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The Creation of a Standard for Fixed Wildfire Fighting Systems

For Structures at the Wildland Urban Interface

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By

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Definition of Codes, Standards, and Recommended Practices	Mitchell/Zimak
Organizations	Zimak
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National Institute for Standards and Technology (NIST)	Zimak
Underwriters Laboratory (UL)	Zimak
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IV. LIST OF ACRONYMS

AHJ	Authority Having Jurisdiction
AISI	American Iron and Steel Institute
ASTM	American Society for Testing and Materials
CBC	California Building Code
CRC	California Residential Code
FM	Factory Mutual Global
HP	Horsepower
IBC	International Building Code
IBHS	The Insurance Bureau for Business and Home Safety
ICC	The International Code Council
IRC	International Residential Code
IWUIC	The International Wildland Interface Code
NFPA	National Fire Protection Agency
NIFC	National Interagency Fire Center
NIST	National Institute for Standards and Technology
MQP	Major Qualifying Project
SFPE	Society of Fire Protection Engineers
UL	Underwriters Laboratory
USDA	United States Department of Agriculture
UNISDR	United Nations Office for Disaster Risk Reduction
WPI	Worcester Polytechnic Institute
WUI	Wildland Urban Interface

1.0 ABSTRACT

Wildfire fighting systems being developed and currently on the market are neither standardized nor regulated, putting their consumers and their properties at risk. This report includes such background information on the nature of wildfires, a methodology outlining the process of creating our standard for these systems, our standard itself, results, and conclusions from the process, followed by a section detailing future recommendations for any further development for our standard. In addition to the creation of the standard, our team applied this document to two existing systems to demonstrate the application of our standard.

2.0 EXECUTIVE SUMMARY

Wildfires have become an international problem. Not only do wildfires cause substantial financial damages, but they also destroy ecosystems and other natural resources. The United Nations Office for Disaster Risk Reduction (UNISDR) warns that the wildfire threat will continue to increase internationally as global temperatures rise and drought conditions increase in severity [1]. In response to the wildfire developments, companies have begun offering fixed wildfire-fighting systems for consumers who live in the most at-risk location, the area isolated between civilization and nature referred to as the wildland-urban interface or WUI. Despite their increased availability, no standard exists to regulate the components, design, and performance of such fixed wildfire-fighting systems [4].

Current international codes address the wildfire threat for structures very differently. The International wildland Urban Interface Code, or IWUIC, concludes that if the roof construction is of a sufficient fire-resistance rating, exterior wildfire-fighting systems have little value. The IWUIC continues that the best alternative is to remove the fuel sources proximal to the structure [4]. Further, the NFPA offers many solutions by creating defensible space, or area around a structure that reduces the presence of combustibles in order to prevent the spread of wildfire [54].

The wildfire products that present the largest threat to structures can be broken up into three major categories; radiant heat, direct flame contact, and firebrands. It is firebrands, however, that are thought to account for the majority of structure ignitions at the WUI [42]. Most recognizable from the "storms" they cause, the tiny combusting particles are carried by wind and greatly assist the spread of the wildfire. While the exact numbers are hard to confirm, it is expected that firebrands were responsible for over 97% of the destroyed homes in the Grass Valley Fire of 2007 in Lake Arrowhead, CA [42]. The life cycle of a firebrand is shown below, Figure A1.

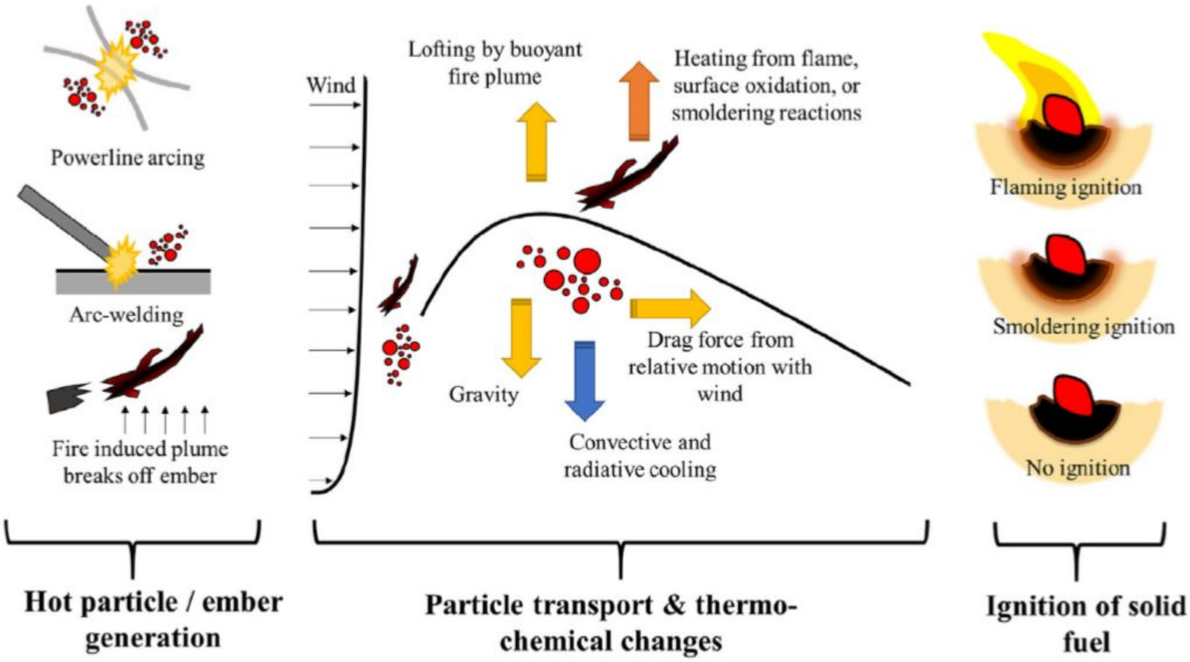

Figure A1: The Firebrand Lifecycle (Urban et al, 2019) [c]

Structural ignition of firebrands can be prevented through two main ways. The first is preventing the small embers from entering a structure through an opening or vent with mesh. The second is preventing the accumulation of firebrands. When firebrands accumulate, the addition of energy and mass assists the single firebrands to begin to act like larger brands which can in turn more easily ignite a structure[43].

A goal for our project was then set to create a technical standard for exterior structural wildfire-fighting systems. This standard is intended to create a common understanding among the multitude of WUI stakeholders in the evaluation of a system's performance for protecting a residential structure from the effects of wildfire threats and exposures. In creating the standard, we utilized a three-phase approach. The first phase consisted of comprehensive background research. This research gave us the insight needed to understand the fundamentals of wildfire, wildfire protection, fire codes and standards, and wildland fire protection system performance. The second phase was outlining the standard. The outline included identifying the scope, goals, objectives, and criteria of the standard and how the standard should be read. The format was intended to look similar to traditional NFPA documents and took inspiration from NFPA 13D, NFPA 551, and NFPA 101. The third phase entailed providing the requirements of our standard's framework with concise technical language including both mandated provisions in the body of the standard and advisory text in the annex. Annex text highlights applications of the mandated provisions and illustrates the application of the standard to two current products available in the marketplace.

Our final standard consisted of 12 chapters and 5 associated annexes. A total of 53 requirements comprised the standard with associated Annex A text elaborating on the requirements. The standard also utilized 8 unique definitions in order to communicate the fire protection requirements. Of the five annex texts, the first became the explanatory text, two were utilized to apply the standard to an existing system, and the last was used as a resource base for references cited in the annexes. An overview of the standard chapters and annex test are below, Table A1.

Chapter	Title
1	Administration
2	Definitions
3	Referenced documents
4	System Performance
5	Wildfire Event
6	System Components
7	Device Discharge
8	Design - System layout
9	System Activation and Operation
10	System Acceptance
11	System Resilience
12	Inspection, Testing, and Maintenance
Annex A	Explanatory Material
Annex B	Wildfire Protection System Compliance: Roofsaver

Annex C	Fire Fighting System Compliance: Platypus
Annex D	Annex A References

Table A1: Standard Chapter and Annex Outline

The final standard was written so that a manufacturer or system designer can easily navigate the requirements. The first three chapters set the standard up and provide the scope, purpose, definitions, and references. The next two chapters require the system designer to identify and state the system goals, objectives, criteria, and define the wildfire threat. Chapter six requires that the system, it's devices, its components, and its materials be qualified for their intended protective purposes by the manufacturer for the stated wildfire threats and non-fire exposures in addition to being approved for use by the authority having jurisdiction. The device discharge chapter, chapter seven, requires that discharge device performance be quantified and documented by the manufacturer, typically through testing. Chapter eight requires documentation to be submitted to the AHJ detailing the layout and calculation method used to ensure all protected assets receive the required discharge density. Chapter nine, system activation and operation, is broken into two parts, the first contains all of the requirements for activation including requiring the system designer to fully detail the sequence of system activation. The second half of the chapter requires the system designer to fully define the system operation which would include when the system re-evaluates the threat and when the system shuts down. The system acceptance chapter, chapter ten, requires documentation to be submitted to the AHJ that details how the acceptance testing was accomplished. Chapter eleven, system resilience, addresses the long term performance of the system once installed and requires the system designer to consider the weathering effects on long term performance of the system. Chapter twelve, inspection, testing, and maintenance, contains all of the requirements for further ensuring the system maintains the ability to operate as installed. This full standard including the annex text is attached Section VI.

After the completion of the standard and its explanatory annex, the standard was applied to two sample cases of systems currently on the market, Roof Saver and Platypus. Each requirement was evaluated, and a decisive verdict on code compliance of “yes” or “no” was attributed to each requirement for each system. Roof Saver passed 15 of the 53 requirements. Platypus was compliant with 10 of the 53 requirements. An assessment was then performed on the results from the platypus system. Each unsatisfactory requirement was provided an example pathway to compliance. These pathways were categorized into three types. Easy Fix, Design creation or Perform Testing. This breakdown helped further solidify the need for a standard as well as provide additional direction for future project work.

Finally, recommendations for the future of wildfire fighting at the WUI were made. Mainly, we looked to see where additional research could assist future system designers and manufacturers in the development and certification of the systems.

3.0 ACKNOWLEDGMENTS

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4.0 INTRODUCTION

Wildfires have become an international problem. Not only do they cause substantial financial damages, but they also destroy ecosystems and other natural resources. The United Nations Office for Disaster Risk Reduction (UNISDR) warns that the wildfire threat will continue to increase internationally as global temperatures rise and drought conditions increase in severity [1]. Internationally, we can expect that future loss of ecosystem services will range from $146 to $191 billion per year. Wildfire events within the United States in 2018 inflicted a total loss of $24 billion. Of the losses, only $18 billion of damage was insured [2]. According to the National Interagency Fire Center (NIFC), homeowners and their properties are still at significant risk, even though the number of wildfire events in the United States has substantially decreased over the past 90 years [3]. Further, wildfires incur losses beyond financial means. Over the past decade, the United States has experienced about 51,000 wildland fires annually: resulting in six million acres of scorched land, destroyed homes, and broken homeowner dreams.

Year-to-date statistics		
2019 (1/1/19 - 9/30/19)	Fires: 39,667	Acres: 4,360,331
2018 (1/1/18 - 9/30/18)	Fires: 49,299	Acres: 7,781,236
2017 (1/1/17 - 9/30/17)	Fires: 49,523	Acres: 8,464,884
2016 (1/1/16 - 9/30/16)	Fires: 45,305	Acres: 4,887,549
2015 (1/1/15 - 9/30/15)	Fires: 49,972	Acres: 9,083,787
2014 (1/1/14 - 9/30/14)	Fires: 41,165	Acres: 3,095,240
2013 (1/1/13 - 9/30/13)	Fires: 38,859	Acres: 4,093,643
2012 (1/1/12 - 9/30/12)	Fires: 48,192	Acres: 8,800,744
2011 (1/1/11 - 9/30/11)	Fires: 60,422	Acres: 7,721,459
2010 (1/1/10 - 9/30/10)	Fires: 56,526	Acres: 2,961,422
2009 (1/1/09 - 9/30/09)	Fires: 70,217	Acres: 5,616,706
10-year average Year-to-Date		
2009-2018	Fires: 50,853	Acres: 6,236,467

Table 1:Yearly wildfire frequency statistics and acres burned in the United States provided by the National Interagency Fire Center [I].

