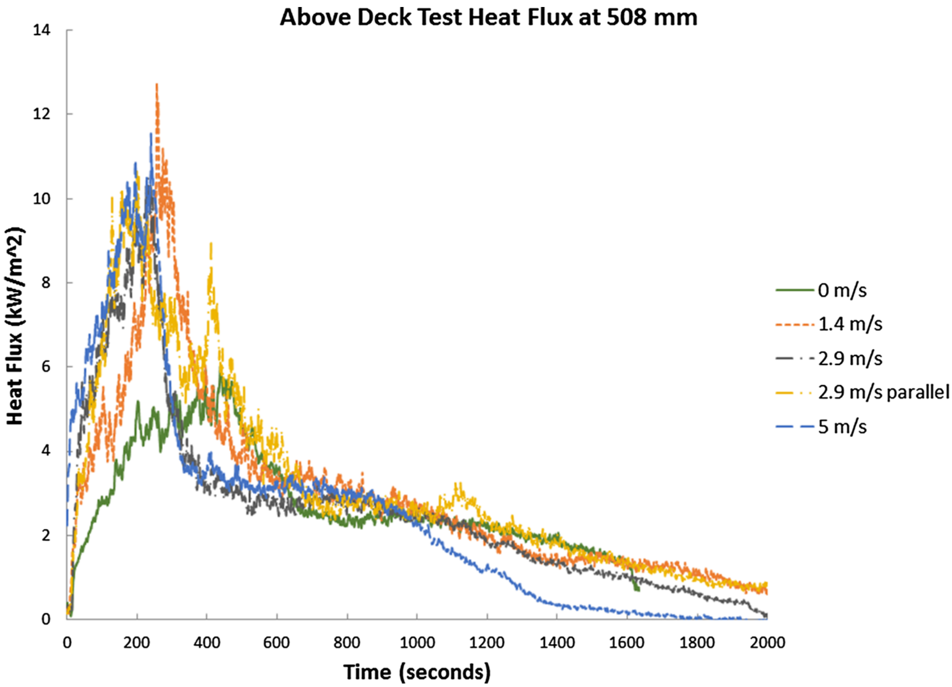

Figure 8. Burning brand test heat flux at 508 mm (20 inches) above deck for different wind speeds.

from the edges of the boards. For all of the burning brand tests, the fire self-extinguished within the 40 min time frame specified in the acceptance criteria.

3.3. Contribution of the Burning Brand to the Heat Flux on the Wall

Four tests were conducted using the wind generator to examine the contribution of the burning brand to the heat flux on the wall. Burning brands were placed on either an inert cement board or a redwood deck. Two wind speeds were examined: 2.9 m/s (6.5 mph) and 5.4 m/s (12 mph). Data for both wind speeds are shown in Figure 12. Similar to previous data, the first approximately 400 s include set up and the brand ignition sequence; a spike occurs when the brand is placed on the deck and the wind generator is turned on. As the brand is consumed, the heat flux and temperature profile on the wall steadily decreases. From Figure 12 it can be seen that the heat flux on the wall is higher with the 2.9 m/s (6.5 mph) wind speed than with the 5.4 m/s (12 mph) wind speed.

Interestingly, for the 5.4 m/s (12 mph) wind, the brand exhibits a higher heat flux when burned on the inert board, possibly because the inert deck boards were white and would reflect more heat as well as the fact that less energy was being absorbed into the deck boards than when wood decking is used. For the inert board, the heat flux on the wall for the inert deck board drops rapidly as the