Every day, homeowners living are at high risk of wildfire, especially the ones that border urban developments, encroached by wildlands, forests, and grasslands. This area isolated between civilization and nature is referred to as the wildland-urban interface or WUI. In response to the recent wildfire developments, companies have begun offering fixed wildfire fire fighting systems for consumers who live in this at-risk location. Despite their increased availability, no standard exists to regulate the components, design, and performance of such fixed wildfire-fighting systems [4].

Without a means to effectively evaluate these systems for wildfire scenarios, confidence with any system's ability to truly protect homes is lacking. As such homeowners, regulators and insurance companies would question the effectiveness and reliability of any proposed system.

Without an established means to reduce the wildfire risk to residential structures insurance companies tend to incur substantially higher premiums for wildfire coverage or refuse to offer wildfire coverage altogether [2]. This has become a trend for structures located at the WUI. Furthermore, homeowners trusting and installing untested and unregulated systems may come at the expense of their lives. Because these systems imply safety, homeowners might be more likely to ignore official evacuation issuances and stay in their homes; homeowners can think that their protective systems are effective in keeping their external structure safe and then conclude that they will be safe inside, assuming that the internal structure is secure from the fire

This project will investigate and qualify the wildfire threat that structures face and develop a standard for fixed wildfire-fighting systems. The standard will provide a methodological approach for developing and evaluating a fixed wildfire-fighting system. The standard will take into account the threats, exposures, design goals, and objectives any fixed fire-fighting system should address and the means to verify and document acceptable performance. The standard will help inform all stakeholders of the intended scope, goals, objectives, acceptance criteria, and overall performance of any proposed fixed fire-fighting system, and how such performance can be verified.

5.0 BACKGROUND

5.1 Fire Codes and Standards

5.1.1 Definition of Codes, Standards, and Recommended Practices

While sometimes used interchangeably, codes and standards have two separate definitions. Codes inform what is required, while a standard specifies how to go about selecting the system and how it must operate [5]. Codes are sets of rules that set the baseline standard for safety [6]. Building codes are often created by groups of people with technical building knowledge to bridge the gap between optimal safety and economic feasibility. One of the most well-known codes, NFPA 101 is commonly referred to as the life safety code. Codes like NFPA 101 dictate the minimum requirements for societal health, wellbeing, and safety [6]. Many codes are prescriptive in nature, meaning they identify in detail what materials can be used and where, how tall or large a building can be, and how a building should be constructed. Prescriptive codes evolve from prior experiences, building hazards, and risks based on the use of the building. While prescriptive codes have had a lot of success in keeping building safety, they are sometimes too rigidly designed to encompass every structure. Since these codes are often based on prior experiences, they can fail to utilize new tools such as state of the art computer modeling and can prevent alternative designs [7]. Performance-based codes instead state the end goals and objectives and establish criteria for determining if the goals have been met [7]. These codes allow for more design flexibility without sacrificing safety. While not entirely non-prescriptive, performance-based codes allow for nontraditional building materials and methods to be used so long as they meet the equivalency of the prescriptive codes.

While codes are not laws, they are written in a way that they can easily be adopted into legislation. Typically, an authority having jurisdiction, or AHJ, will select the applicable codes for their domain. The AHJ can choose to enact whole codes, portions of codes, or their own codes all together. Standards lay out the methodology of meeting the codes. Typically, standards include more detail and explain the method to get the desired level of safety [8]. Multiple standards are often referenced within the code to keep the code to a manageable size. The NFPA defines a standard as a document that only contains mandatory provisions. The word “shall”, within the context of standards, indicates requirements that are non-negotiable. Any non-mandatory provisions to support how the standard appears in the appendix, annex, or footnotes are not considered part of the standard. A recommended practice is similar in structure and content to a standard. However, the recommended practices only contain non-mandatory provisions. They use the word "should" to indicate metrics that are advised by professionals but not explicitly required [10].

5.1.2 Types of Standards

Our team is going to attempt to create a standard that has the format of NFPA standards. The main types of standards that are are the product, design, and installation standards

5.1.2.1 Product Standards

. A product standard on a basic level defines a product. This includes what the product is, how it should work, its included parts, clear labeling requirements, its maintenance requirements, and its installation procedure/requirements, if applicable. This also may include the inspection and testing procedure for a product's manufacturer. Both the manufacturer and consumer are able to use this type of standard [11].

5.1.2.2 Design Standards

Another type of standard compared to our project is designing a standard. This kind of standard lays out the requirements for a product's design. The quantitative and qualitative measurements are detailed to describe how a product is required to look and behave. These standards may also include required verification tests and label tests. Verification tests ensure the structural integrity of the product and are to be repeated as materials, design, and manufacturing methods are changed/updated. Label tests are conducted to test that the physical attributes of a product remain clear and/or readable after an amount of time, use, and weathering; physical attributes include visible instructions, names, material color, and the like [12]. A product or system manufacturer is more likely to utilize this standard over a consumer.

5.1.2.3 Installation Standards

Our team has also taken installation standards into consideration. An installation standard outlines the basic setup of a system or product. It requires certain measures to be taken within the procedure of installing an apparatus. This can include where a product needs to be located, the acceptance criteria of a successful layout, the requirements of the installation in general, any tests and testing procedures, the required tools for installation, system resource and activation details (if applicable), any storage and maintenance requirements, and the like. This type of standard is very useful for a manufacturer, consumer, and system installer [13].

5.1.3 Organizations

5.1.3.1 The National Fire Protection Agency (NFPA)

The National Fire Protection Agency, or NFPA, started in 1896 when a small group of men from the sprinkler and insurance fields met in Boston, MA to discuss the inconsistencies of sprinkler system design and installation. At the time, there were nine different standards for pipe sizing and sprinkler spacing. Together, the group created their first document "Report of Committee on Automatic Sprinkler Protection", which would ultimately become the first of NFPAs standards, NFPA 13, The Standard for the Installation of Sprinkler Systems [14].

Today, The NFPA is a global self-funded nonprofit. The NFPA comprises over 250 technical committees and 9000 volunteers who review and amend the codes and standards [15]. Their mission is to help save lives and reduce loss with information, knowledge, and passion. The NFPA strives to become the "leading global advocate for the elimination of death, injury, property, and economic loss due to fire, electrical and related hazards" [16]. They maintain over 300 codes and standards directed at minimizing the risk and effects of fire and are known internationally. NFPA 13, the Standard for the Installation of Sprinkler Systems, regulates the minimum design and installation requirements for automatic fire sprinkler systems and exposure protection sprinkler systems [13]. NFPA 13D is a smaller standard covering much of the same material as NFPA 13 is tailored for the protection against the fire hazards in one- and two-family dwellings specifically [17]. NFPA 13D is much more manageable to read and focuses closer on the residential structure as opposed to all types of structures NFPA 13 is concerned with. In addition to standards, the NFPA also supports several guides. While not intended to be adopted into law, they often help the community make decisions and outline a process for code acceptance. NFPA 551 is Guide for the Evaluation of Fire Risk Assessments intended to support AHJs in the evaluating of a fire risk assessment [18]. In addition to codes and standards, the NFPA also is committed to research, training, and education. The NFPA also hosts a national educational program called Firewise, which aims to reduce wildfire risk. The program is aimed at teaching residents at the WUI to come together and adapt to living in wildfire-prone areas [19]. Through a selection of videos, brochures, and free training, the NFPA is working to prepare homes for wildfire.

5.1.3.2 Factory Mutual (FM) Global

Factory Mutual Global, FM Global, is a property insurance company focused on minimizing financial impact during property loss accidents and events. In addition to reducing business risks and providing claim support to over one-third of the Fortune 1000 companies, they also maintain a large number of exacting standards for property protection [20]. The Global Property Loss Prevention Data Sheets were designed over 200 years of property loss experience, standards committees, and manufacturers among others [21]. The most prevalent datasheet to wildfire risk is FM 9-19 Wildland Fire. This datasheet sets additional standards for property protection at the WUI including classifying the fire hazards in terms of radiant heat exposure and natural surrounding flammable material, property layout, and home construction. Most importantly, this standard makes reference to the installation of outdoor sprinklers and provides insulation criteria [22]. This standard states that sprinklers installed outside of a structure at the WUI must be quick response, vertical sidewall type, approved non-storage sprinklers, 165°F rated, and oriented in a way such that the deflector away from a wall and spaced 6 to 12 inches from the wall. Additionally, FM 9-19 makes reference within 2.4.2.4 that states all sprinklers must be in accordance with Data Sheet 2-0, Installation Guidelines for Automatic Sprinklers and that the sprinklers should operate automatically. Data Sheet 2-0 provides guidance on components that can be used on the sprinkler system, how the components can be secured, sprinkler response times, sprinkler distribution and spacing, and documentation and information required for FM Global plan review and acceptance [23]. While this standard does give several areas where sprinklers should be installed, the FM 2.0 does not directly state anywhere when sprinklers are required for wildfire protection.

5.1.3.3 National Institute for Standards and Technology (NIST)

The National Institute for Standards and Technology, or NIST, is run by the United States Department of Commerce. Their resilience research focuses on expanding the technical basis needed to improve codes and standards for the design, construction, and maintenance of structures [24]. The wildland-urban interface fire group focuses on the scientific research and risk exposure metrics needed to predict wildfire spread and to better equip residences to combat wildfire hazards. The group also developed and conducted research with the NIST Firebrand Generator, or dragon (shown below). This device can produce a continuous flow of burning embers that mimic firebrands to better understand firebrand threats. Having been quantified with real wildland-urban interface fire data from the Angora Fire, the dragon hopes to determine vulnerabilities in roofing assemblies, building vents, siding, and eaves [25].

In a technical note published by the National Institute for Standards and Technology, NIST, entitled: "Framework for Addressing the National Wildland Urban Interface Fire Problem," a WUI-Hazard Scale for classifying risk and pre-action dependent on structure material and construction was proposed. Defined by the construction's exposure and vulnerability, this scale (see Table 2) details structures rising in risk from WUI 1 (non-combustible assembly) to WUI 4 (highly combustible assembly) [26]. A pivotal step in the scope of a wildfire event lies in identifying what buildings at the WUI are most at risk and how to account for this.

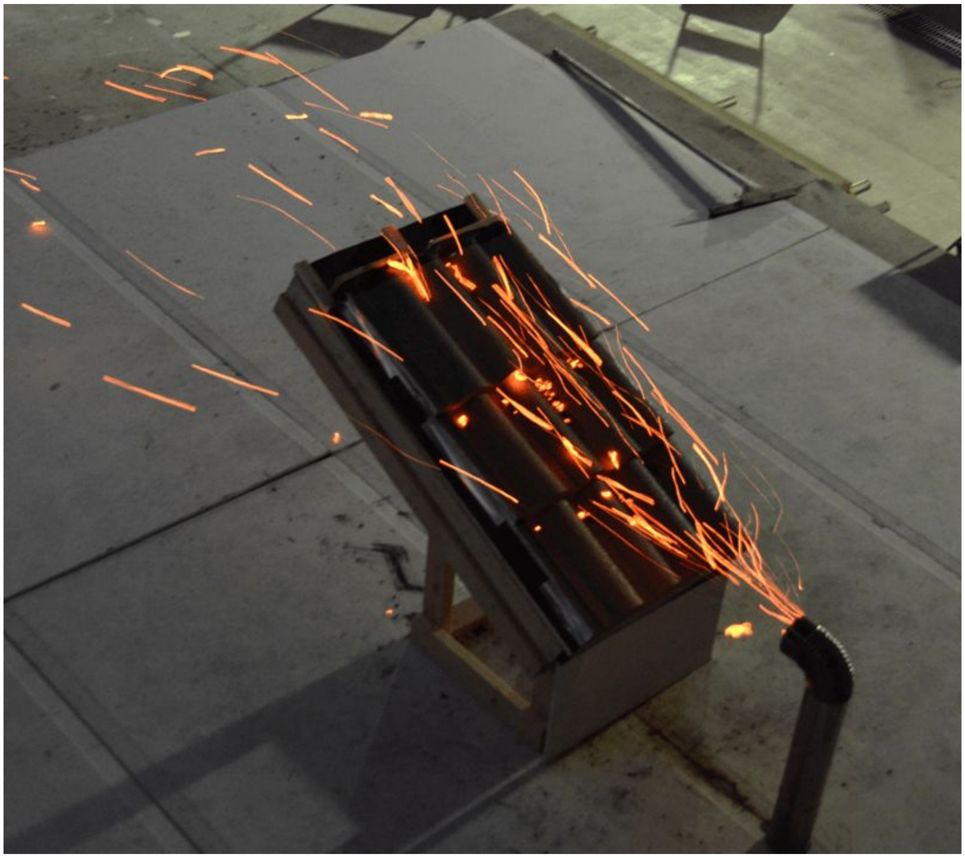

Figure 1: The NIST Dragoon firebrand shower at 6 m/s attacking concrete roof tiles in a test conducted to show how firebrands slip under roofing tiles [a]

5.1.3.4 Underwriters Laboratory (UL)

Underwriters Laboratory, UL, is a nonprofit dedicated to advancing public safety through the discovery and application of scientific knowledge [27]. The fire safety division's suppression team provides scientific testing for residential and commercial sprinkler systems. UL tests and certifies both the sprinklers and sprinkler nozzles according to their testing standards; UL 199 Standard for Safety of Automatic Sprinklers for Fire-Protection Service, UL 1767 Standard for Safety of Early-Suppression Fast-Response Sprinklers, UL 1626 Standard for Safety of Residential Sprinklers for Fire-Protection Service, UL 2351 Standard for Spray Nozzles for Fire-Protection Service, and EN 12259-1 Requirements and Test Methods for Sprinklers [28].

5.1.3.5 The Insurance Bureau for Business and Home Safety (IBHS)

The Insurance Bureau for Business and Home Safety, IBHS is an independent, nonprofit, scientific research and communications organization whose goal is to create more disaster-resilient businesses and communities [29]. The IBHS test facility is the only test facility in the world capable of testing one and two-story homes under repeatable conditions. The area is six stories tall and 145 feet by 145 feet. The test chamber can reach wind speeds of category 3 or

130 mph supplied by one hundred and five 350-HP fans [29]. The IBHS has completed multiple full-scale house tests that dive into the effects of wildfires at the WUI, mainly looking at the effects of firebrands and embers on structure ignition. These tests have looked into how firebrands ignite a structure, where firebrands collect, and the effects of defensible space on structure ignition. IBHS also interacts with the general population through social media: posting test videos and making recommendations for the general homeowner. In addition to wildfire research, IBHS also supports a variety of testing to improve structures, such as homes and roofs, from wind, hail, and cross-loaded damage [29].

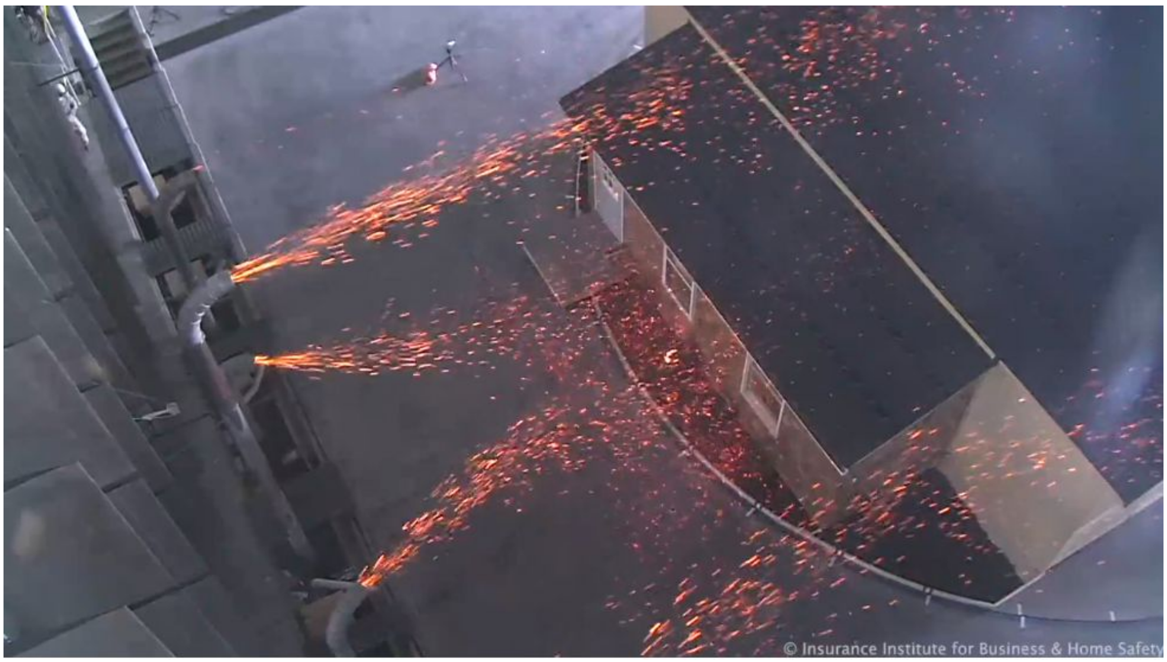

Figure 2: A 2013 IBHS test with firebrand ember generators to simulate a UWI wind storm igniting a residential building [b].

5.1.3.6 The International Code Council (ICC)

The International Code Council, or ICC, publishes codes regarding building, fire, and life safety. The International wildland-urban interface code, or IWUIC, was published to provide the minimum special regulation for the safeguarding of life and property from wildfire. The Code is also written to protect against adjacent structural exposures and from structure fires from spreading to wildland fires [4]. Appendix G recognizes that there are no nationally accepted standards for the design and installation of exterior fire sprinkler systems [4]. It further references the use of self-defense mechanisms or wildfire-fighting systems. The IWUIC concludes that if the roof construction is of a sufficient fire-resistance rating, exterior sprinklers have little value. Systems designed to raise the partial pressure of water vapor around the structure are also unsupported as healthy plant life would accomplish the same purpose. The appendix concludes that the best alternative to total code compliance of the IWUIC is to remove fuel sources proximal to the structure.

5.1.3.7 California Building Code and California Residential Code

The building built at the WUI in California must adhere to chapter 7A of the California Building Code (CDC) and chapter R337 of the California Residential Code (CRC). These two codes regulate the types of materials and components allowed to be used in the assembly of a structure due to the higher risk of encountering a wildfire event. Both codes provide guidance on selecting the following for a residence at the WUI: roofs and roof edges, exterior walls/siding, eaves, and porch ceilings, windows and exterior doors, exterior decking and stairs, and underfloor/appendages. [30]

WUI scale	Building Construction Class	Ignition Vulnerabilities from Embers and Fire	Building Construction and Landscaping Attributes for Protection against Embers
E1 or F1	WUI 1	None	Normal Construction Requirements: - Maintained Landscaping - Local AHJ-Approved Access for firefighting equipment
E2 or F2	WUI 2	In this area, highly volatile fuels could be ignited by embers. Weathered, dry combustibles with large surface areas can become targets for ignition fro m embers.	Low Construction Hardening Requirements: - Treated combustibles allowed on structure - Attached treated combustibles allowed - Treated combustibles allowed around structure - Low flammability plants - Irrigated and well maintained Landscaping - Local AHJ-Approved Access for firefighting equipment
E3 or F3	WUI 3	Exposed combustibles are likely to ignite in this area from high ember flux or high heat flux	Intermediate Construction Hardening Requirements: - No exposed combustibles on structure - Combustibles placed well away from structure - Low flammability plants - Irrigated and well maintained landscaping - Local AHJ-Approved Access for firefighting equipment
E4 or F4	WUI 4	Ignition of combustibles from direct flame contact is likely.	High Construction Hardening Requirements: - No exposed combustibles - All vents, opening must be closed - Windows and doors must be covered with insulated non-combustible coverings. - Irrigated and well maintained low flammability landscaping - Local AHJ-Approved Access for firefighting equipment

Table 2:Structures by Building Construction Types - including their ignition vulnerabilities and appropriate precautions each building type should take to prepare for the risks of a wildfire [II].

5.1.4 How NFPA Codes, Standards, and Recommended Practices are Developed

The National Fire Protection Agency, NFPA, utilizes a tiered system for code and standard development. NFPA Board of Directors first appoints a thirteen person Standards Council that will oversee the development and refinement process of a particular standard. These members come from a broad range of technical experiences but are all very familiar with the standards development process. The Standards Council will then create committees and/or subcommittees, who work within a portion of the standard where their technical skills lend them as an asset. These committees contain a variety of professionals, and no more than one-third of the committees can be from the same interest category. Interest categories include personal in the following fields: insurance, consumers, enforcing authorities, labor, installers/maintainers, special experts, research and testing, users, manufacturers. The diverse group ensures that the standard will be practical for use across the board, and doesn't benefit a single group more than the other [31].

Once the committee is created, the standards development process ensues. This process takes approximately two years and every standard is revised every three to five years [32]. The NFPA breaks the stages of standards development into four major components; public input, public comment, NFPA technical meetings, and council appeals and the issuance of the standard. During the public stage, general input is accepted from the general population and other committees for the first draft. The technical committee will revise the current standard and make changes as necessary in alignment with the public input. The consensus is held by a majority vote, and the first draft revisions are voted on at a two-thirds vote. A first draft report containing the revisions, public input, and technical committee statements is then posted for the public [32].

The first draft and associated report are then opened back up for public comments. At the close of the public comment stage, the technical committee will then hold another draft meeting. If there are no public comments, then the standard goes right to the standards council to be issued. At this meeting, public comments are reviewed and each comment receives an action or response. The committee then votes again with a two-thirds majority vote. A second draft report is then published which contains the public comments and actions, committee statements, committee comments, and ballot statements. At this time, the public may submit a formal notice of intent to make a motion to further improve the standard, or the standard can be passed over to the Standards Council [32]. Assuming that the second draft does not receive public intent to make a motion, the standard will be handed over to the issuer of NFPA standards, the Standards Council. When this council of no more than 30 voting members from a broad range of backgrounds meets, they will also hear any appeals to ensure that a fair due process was followed when creating the standard (How the NFPA Standards Development Process Works). Once the Standards Council approves, the standard becomes effective after twenty days [32].

5.2 Causes of Wildfires

5.2.1 Human and Natural Causes and Statistics

According to the U.S Department of the Interior, approximately 85% of wildfires are started by human activity, whether intentional or unintentional. These activities can include unattended campfires, arson, burning of debris, discarded cigarettes, or even just accidentally inflicting a spark with a metal baseball bat onto dry vegetation. Fires can also start because of vehicle sparks, heat, and electricity. Electrical sparks can also occur from power line work or open electrical systems near dry vegetation, also known as flammable fuel [33].

In addition to human activity, house fires are also a considerable cause of wildfires, especially if surrounded by vegetation or other residences. Common causes of these fires include cooking equipment, smoking in bathrooms, candles, curious children, faulty wiring, lighting, and so on. Strong winds can contribute as well to the spreading of these fires [34]. Although house fires are not necessarily outside, they can still contribute to bigger fires. About 10-15% of wildfires are naturally caused. To start and spread a fire, there are five basic factors that are needed. One, there needs to be dry weather, preferably drought-like conditions. Two, strong winds are essential for the spreading of fires from source to source. Three, a flammable fuel is required in the mix. Flammable fuel can be any type of easily flammable material, which is often found to be dry vegetation. Leaves, withered plants, and so on. Next, nature will require warm temperatures to encourage combustion. A perfect example of a hot weather condition is a major heatwave. Finally, the last factor that nature needs to start its own fire is a spark. This can come from lightning, power lines themselves, etc. [35].

5.2.2 Locations at High-Risk

Rank	State	Estimated number of properties at risk	Rank	State	Percent of properties at risk
1	California	2,019,800	1	Montana	29%
2	Texas	717,800	2	Idaho	26
3	Colorado	371,100	3	Colorado	17
4	Arizona	237,900	4	California	15
5	Idaho	175,000	5	New Mexico	15
6	Washington	160,500	6	Utah	14
7	Oklahoma	153,400	7	Wyoming	14
8	Oregon	151,400	8	Oklahoma	9
9	Montana	137,800	9	Oregon	9
10	Utah	136,000	10	Arizona	8

Table 3: The top 10 states based on the level of high to extreme risk of wildfires from the 2019 Verisk Wildfire Risk Analysis [III].