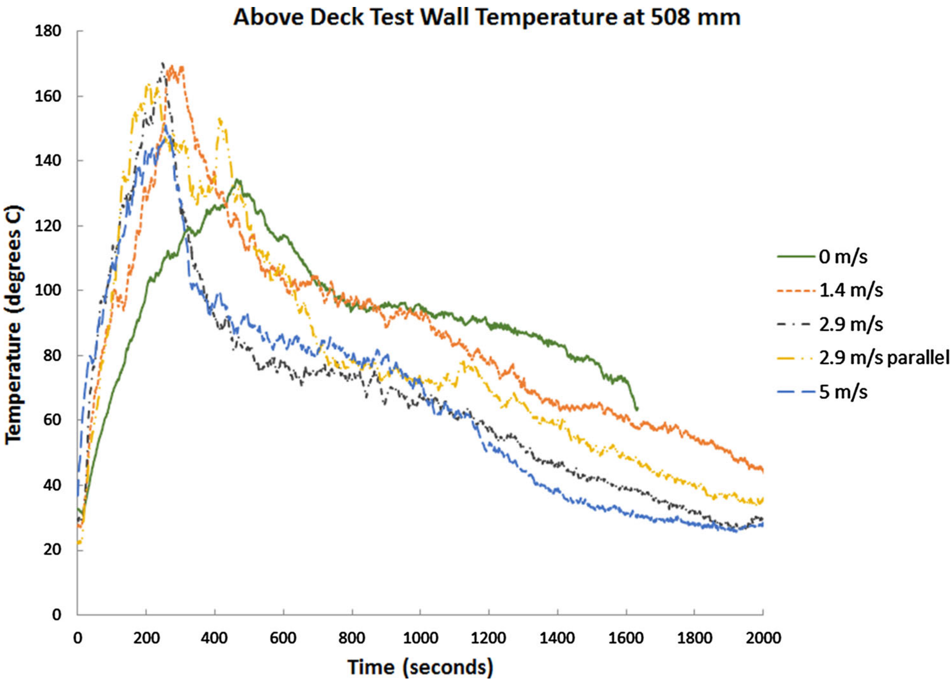

Figure 9. Burning brand test temperature at 508 mm (20 inches) above deck for different wind speeds.

brand is consumed. At both wind speeds on the inert deck boards, the brand stopped glowing at approximately 25 min. In contrast, flaming on the redwood deck stopped at 29 min for a wind speed of 2.9 m/s (6.5 mph) and after 32 min at 5.4 m/s (12 mph).

4. Discussion

The goal of this preliminary research was to understand how geometry, instrumentation and wind speed affect fire transfer from a deck to a structure. Instrumenting the wall with heat flux sensors and thermocouples provided information on the damage mechanism to the wall and enables a more complete understanding of how a deck interacts with the structure. With this modified test, damage to a structure could be predicted by comparing heat flux and temperature data to a specific material's ignition properties. For example, a heat flux of 25 kW/m^2 (2.3 kW/ft^2) will ignite wood structures without an ignition source and, with an ignition source, heat fluxes as low as 15 kW/m^2 (1.4 kW/ft^2) will ignite unprotected wood on a wall surface [19]. The deck ignition protocols were established based on the temperature and heat flux measurements to ignite the deck without igniting the wall to allow the observation of fire transfer.

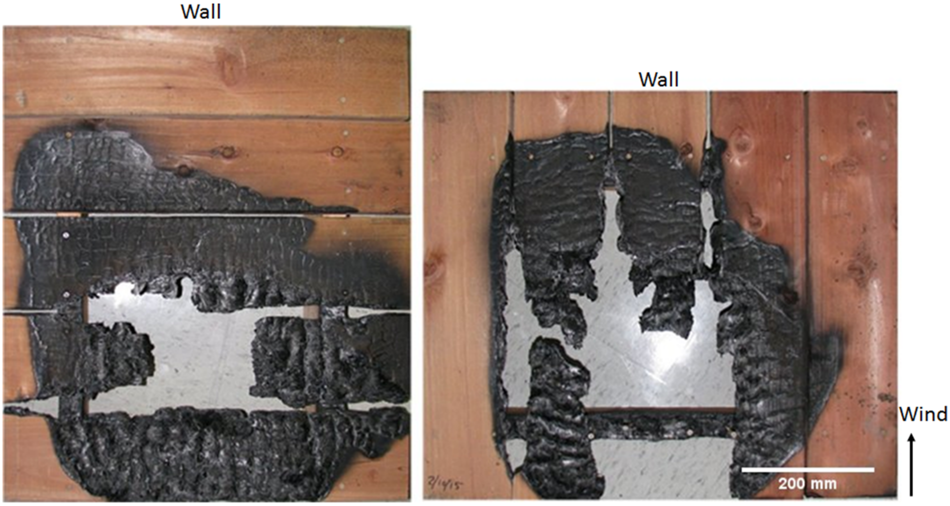

Figure 10. Comparison of perpendicular and parallel decks at 2.9 m/s (6.5 mph) wind speed.

4.1. Below Deck Flame Tests

For the below deck tests, deck ignition occurred where the burner flames penetrated through the deck board gaps. Once ignition of the deck occurred, there was a spike in the HRR. After the burner was turned off, flaming combustion was typically concentrated in the gaps, most likely due to a self-sustaining process where the edges of the boards are reciprocally heated and support combustion. For the decks with boards oriented perpendicular to the direction of wind, the joists protected the ends of the deck boards from the propane burner flame. However; in some of the tests the fire spread around the joists igniting the exposed ends.