According to the data collected and analyzed by the 2019 Verisk Wildfire Risk Analysis, California and Texas are at an extreme level of wildfire risk. This calculation is determined and ranked based on the estimated number of properties at risk. In terms of the percentage of state properties at risk, however, Montana and Idaho are ranked to be at an extreme risk level as well. This could be attributed to the fact that Idaho and Montana are smaller states than California or Texas, however, almost one-third of all of Montana's and one-fourth of Idaho's properties are at risk, this still represents a considerable percentage for these states [36]. The National Interagency Fire Center provides data of the top wildfire ranking states in the year 2018 and the number of acres burned within that year (See Table 4) [37].

Rank	State	Number of fires	Rank	State	Number of acres burned
1	Texas	10,541	1	California	1,823,153
2	California	8,054	2	Nevada	1,001,966
3	North Carolina	3,625	3	Oregon	897,263
4	Georgia	2,572	4	Oklahoma	745,097
5	Florida	2,249	5	Idaho	604,481
6	Oregon	2,019	6	Texas	569,811
7	Arizona	2,000	7	Colorado	475,803
8	Washington	1,743	8	Utah	438,983
9	Oklahoma	1,707	9	Washington	438,834
10	Minnesota	1,344	10	Alaska	410,683

Table 4: Top ten states based on the number of fires and the number of total burned acreage in 2018 from the National Interagency Fire Center [IV].

5.3 Wildfire Dynamics

5.3.1 Fuel Types

There is a variety of fuels present during wildfire events, which can be broken up into three main categories. Fine fuels ignite easily and burn quickly but, usually, do not have enough mass to sustain long term ignition. Larger fuels like trees and logs can burn for long periods of time due to their high mass, but often require enormous amounts of energy to ignite. Structures at the WUI can also ignite, but require varying amounts of energy to do so depending on their material. If proper defensible space criteria are followed, it can generally be assumed that the main fuels at the WUI will be finer fuels and structures, and many of the larger fuels have either been removed or modified to mitigate the possibility of enough energy contacting the larger fuels to produce ignition [19].

5.3.1.1 Finer Fuels

Smaller dry fuel sources are the most convenient sources for ignition during natural wildfires. Defined often as 1-hour fuels, these fuels can easily reach the moisture level of the surrounding atmosphere in as little as one hour [38]. Even after a weather event, these fuels will be able to dry out completely on an abnormally hot or dry day which increases their ignitability dramatically. These fine fuels like grass, leaves, needles, chaff, mulch, and compost typically are the fires fuels ignited in 66% of all outdoor fires [39]. They typically have a large void fraction which provides good thermal insulation and availability to oxygen. When potential ignition sources like firebrand contact these fuels, they reach their ignition temperature much faster than larger nonporous materials [38].

5.3.1.2 Structures

Structures at the WUI are composed of many different materials with a variety of different thermodynamic properties. As such, it is much more difficult to predict how wildfires will affect a single structure. However, it is generally accepted that structure fuels are more difficult to ignite and the typical pathway or structural ignition involves an intermediate fuel source first. A finer fuel that ignites may then ignite a portion of them with enough potential to sustain ignition. Additionally, structures may ignite from substantial ember and firebrand accumulation or from radiant heat effects [38]. In the end, it is impossible to assign a single value for ignition criteria to a structure, and single components must be studied within the context of the wildfire threat and adjacent fuel loads.

5.3.2 Burning Patterns

The National Park Service (NPS) defines three separate burning patterns produced by wildfires: ground fires, surface fires, and crown fires. Each of these burning patterns operates at different elevations relative to one another. Ground fires consist of the burning of organic matter just at the soil's surface. Surface fires are defined as the burning of material including leaves, fallen branches, etc. around ground level. Crown fires burn at the peak of trees and constitute the most intense type of fire at the WUI. Due to high wildfire speed, an abundance of fuel, and the height of the flames and resulting firebrands, crown fires represent the most difficult wildfire burning pattern to contain and control [40].

5.3.3 Products of Wildfire

5.3.3.1 Firebrands

Firebrands are a dangerous byproduct of wildfire and are thought to account for the majority of structure ignitions at the WUI. While the exact numbers are hard to confirm, it is expected that firebrands were responsible for over 97% of the destroyed homes in the Grass Valley Fire of 2007 in Lake Arrowhead, CA as much of the immediately surrounding area of the homes were untouched by wildfire [41]. Most recognizable from the "storms" they cause, these tiny combusting particles are carried by wind and greatly assist the spread of the wildfire [42]. The life cycle consists of a generation step, followed by a transition flight, smoldering and then sustained ignition of a fuel bed which caused a new flaming fire. The graphic below shows these steps and the other factors that affect the firebrand life cycle. While we are primarily concerned with wildland firebrands, sparks from arc welding and powerline arcing can prove just as hazardous [43].

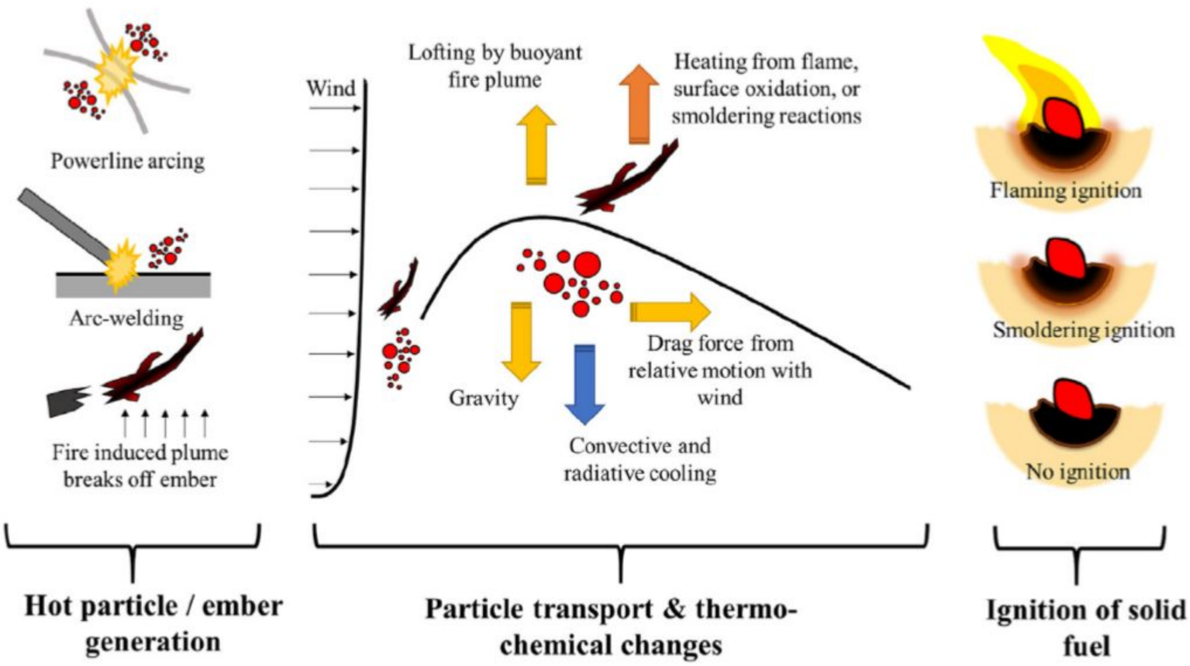

Figure 3: The Firebrand Lifecycle (Urban et al, 2019) [c]

The lifecycle of a firebrand begins with the breakaway of smaller combustible pieces from the main fuel source due to thermal decomposition. These sources can be broken down into wildland fuels and wooden structures. Wildland fuels that produce firebrands are typically grasses, shrubs, and trees [44]. These types of firebrands are typically cylindrical in shape. Firebrands from wooden structures tend to be shaped more like disks as they are more likely to be fragments from broken roofs and siding [45].

Figure 4: Firebrands from a 5.2-meter tall tree with a moisture content of 20% (Manzello, 2017) [d]

The firebrands are then moved from the parent fuel through ether lofting effects from the fire plume or ambient winds. The trajectory of the firebrands can be calculated as they are studied to follow Newton's law of motion for flying particles. In addition to drag, lofting, and wind effects, the firebrand is also sustaining a combustion reaction while traveling [44]. During this reaction time, heat is transferred to the surrounding area and the firebrand continues to degrade. In turn, the reaction also reduces the firebrand size.

The firebrand then will land on a fuel bed and transfer energy to the fuel. If the firebrand has enough energy, the fuel bed will start to pyrolyze and has the potential to combust. Assuming the firebrand has enough energy to ignite the combustible fuel vapors, the fuel bed will transfer over to sustained ignition [45]. Re-radiative effects, additional firebrand accumulation, and a low fuel moisture content, and added surface roughness all assist the firebrand in igniting the fuel bed [46]. Beds with lower moisture content have the highest potential for firebrand ignition. Additionally, if the firebrand is already supporting sustained self-ignition and if flaming, the fuel bed is more likely to ignite the fuel bed [47].

Preventing structural fires from firebrands can be accomplished in two ways; by preventing the firebrands from accumulating and preventing firebrand access to flammable materials. When firebrands accumulate, typically around roofing, gutters, eaves, vents, siding, windows, glazing, decks, porches, patios, fences, mulches, and debris, the ignition process changes. The addition of energy and mass assists the single firebrands to begin to act like larger brands [43]. As a result, smaller firebrands that may have been unable to ignite a fuel bed before may gain enough energy once they collect. Not only do these areas allow firebrands to collect, but they also collect finer flammable fuels like leaves and pine needles. These fuels are easily ignitable and then can spread the fire through direct flame contact to portions of the house [42].

Similarly, structures should be built to minimize areas where firebrands can access flammable materials. NFPA firewise suggests the defensible space model prevents local vegetation from igniting from firebrands, which can cause a fire large enough to ignite a structure. Additionally, the NFPA suggests installing ⅛ inch metal mesh covers over any opening, wents, and eaves which will prevent firebrands from contacting potentially low moisture fast-burning fuels [19].

5.3.3.2 Radiant Heat

Radiant heat is one of the three fundamental heat transfer methods and is one of the most well studied and understood products of a wildfire [42]. Radiant heat is often measured in units of kilowatts per square meter, kW/m^2, and represents the amount of energy on a given surface over time. Ignition occurs once the radiant exposure and the surface temperature exceeds critical values. Theoretical models suggest that from the largest crown fire, homes could theoretically ignite from radiation up to 40 meters away [48]. As part of the International Crown Fire Modeling Experiments, wooden planks were studied at various distances from full-scale crown fires. Surfaces further than 20 meters away from the wildfire never ignited, and only half of the panels 10 meters away from the wildfire combusted. In practicality, structures are more likely to ignite from flame contact or firebrands [41]. Proper vegetation selection and defensible space around the structure is often enough to prevent radiant heat exposures from wildfire [49].

5.3.3.3 Flame Contact

Direct flame contact occurs when localized fuels combust in proximity to the structure. While not considered a primary source of ignition, the products of combustion such as radiant heat and firebrands are much closer to the structure and can ignite the structure before the wildfire. Direct flame contact poses a greater hazard from vegetation, firewood stacks, and furniture close to structures. Wildfire firebrands and radiant heat can ignite the localized fuels and then, in turn, ignite the structure. Often following defensible space guidelines can mitigate much of the direct flame contact hazard [49].

5.3.4 Wildfire Damages

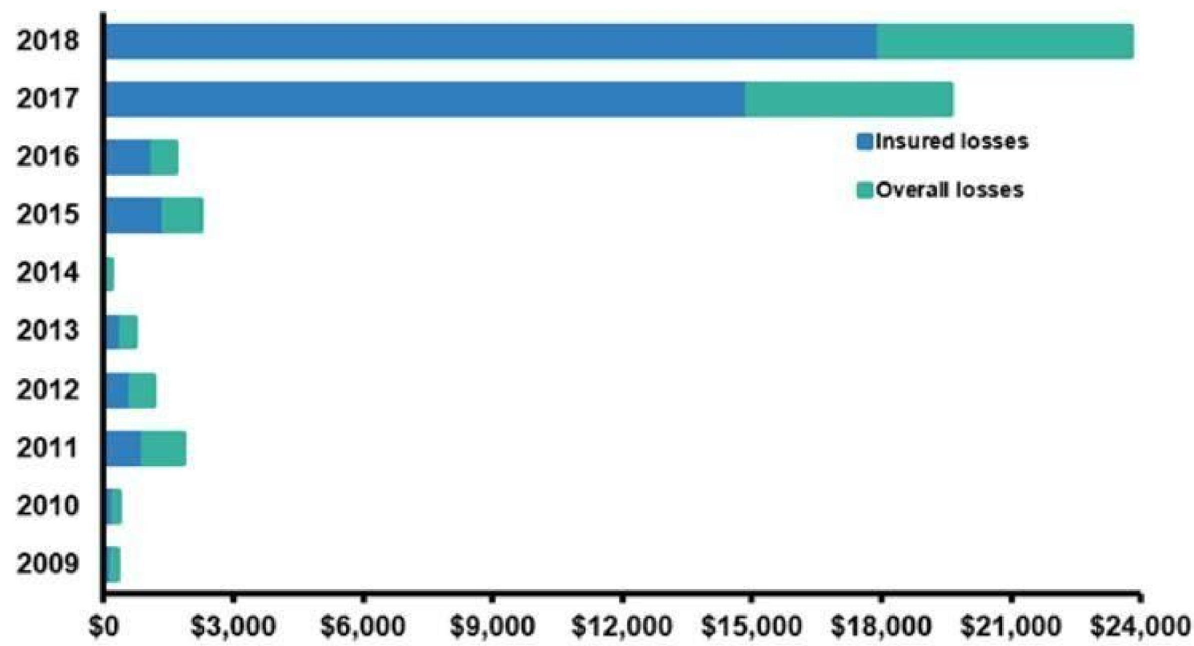

Figure 5: National, insured and overall, financial losses between the years of 2008 and 2017 in millions of US dollars from the Natural Catastrophe Risk Analysis Service [e].

Wildfire poses a serious problem to the stakeholders that must manage the natural disaster itself as well as its consequences. Stakeholders include homeowners, manufacturers, contractors, and insurance bureaus. In 2018 alone, wildfires made up approximately $24,000 in losses across the United States [50]. Homeowners, in general, have a tough time protecting their homes with fire insurance if they are in a fire-prone area or area of high to extreme risk of wildfires. Standard home insurance does include coverage in the event of a fire, but owners will need to pay for more coverage if they are at higher risk of wildfire damage. A testing standard for firefighting products would likely give homeowners more confidence that their houses would be defended; this also gives ease to insurance companies as they will feel better in covering the damage that is made by a wildfire, if the damage is more likely to be prevented, lowering the cost of coverage for the fire damage totally. Regulators and legislators tasked with the responsibility of responding to a growing understanding of what regulations to anticipate wildfire [51]. Approval laboratories test and work to define what factors inform the start and growth of these wildfires at the WUI. Firefighters risk injury and resources in attempting to suppress wildfire events.

5.4 Current Wildland Fire Prevention and Firefighting Methods

5.4.1 Prescribed Burns

Early wildland fire management in the U.S. viewed wildland fires as something to be avoided at all costs [52]. From the late 1920s to the late 1960s, the National Forest Service engaged all fires in order to suppress them to the smallest area possible. In the early 1970s, policy changes took into effect the positive second and third-order effects of wildfire and their necessity for a healthy ecosystem. Prescribed burns allow for natural control of the ecosystems with reduced physical labor [53]. These burns utilize the deliberate application of fire under high controls to prevent natural uncontrolled fires. Once natural fires start, their behavior will be controlled by wind, available fuel, and topography. Prescribed burns utilize natural or constructed firebreaks, optimal wind, climate conditions, and pre-slotted personnel to manage combustible fuels. The objective isn't to burn as much as possible, but rather to target certain areas to control the growth of potential future wildfires [53]. Prescribed burnings do not eliminate the threat of wildfire in the area; they are intended to mitigate the risks and reduce the effects by limiting fuel sources.

5.4.2 Defensible Space

The concept of defensible space was developed in the late 1990s by a retired USDA Forest Service fire scientist. The idea was to minimize the effects of radiant heat on the structure from surrounding natural materials in hopes of preventing structure fires at the WUI [54]. This approach utilizes three concentric circles spaced from the house to form a tiered system of fire protection.

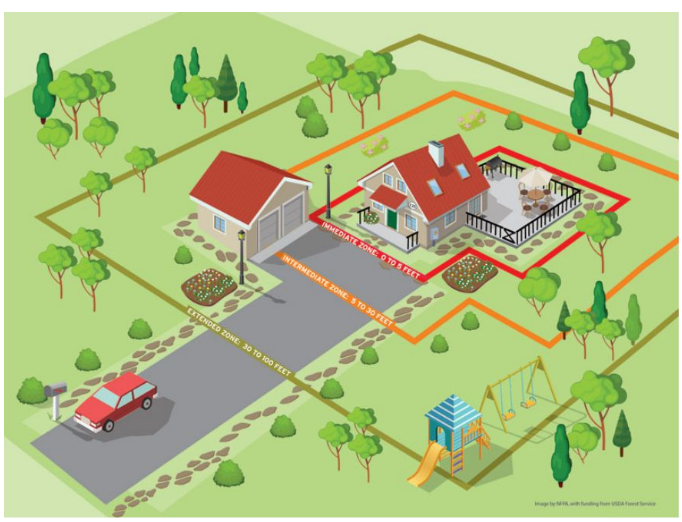

Figure 6: NFPA Firewise graphic depicting the three zones for wildfire defensible space and recommended modification for each zone [f].

The inner-circle or immediate zone represents the house to 5 feet away from a building's exterior. This zone focuses on removing flammable materials from the roof and gutters, closing and sealing off access ports like vents to the house, and removing firewood stacks or other flammable materials near the wall exteriors or deck [54]. Any tree branches hanging above or touching the house should be removed. By modifying the space immediately around the structure, direct flame contact and heat radiation are reduced, allowing for a better chance of wildfire survival. Additionally, defensible space allows firefighters to maneuver if a house catches fire and requires their assistance [55].

The second tier, the intermediate zone, extends from 5 feet to 30 feet out from the structure. This zone focuses on limiting ground fuels and spacing aerial fuels out in a manner that the fire cannot travel easily between tree canopies. Flammable liquids or gases should be placed on non-flammable surfaces, grass should grow no more than 4 inches, and trees should be pruned in a manner that a ground fire cannot ascend the tree [54]. Tree canopy crowns should be 18 feet apart, and mature trees should be at least 10 feet away from the structure. However, the local jurisdiction may amend these numbers to better assist firefighters in high-risk areas [55]. Sloped areas will need to increase in distance because the slope brings the trees' crowns together, allowing the fire to grow and spread faster.

The outermost zone, or the extended zone, extends up to 100 feet away from the structure. The objective of the extended zone is to interrupt the fire to reduce the flame height and contain flames to the ground. Heavy deadfall, including accumulated dead branches and trees, smaller conifers, and vegetation near adjacent vacant structures should be removed. Trees up to 60 feet out from the structure should be spaced with at least 12 feet between canopy tops and 6 feet for trees up to 100 feet out. These numbers are suggestions for flat terrain, and the local authority may amend the requirements. Any fuel modification further than 100 feet out from the structure on flat terrain has shown little added value in wildfire protection. The added labor and time would be better used for protecting and refining the immediate zone and reducing combustible material in the intermediate zone [28].

5.4.3 Wildfire Firefighter Crews

Defensible space plays a large role in deciding how wildland fire crews decide to protect structures. Before any structures can be saved, the safety of the fire crew's personnel and the general population must be ensured. If a structure has little defensible space, presents a hazard to the fire crew as they attempt to fight the fire, or lacks safe escape routes, the crew will often not risk saving the structure. Often there are more structures than resources at the WUI, resulting in the need for fire crews to triage houses located within proximity of each other. Triage criteria usually include the amount of defensible space, available firefighting resources, and local landscape relative to the wildfire progression. These factors are taken into account relative to the surrounding houses and the trained crew will select the houses that are most likely to survive the fire with the end goal of saving as many structures as safely possible [56].

5.5 Current Wildfire Firefighting Products on the Market

Marketing competition is high within the U.S. Automatic Fire Sprinkler System Manufacturing market industry, with an overall positive trend. The main product segments are between residential and nonresidential wet/dry pipe systems. Minor products include hybrid (water and dry) pipe systems, included in the “other” category of the market segmentation, which requires dual heat sensor technology to detect and prevent unintentional water discharge.

The IBISWorld U.S. Industry Report provides information that this market’s annual growth between 2013 and 2018 was 1.4%; it also predicts future annual growth to be 2.4% between 2018 and 2023. This makes sense, as the U.S. wildfire trends prove to increase as time passes. Within the $390.6 million revenue, 19.2% of the major market segmentation is in residential fire protection systems (~$75 million), including apartment buildings, multifamily units, condominiums, and single-family residences. Between 2013 and 2018, spending on fire protection systems on residential structures increased annually by 5.1% [57].

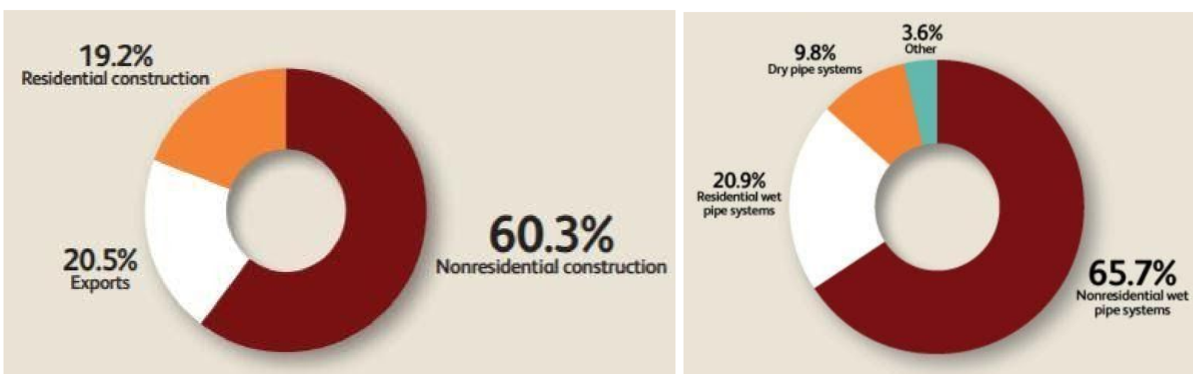

Figure 7: Major market segmentation (left) and product segmentation (right) of the U.S. Automatic Fire System Manufacturing Market from IBISWorld [g].

The current market for commercial wildfire suppression systems is limited and inconsistent. These companies present a variety of products varying in quality and cost. This variety of products combined with a lack of standard guaranteed performance can result in confusion for consumers. No unified body regulates the performance or credibility of the products of these companies. These systems have the potential to put their companies in the position of offering their services that may not provide adequate protection. The usage of infrared (IR) sensors for wildfire detection, water-based solutions for fire suppression, and the use of an exterior sprinkler system are the common factors across most residential wildfire firefighting companies. Features of 24/7 surveillance, manual/automatic operation and branded aqueous solutions are emphasized in the advertisement of these products [58][59][60][61][62].

Existing Commercial Firefighting Systems

Brand	Features
FOAMSAFE	Distributed by the CFPI Foam, IR, Self-Contained, Auto/Manual, 24/7 Monitoring
FlameSniffer	Residential and Structural Water, IR, Self-Contained, Auto/Manual Control, 24/7 Monitoring
Roofsaver Sprinklers	Budget Wildfire Suppression System Water, Fully Manual Setup and Operation
Colorado Firebreak	Large Property Installation Foam, IR, Self-Contained, Auto/Manual Control, 24/7 Monitoring
waveGUARD	Roof Sprinkler Wildfire Suppression System Water Solution, IR, Self-Contained, Auto/Manual Control, 24/7 Monitoring

Figure 8: Composed list of five existing commercial wildfire firefighting systems as well as the features of each system [h][i][j][k][l].

5.5.1 WaveGUARD

The idea behind the waveGUARD Exterior Wildfire Defense System was conceived by landscaping and irrigation businessman Randy Lang in 2011. With Ken DiPaolo, an irrigation design and development professional, waveGUARD was launched in spring 2015. waveGUARD, over the last several years, have focused their efforts on providing their service to the California area in light of the major wildfires [63].