One of the goals of the preliminary below deck flame tests was to find an ignition protocol that would ignite the deck but not the adjacent wall. While the effective net peak HRR for the decks were all similar, the 70 kW and 80 kW burner fires were too intense. Observing fire transfer from the deck to the wall would be impossible with such an intense ignition exposure. A 50 kW burner fire size required longer exposure times such that preheating occurred and affected the extent of damage to the deck. Therefore, it appears with this burner location, a 60 kW fire was best for igniting the deck without causing damage to the adjoining wall. Alternatively, a smaller fire may work, if the burner is located closer to the deck, this scenario has not yet been investigated.

4.2. Above Deck Burning Brand Tests

For the two tests at 2.9 m/s (6.5 mph) with the deck boards perpendicular and parallel to the wind direction, the total area charred and the flame spread distance from the leading edge were not affected significantly by the deck board direction.

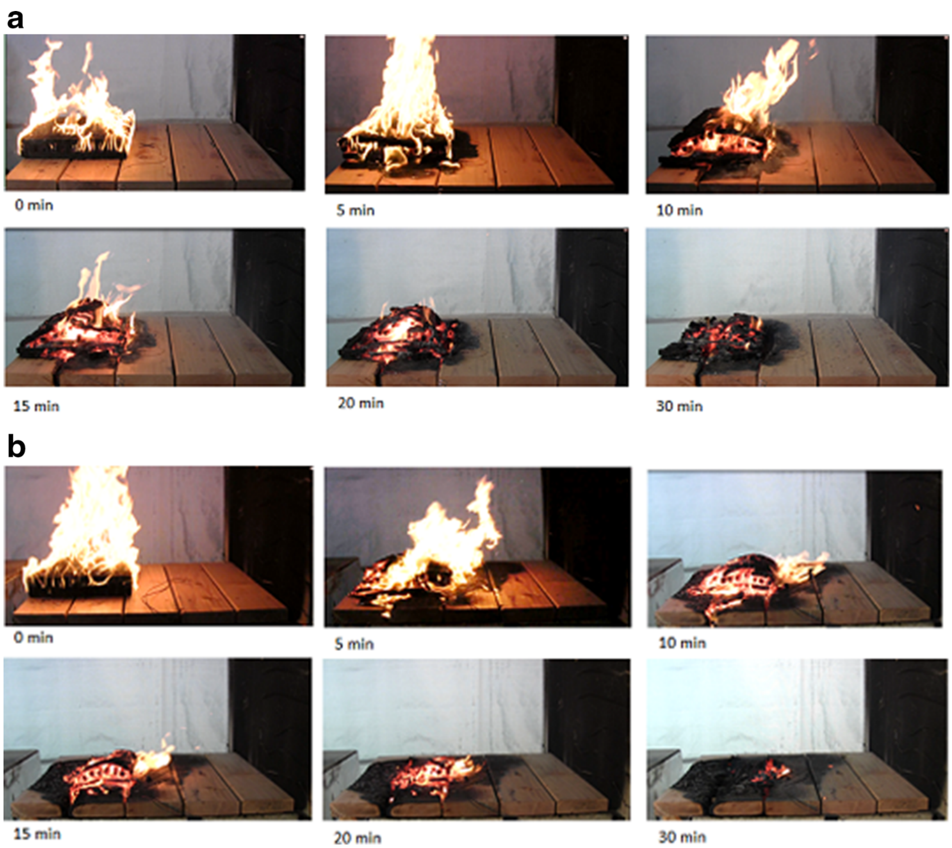

Figure 11. a Time stamped screenshots during 0 m/s burning brand test. b Time stamped screenshots during 2.9 m/s (6.5 mph) burning brand test.

However, there was a distinct difference in the remaining structure with less decking material present at the end of the parallel orientation test when compared to the perpendicular test. This can be attributed to the re-radiation in three affected gaps in the parallel test as opposed to on two affected gaps in the perpendicular test. Additionally, the wind assisted flame spread in the gaps towards the wall.

One of the goals of the preliminary above deck burning brands tests was to find a wind speed that resulted in the most severe results to the wall and the greatest flame spread. If the wind speed was too low, the wind did not promote flame spread. Based on the results, 2.9 m/s and 5.4 m/s (6.5 mph and 12 mph) showed the most severe temperatures and heat flux to the wall. While the peak at 5.4 m/s (12 mph) was briefly higher than that of the 2.9 m/s (6.5 mph) test, the 2.9 m/s (6.5 mph) had a broader heat flux peak. Overall, these measurements suggest that the 2.9 m/s or 5.4 m/s (6.5 mph and 12 mph) represent the worst case scenario for fire transfer to the wall.