The waveGUARD corporation emphasizes the features their system provides: a patented exterior wildfire defense system, it's an automatic/self-contained operation, 24/7 365 Monitoring, and a patented fire-retardant water additive Micro Blaze Out. Using a custom layout of exteriorly mounted sprinklers, the waveGUARD system is designed to cover a 30'-40' perimeter of defensible space around the property. IR detectors identify the system of a wildfire threat, setting off the system. Alternatively, the owner of the property is able to activate the system manually using an application on their phone [64].

5.5.2 Roofsaver Sprinklers

Roofsaver is a sprinkler company that designs exterior wildfire and bushfire protective systems. The system itself is a sprinkler kit that is designed to soak fuels to make them less likely to ignite. These fuels include the roof of the house, shrubbery, trees, decks, gutters, and the like. An intended side effect of this method of wetting the fuels is increasing the humidity of a house's atmosphere and decreasing the ambient temperature. In simpler terms, this device just works as a sprinkler on top of a house, connected to the house's water supply via a standard garden hose connection. A complete sprinkler system kit is $269.00; additional hoses, hose holders, and sprinkler heads are also available for purchase. Compared to other devices this is a low-priced system. This company's satisfaction guarantee states specifically that the roof saver device is intended for ignition prevention, and it is not designed to put out a fire.

In the case of a wildfire, consumers are instructed to turn and leave on the water pressure from the house hours before the fire arrives during the preparation of evacuation. The manufacturer's claim that this apparatus will prevent a fire by thoroughly soaking a house's surrounding fuels and can withstand 100 mph wind. In addition to this, it is promised to be sturdy yet does not require a penetrative anchor of sorts; it only needs a ridgeline hose holder to stay in place. The system is lightweight (approx. 5 lb.) and is made from high-quality brass fitting and impulse sprinklers; the setup is easy enough for a common consumer to assemble in as quick as a few minutes. The manufacturer of this product provides an installation guide for these sprinklers on a house, and it includes how many sprinkler heads are needed per the square footage of a house. This indicates that one sprinkler is expected to cover 900 sq ft of property. Below is the guide provided on the website Although the pitch on the website is promising some details of this product are not [65].

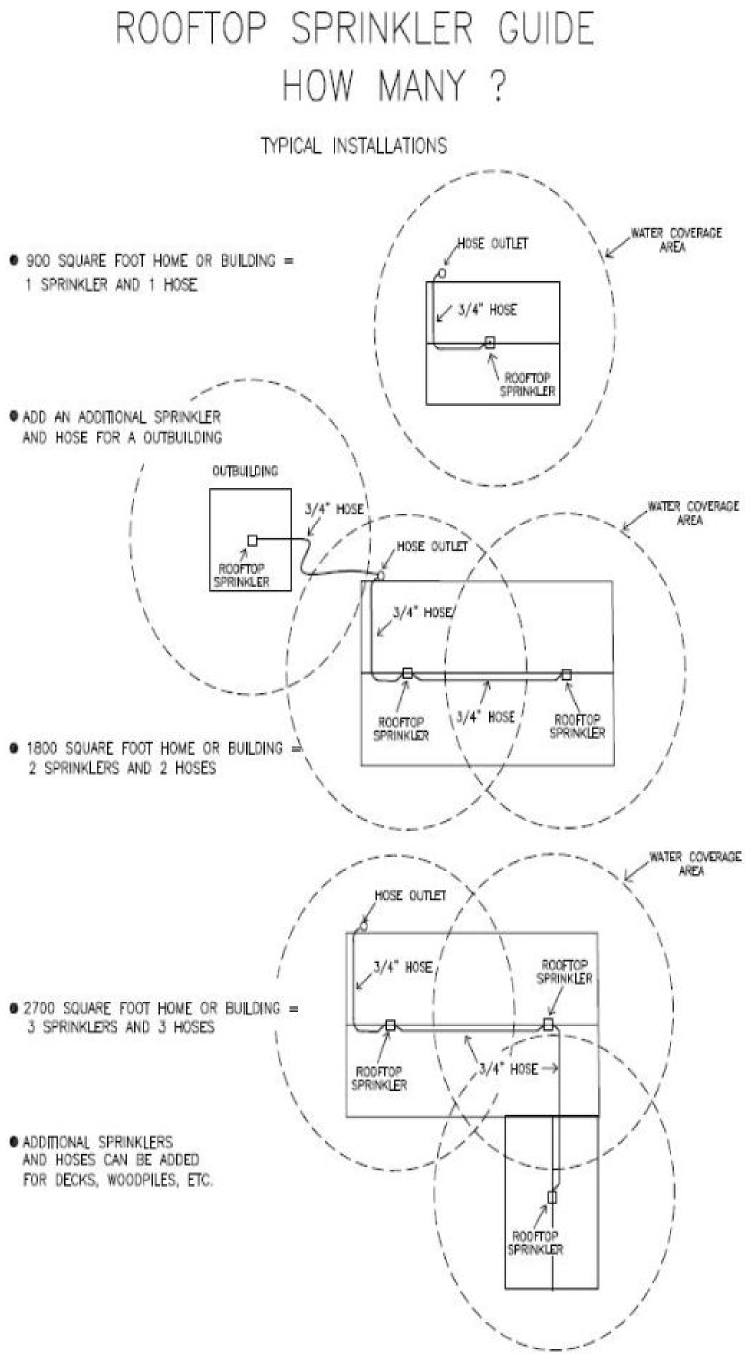

Figure 9: RoofSaver Sprinkler and Roof Installation Guide [m]

The most valuable goals of this system are to prevent the ignition of a home’s exterior, to operate independently, and to be maintainable. This system, however, does not guarantee complete property protection or the lack of personal injury. A house and its owner are still at the mercy of the wildfire. There are three system stages (one, two, and three) provided by the Roof Saver Company. Only if a consumer purchases a stage three system will the fire preventing system operate independently of their house's water supply. The other two stages are not guaranteed to work if a consumer's area loses water pressure or electricity. Furthermore, Roof Saver may make a consumer hesitant to purchase it because the company does not quantify the specific threats the system is protecting against, there is no proof that the apparatus works (outside of one customer's testimonial), and conditions of operation within actual fire conditions are not specified, in regards to factors such as wind affecting water direction and flame/heat contact on materials. From this evaluation of Roof Saver, our team can pinpoint focal points that we value and areas that our standard needs to focus on. Our standard will dive deeper into the system's goals and require that any system's manufacturer should clearly inform their consumer of a system's function, goals, shortcomings, criteria for success, and the like. This will close the gap between the knowledge of the manufacturer and the system's user.

5.5.3 Platypus Sprinklers and Controller

The Platypus sprinkler system was designed by Jamie Boyles from Gippsland Australia [66]. The system is marketed for bushfire and ember protection; it has also been flow and pressure-tested. Water from the sprinklers is intended to keep any accumulated debris wet and create a curtain of water that would prevent embers from igniting portions of the structure [67]. It features an innovative sprinkler head and system controller that is designed to be water efficient and won the Smart WaterMark Product of the Year Award for its innovation, marketability, sustainability and good design [68]. The sprinkler has two heads that spin on a central shaft designed to ensure water droplets spray out and down from the sprinkler head in a full circle [67]. The sprinkler, shown below is composed of a glass-reinforced nylon head with UV stabilizers and flame retardant.

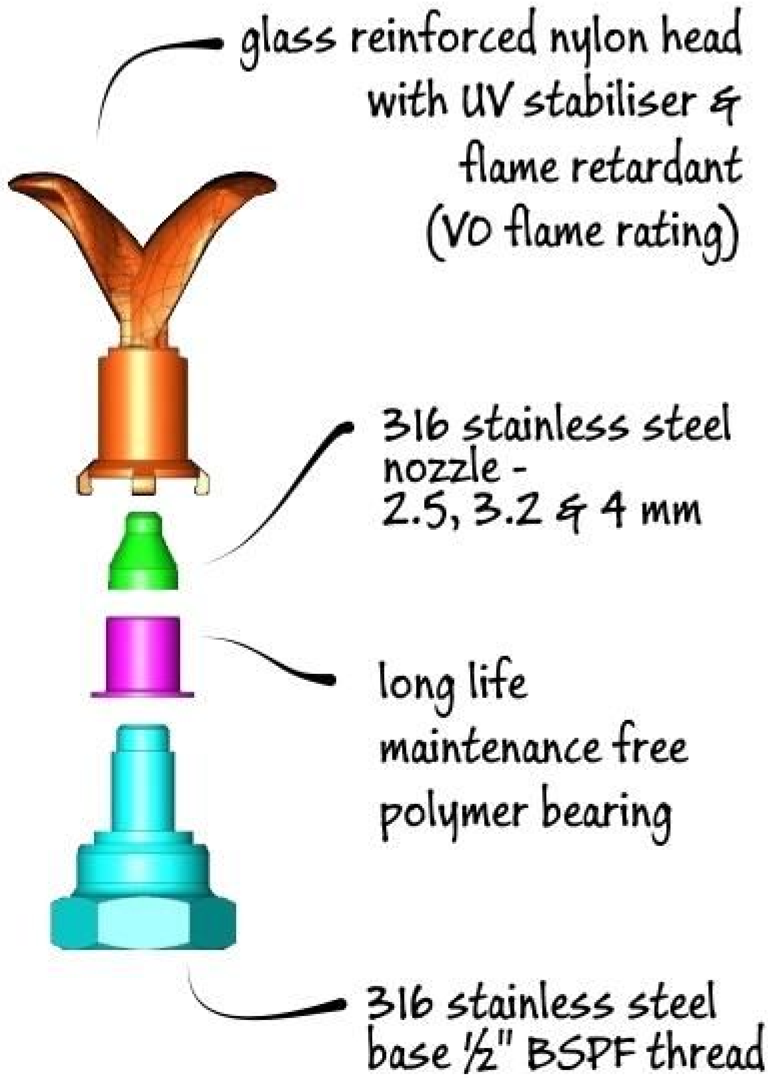

Figure 10: A Platypus sprinkler heads deconstructed to show detail [n]

The sprinkler does not have any outer support that affects the water spray pattern, additionally, the water is sprayed out and down to prevent water loss to the wind. The sprinklers are designed to be able to run at a low minimum pressure to allow for sprinklers in the same system and assist inefficient water usage [67]. Following tests at the University of South Australia, installation criteria were developed, and are tabulated below.

Available Nozzle sizes (mm)	Maximum spacing (meters)	Nominal flow rate at 300kPa in Lpm
2.5	3.5	6
3.2	3.5	9
4.0	4	14

Table 5: Platypus Installation Criteria Tabulated

The sprinklers are typically mounted on the outer edge of the roof and along the ridgeline. When installed during house construction, the system piping can be kept all internal to the structure. The system can also be installed after the structure is built with exposed copper piping mounted to the roof area. The platypus company has their own in house design and installation team. An example installation diagram is shown below.

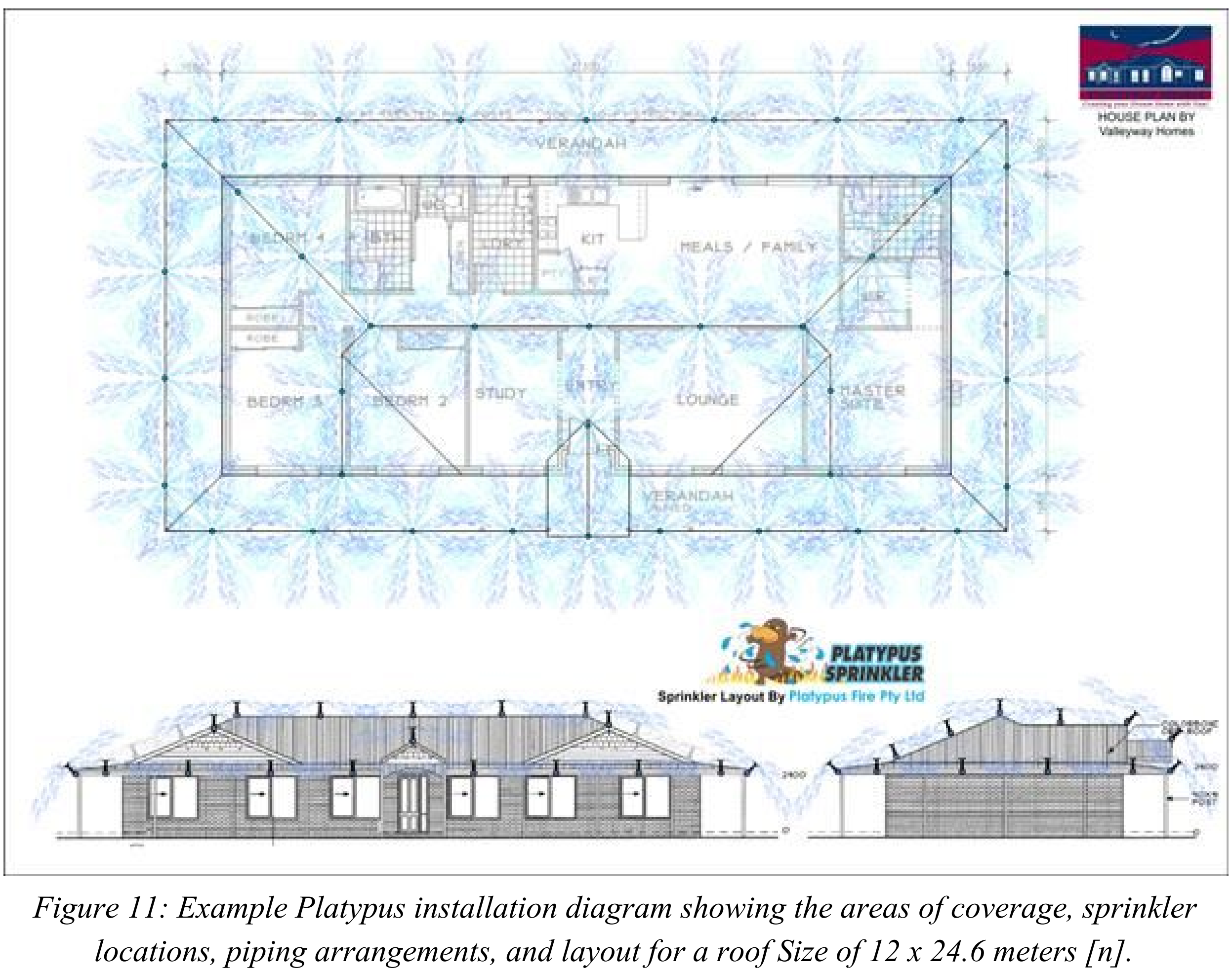

Figure 11: Example Platypus installation diagram showing the areas of coverage, sprinkler locations, piping arrangements, and layout for a roof Size of 12 x 24.6 meters [n].

The above system was designed for whole-house coverage at a cost of just under $15,000. The whole house system contains 38 sprinklers, 3 zones, a minimum flow rate of 228 Lpm, and a recommended quantity of water of 27360 liters [67]. The option is available to only place the sprinklers on the ridgeline for combustible roof protection at a cost of around $6300. Both designs prices do not include the cost to supply pumps, tanks, and pipework to the building connection point.

The system is activated through one of three methods. The owner can activate the system directly at the system from the system control pad or by text message. Additionally, the system can automatically activate at a controlled and consistent ambient air temperature. The system runs for a user-defined amount of time up to 60 minutes and then the temperature is measured again. If still above the set point or if the owner overrides the controls, the system will run again. Whenever the system starts or stops a test message will be set to a preset user-defined phone number. The controller costs $2200, and can control the pump start and stop, fuel levels, system runtimes, water pressure, and sends its own annual automatic service reminder [67].

Key features of the Platypus system that inspire confidence include defined installation criteria and provisions for automatic system operation. Both of these features connect back to sprinkler design requirements that may be found in NFPA 13 or 13D. Defined installation criteria both regulate the system and conveys to the system user that the system is designed following some goals and objectives. The additional testing is done to quantify the spray pattern, discharge, and device performance only adds to the argument that the system has criteria for system operations. While the discharge devices do not have a thermal element that activates the discharge flow, the system does contain thermal sensors that activate or reactivate at a set temperature.

The biggest question left unanswered by the system designer and manufacturer is how the system will interact with the wildfire. There is no explicit statement explaining what threats, hazards, exposures, or any wildfire quantification that the system is designed to protect against. While the system is advertised for bushfires, there is no quantification of how the system will interact with the fire or what fire effects the system will protect against. It is left up to the system user to assume what effects the system will protect against, such as firebrands or flame contact from adjacent fuels. This assumption can prove problematic if the occupant over-trusts the perceived safety of the system and ignores other wildfire safety factors, such as defensible space maintenance, debris from roofs sweeping, or evacuation orders.

5.6 Fire and Water Spray Test Methods

There are a multitude of fire tests available that quantify materials based on how well they can withstand fire, how they react to heat, and what the products of combustion are. Many tests utilize heating material with constant radiant heat flux and observing the effects of the heat.

Test methods like ASTM E1354/ NFPA 271 / ISO 5660 utilize a cone calorimeter to measure heat release rate by looking at oxygen consumption [69] The cone calorimeter can also calculate a materials ignitability, mass loss rate, and smoke release rate. There are also a variety of methods for sprinklers to become listed and approved for use. UL standard 199, Standard for Automatic Sprinklers for Fire-Protection Service, tests potential sprinklers against a variety of conditions the sprinklers should be able to withstand [70]. The strength, load, and thermal properties of the heating element are examined. Flow, leakage, and hydrostatic strength of the sprinkler orifice are tested against a water hammer test and a 30-day leakage test. The sprinklers are put through a pan test in order to observe the spray patterns of the sprinkler spray under a standardized pressure and flow. UL 1626, Standard for Residential Sprinklers for Fire-Protection Service, is a similar standard specifically for residential sprinklers. While not as comprehensive as UL 199, this standard is intended to cover the residential sprinklers mentioned in NFPA 13, Standards for the Installation of Sprinkler Systems, NFPA 13D, Installation of Sprinkler Systems in One- and Two-Family Dwellings and Mobile Homes, and NFPA 13R, and Residential Occupancies up to and Including Four Stories in Height Sprinkler Systems.

These standards are designed for the application of systems within the controlled conditions of an interior fire; they may not take into effect all of the wildfire factors. However, the basis of these tests still holds true. Discharge devices still need to deliver liquid to the fuel sources at an acceptable quantity no matter the location. Ignition of adjacent fuels and containment still needs to occur in both outdoor and indoor scenarios. While these tests may not be utilized “as is”, it is likely that the intent and general methodology of the test will be adapted to investigate wildfire effects on fire fighting systems.

6.0 METHODOLOGY

The goal of our project was to create a technical standard for exterior structural wildfire-fighting systems. This standard is intended to create a common understanding among the multitude of WUI stakeholders in the evaluation of a system's performance for protecting a residential structure from the effects of wildfire threats and exposures. To create the standard, we utilized a three-phase approach. The first phase consisted of comprehensive background research. This research gave us the insight needed to understand the fundamentals of wildfire, wildfire protection, fire codes and standards, and wildland fire protection system performance. The second phase was outlining the standard. The outline included identifying the scope, goals, objectives, and criteria of the standard and how the standard should be read. The format was intended to look similar to traditional NFPA documents and took inspiration from NFPA 13D, NFPA 551, and NFPA 101. The third phase entailed filling our standard's framework with concise technical language including both mandated provisions in the body of the standard and advisory text in the annex. Any mandated text will include provisions on how various performance aspects of a given system can be verified. Annex text will highlight applications of the mandated provisions and illustrations of the application of the standard to current products available in the marketplace. We continually reviewed and revised our standard throughout this process.

6.1 Phase One - Background Research

Our group conducted comprehensive background research to better understand the wildfire threat, exposures, and hazards at the WUI: primarily by researching FPE literature reviews, major international fire protection documentation including codes, standards, and recommended practices, and current industrial technology. The main question we sought to answer was what should our standard contain and why? To answer this, we had to further question how we could define a wildfire? How do wildfires interact with structures? What systems are currently available for wildfire protection? How are current codes, standards, and recommended practices addressing the issue of wildland fire protection?

This research informed our knowledge of the three primary wildfire threats: firebrands, radiant heat, and direct flame contact. Additionally, other factors that affect wildfire scenarios were researched, including the materials of construction, local codes, and current commercial wildfire protection systems. The knowledge collected during the research phase was populated into the background section and assisted in formulating the outline of our standard.

6.2 Phase Two - Outlining the Standard

The standard was outlined through the constant systematic revision from multiple information sources. Each of these sources was chosen to answer a major question we believe our system needed to answer. These questions were gathered from our previous research into other codes, standards, and recommended practices. Additionally, we selected three current wildfire protection systems and identified all of the aspects in these systems that either inspired our confidence or made us wary of their performance. These factors were then combined to provide additional outlines and questions.

We started by asking what the system needed to do and how the designer will communicate this. To answer this, we utilized the first five components of the SFPE performance-based design (PBD) approach (shown below) to outline what the system needs to do. We initially defined the scope for our whole standard by reviewing existing codes, standards, and recommended practices in addition to system stakeholders' needs, wildfire literature, and wildfire protection systems on the market.

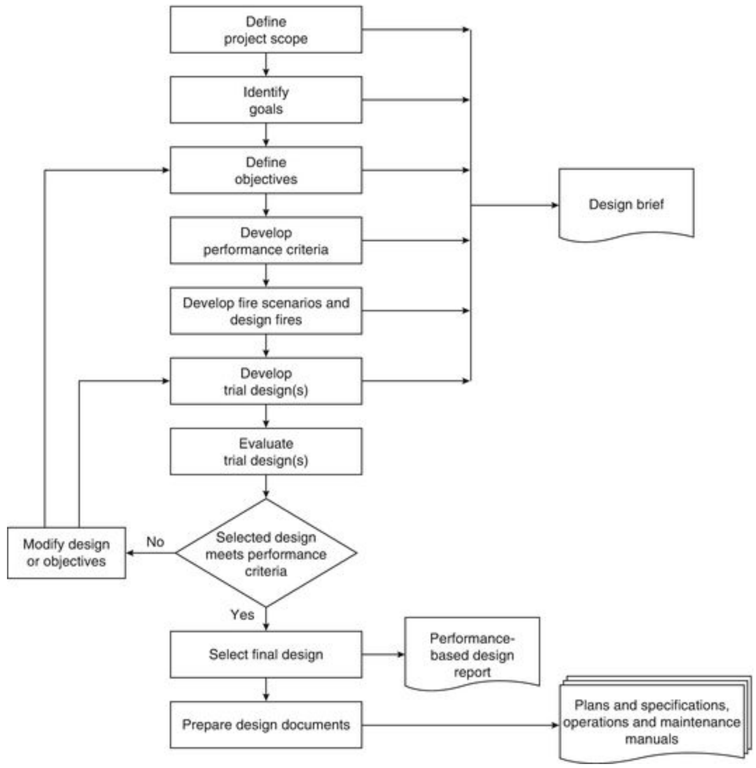

Figure 12: SFPE Performance-based design flowsheet used to frame the system standard [o].

After the scope was designed, we outlined how the system manufacturer should communicate their systems goals, objectives, and acceptance criteria. The fifth element of the SFPE PBD approach, "develop fire scenarios and design fires," answers the question of how the wildfire threat should be quantified. In addition to wildfire threats, we knew from previous research that the system that provides exterior protection would experience environmental exposures. We looked to answer the question of how the system is designed and installed to operate in this environment.

The next question we looked to answer was how the system components should be selected and what makes them eligible for selection. To answer this question we looked at how NFPA 13 and 13D handled the selection of system components. We then translated the intent behind the established statements into meaningful subheadings both in the "system components" and "device discharge" section. These sections each looked at how devices must be quantified for use.

The next question was regarding how the system will be designed and installed on the structure. We wanted to know how the manufacturer decided to piece together the selected components and why. This section was intended to ensure the system was designed to provide the protection the system designer stated it would. Once the system was together and installed, how does anyone know it will work? The system needed to activate and operate. We asked the questions, how does the system designer prove that the installed system does what the designer said it would and what would quantify this? Additionally, we asked when will the system activate? How will activation occur? Is there a delay between system activation and protection? What does a normal system operation look like? Does the system have enough resources to provide protection? Finally, we asked, how will the system be maintained? Will inspections be required, and what should these activities look like?