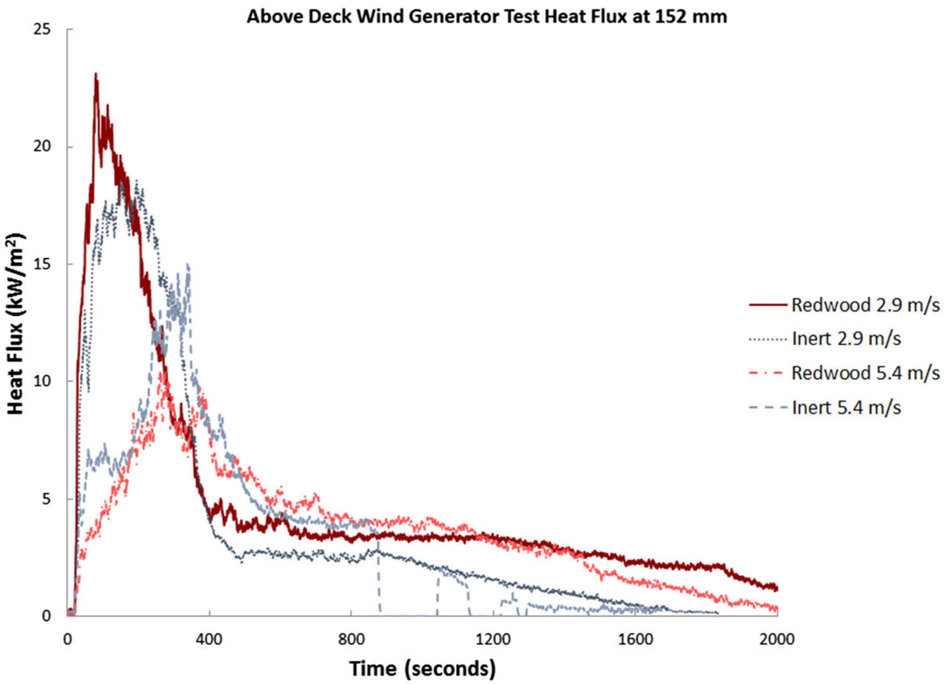

Figure 12. Heat flux at 152 mm (6 inches) above the deck for redwood and inert deck tests with the wind generator at 2.9 m/s and 5.4 m/s (6.5 mph and 12 mph).

4.3. Contribution of the Burning Brand

Additional tests were conducted to explore the contribution of the burning brand to the measured heat flux on the wall by examining the heat flux emitted from a burning brand placed on a deck made of inert cement board. In the beginning of the test, when the heat flux on the wall is the highest, the brand has a large contribution to the heat flux on the wall. The 2.9 m/s (6.5 mph) wind speed causes a higher heat flux on the wall and is a probable cause for why the redwood decks appear to have a higher heat flux on the wall at 2.9 m/s (6.5 mph) when compared to 5.4 m/s (12 mph). However, after the band is consumed, the heat flux from the redwood decks at the two different wind speeds is comparable, but the 5.4 m/s (12mph) test sustained flaming combustion slightly longer. It appears that, to achieve the highest heat flux on the wall over the length of the test, a combination of wind speeds would be best with the wind speed starting at 2.9 m/s (6.5 mph) at the beginning of the test and then moving to 5.4 m/s (12 mph) once the brand has been consumed.

5. Conclusions and Future Work

This preliminary investigation examined the fire transfer from a burning wood deck to the adjoining structure were conducted to gain a deeper understanding of how experimental variables affect the ignition and flame spread on wood decks. For the under deck tests, it was found that a burner with a 60 kW fire would be enough to ignite the deck without causing harm to the adjoining structure, allowing for the examination of the thermal exposure to the wall. The under deck tests conducted maintained an effective net HRR below 70 kW/m^2. The above deck tests shows that wind speeds of 2.9 m/s (6.5 mph) resulted in the highest temperature on the wall and the highest heat flux occurred at 2.9 m/s and 5.4 m/s (6.5 mph and 12 mph). The tests conducted at these wind speeds on redwood and inert decks show that the deck contributed very little to the thermal exposure on the wall after the brand was consumed and that the flame spread very little past the footprint of the Class A brand.

Future work will focus on examining how geometry, materials and the environment may affect fire transfer from the deck to the structure. The results of these tests focused on redwood, but it is important to further study how these results might apply to different wood species including multiple replicates to quantify the experimental error. Importantly, the wood moisture content in these tests was higher than would be expected in WUI fires. The ultimate outcome of the project is to determine how a wood deck contributes to structural ignition and provide mitigation strategies that will reduce the wildfire threats to structures in the form of improved test methods.

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