Our outline was reviewed and readjusted multiple times, each time as a result of posing a new question or to combine topics under the same intent.

6.3 Phase Three - Developing Provisions and Annexes

After we framed our standard, the outline was filled in with mandatory text. For the standard, the verb “shall” was used to imply a requirement. As a tradition, an “Annex A” document also accompanied the standard text as a supplement that is not intended to be mandatory in nature. Therefore, the verb “should” was used in all annex texts, which is the advisory text. We utilized a variety of existing NFPA standards to assist with maintaining a regulatory vernacular. Our primary model documents include NFPA 13D, NFPA 101, and NFPA 551: Guide for the Evaluation of Fire Risk Assessments.

The administration chapter standard and annex text were written in the format that paralleled NFPA documents. Definitions of terms we deemed important were intended to provide clarity and consistency throughout the standard and create a common language. Definitions were derived from the SFPE handbook 5th edition, Merriam-Webster’s Collegiate Dictionary, 11th edition, the ICC International Wildland-Urban Interface Code 2018 edition, and a multitude of NFPA codes and standards including NFPA 101 2018 edition, NFPA 13 and 13D 2019 editions, and NFPA 1144 2015 edition. NFPA official definitions were quoted right from their use in NFPA documentation. IWUIC definitions were quoted directly from the ICC source in order to minimize confusion between defined terms.

All codes, standards, recommended practices, or test methods referenced by our standard were compiled under reference documents. System design goals, objectives, and criteria requirements were written in a way that allowed the system designer to be flexible with the design of their system, but not to the point where information that quantifies their system was left out. The quantification of the wildfire was accomplished by requiring the system designer to define the threats, fuel sources, and duration of the wildfire event. The wildfire event text was written so that it became the system designer's job to quantify what the fire that the system will protect against. In addition, the system designer must also select the best threats to represent the level of protection the system will provide. Sources used to back up the annex text included reports published by NIST and their Dragon apparatus.

The text that comprises the system components chapter included requirements mandating that the components of the system need to withstand a multitude of natural and wildfire effects while maintaining the ability to operate. Requirements were written such that it is the job of the system designer to select appropriate parts for the system to ensure proper operation. It is the job of the manufacturer to verify that the components designed for the wildfire system are able to withstand these effects through testing and quantification of the components' capabilities.

The device discharge chapter was written such that devices were required to have a prescribed discharge and spray criterion provided by the manufacturer. Additionally, the manufacturer must develop the criteria and acceptable test methods to prove that the device operates as stated. The motivation for this text was the quantification of the discharge and spray criteria necessary for the system designer to select an appropriate device when protecting the selected protected asset. This protection was also written to include the relationship to the goals, objectives, and fire threats. Text and vernacular was based on NFPA 13, NFPA 13D, and FM global documentation.

The system layout chapter was written with the intent of providing the system designer with a process to document how and why the system components were combined to protect the structure. To confirm that all protected assets receive adequate discharge spray, calculations and diagrams are required to be presented to the AHJ. The text was inspired by NFPA 13 and NFPA 13D documents, especially areas including hydraulic calculations for piping. Additional inspiration and text formation came from the evaluation of the three chosen systems and the questions they posed.

The system activation and operations chapter was intended to get the system designer to state the key information necessary to qualify their system. Additionally, the questions regarding the number of devices and what times in the activation cycle will discharge, how fast the devices can discharge, and how the system designer arrived at these values are intended to be explained in this chapter. Inspiration was pulled from NFPA 13 and 13D.

System acceptance text revolves around the methods the system designer utilizes to quantify to ensure the system is suitable for the specific to the wildfire threats the system is designed to address. This section was intended to address the acceptable damage thresholds for both the structure and the interior with respect to smoke, water, and fire. Inspiration for this chapter primarily came from the questions raised earlier in the writing process regarding the system purpose and overall goals, objectives, and acceptance criteria.

The system resilience chapter is intended to address the long term performance of the fire protection system. Similar to the wildfire chapter, this chapter was written to address the exposure the system will need to withstand. The intent of this chapter is to ensure that the system components are able to withstand the standard daily conditions in addition to performing in response to a wildfire event. The text in this chapter was to mandate that the system designer considers the variables associated with keeping the system operational throughout the system lifespan. Inspiration for the text in this chapter came from NFPA 13D and the questions we raised during our initial questions raised earlier in the writing process regarding the system capabilities.

In conjunction with the system resilience chapter, the chapter revolving around the inspection, testing, and maintenance of the system was written in a way that will clearly identify which party is responsible for what aspect of system upkeep. This section also contains the inspection testing and inspection as the final component when the standard is ready to finish. The intent of this chapter was to convey the necessary information regarding system upkeep, how this information was obtained, and which party will be responsible in addition to system commissioning. Inspiration for the standard and annex text came primarily from NFPA 13and 13D. To cut down on the complexity of the material presented in the NFPA documents, the main ideas and motivations were extracted to form your body of the text.

6.4 Standard Application - Applying the Standard to Two Test Cases

Once the standard was complete, we reviewed the standard layout and text to ensure the standard is versatile enough for the new wildfire protection system market and encompasses the minimum property safety required from these systems. We then applied our standard to two existing systems. This process included going requirement by requirement down the standard. If the system met the requirement, the system was considered compliant in that regard If the system could not meet the requirement in its entirety, then the system was considered non-compliant. Regardless of compliance, a comment was left explaining why or why the system was not compliant. When the system was not compliant, the comment also included potential pathways to become compliant. These pathways were categorized into three types. "Easy Fix" refers to any deficiency that can be solved by quantifying, stating, or clearing up some ambiguity. An example of this is the "pumps" requirement where the system designer did not explicitly state appropriate locations for the fire pump. The easy fix, in this case, would be a statement for the system designer detailing properly protected locations for any pumps used. "Design creation" refers to the need for the system designer or manufacturers to create some product, method, or documentation to further explain their thinking or criteria. "Perform Testing" refers to the need for an additional test or qualification of system parts or components. An example of a requirement that was labeled as "preform testing" is Device Output Characteristics, where the discharge devices must be tested under the expected wildfire conditions.

Following any revisions that happened during this process, we published our standard in accordance with WPI's MQP submittal process.

6.5 Sample Structure

The architectural engineering component of this MQP project consisted of calculating fire performance of a lightweight cold-formed structural steel wall stud and rafter stud for the duration of a defined wildfire event. Through analysis of transient heat transfer on specified structural steel members a sample structure is provided for exterior wildfire-fighting system designers to apply their system layout to demonstrate how their system could limit critical heating of these studs that would result in structural failure. The final product included the recommended wall and rafter stud sizing and insulation for the defined wildfire event and a Revit model of full lightweight steel stud structure. These calculations and designs took into account the International Wildland-Urban Interface Code (IWUIC 2015), International Building Code (IBC 2018), International Residential Code (IRC 2018), and AISI 100 North American Specification for the Design of Cold-Formed Steel Structural Members for code and specification compliant materials of construction and design. These designs will be presented as a separate deliverable from the standard but will be included in the appendix text.

7.0 Results

7.1 Background Research

Our final background research was consolidated and presented in section 5 of this document. The final 28 pages of background represent our major findings that were critical to the development of the standard and during the cultivation of our own knowledge base. A variety of code and standards organizations are touched upon in addition to the process that NFPA utilized when writing standards. The causes of wildfires and wildfire dynamics are explained. We chose to condense the products of wildfire into three categories, firebrands, direct flame contact, and radiant heat, in order to best utilize the information when writing the standard. Current wildland fire prevention and fire fighting methods were presented in order to gain a better understanding of the overall current situation. A variety of current wildfire firefighting products are reported on, including the two systems utilized later in the application of the standard in Annex C and Annex D. Finally, wildfire water spray and tests methods were presented in order to gain a better understanding of the current test method for more traditional interior systems. We will later utilize some of these tests when discharge devices are quantified.

7.2 Outlining the Standard

Our final standard consisted of 12 chapters and 5 associated annexes. A total of 53 requirements comprise the standard with associated Annex A text explaining the requirements. The standard also utilized 8 unique definitions in order to communicate the fire protection requirements. Of the five annex texts, the first became the explanatory text, two were utilized to apply the standard to an existing system, one was utilized as for the AREN requirements, and the last was used as a resource base for references cited in the annexes. A chapter outline of our final standard is below, Table 6.

Chapter	Title
1	Administration
2	Definitions
3	Referenced documents
4	System Performance
5	Wildfire Event
6	System Components
7	Device Discharge
8	Design - System layout
9	System Activation and Operation
10	System Acceptance
11	System Resilience
12	Inspection, Testing, and Maintenance
Annex A	Explanatory Material
Annex B	Wildfire Protection System Compliance: Roofsaver
Annex C	Fire Fighting System Compliance: Platypus
Annex D	Annex A References

Table 6: Standard Chapters and Annexes Outline

This outline was chosen in order to best direct the system designers and manufacturers when using the standard. The first three chapters set up the standard, provide the scope and purpose, set the common language used in the standard, and provide the references to other standards. The next two chapters, four and five, are used to define the goals, objectives, criteria, assumptions, and wildfire threat. These statements made by the system designer are used throughout the rest of the standard and are intended to communicate the protection level the system will be able to provide. Chapters six, seven, and eight detail how the system and its components are designed. These chapters hold all of the requirements that state what components may be used and where, how these components were quantified for wildfire use, and how the system was designed in order to provide adequate coverage to the protected assets.

Chapter nine, contains all of the requirements for system activation and operation, including when the system will activate and under what conditions, how the system operation is defined by the system designer, and when and under what conditions will the system shut down. Section ten, system acceptance, includes the requirements for how the systems will be tested once installed on the structure. Chapters eleven and twelve both have requirements that mandate what happens to the system once installed on a structure with the intent of ensuring proper system operation of the system life. Chapter eleven covers the natural and non-fire exposures the system will need to resist, and chapter twelve covers all of the inspection, testing, and maintenance of the system.

7.3 Developing the Provisions and Annexes

Both the standard text and Annex A text were written in parallel. While the standard text contained all of the mandated provisions, the Annex A test provided clarifications, pathways for compliance, and sometimes additional text that the systems designer or manufacturer should do when complying to the standard, but are not required to as long as the standard requirements are met.

The scope for the standard was set to“ provide a means of evaluation for fixed firefighting systems designed for structures at the Wildland Urban Interface (WUI)”. The scope was selected to allow a multitude of spray systems, and not just water-based, to utilize the standard. The standard was intended to provide the minimum necessary guidelines for wildfire fighting systems that are designed to respond to and mitigate the threats and non-fire exposures from wildland fires in order to improve the protection of the structure and to mitigate property loss in order to quantify a system’s criteria for successful performance. The standard is not intended to discuss life safety goals since occupants are assumed to have evacuated before a wildfire event.

The final definitions section of the standard contains 25 definitions to develop the common language of the standard. Of these definitions, five were utilized directly from the NFPA as official NFPA definitions. The other twenty definitions were written through the combination of NFPA, ICC, Dictionary, and our own input. These definitions were then revised several times so that their final wording better matched the intended meaning. Several definitions, including, duration of the fire event, non-fire exposures, minimum specified output value, and protected asset were created specifically for the standard. These definitions are all available in chapter two of the standard, and the meaning, derivation, or explanation for all of the definitions are available in Annex A.

Chapter three contains the tree NFPA standards referenced in our standard text including NFPA 13: Standard for the Installation of Sprinkler Systems, 2019 Edition, NFPA 13D: Standard for the Installation of Sprinkler Systems in One- and Two-Family Dwellings and Manufactured Homes, 2019 Edition - Chapter 10 Discharge and Hydraulic Calculations, and NFPA 16: Standard for the Installation of Foam-Water Sprinkler and Foam-Water Spray Systems, 2019 Edition – Chapter 8 System Acceptance. Annex E contains three additional publications and four additional references used in the annex text.

Chapter four requires a system designer to disclose how its goals are meant to address the damage prevention of the structure through the statements of goals, objectives, capabilities, criteria, and assumptions. These goals aid the development of a shared understanding between nontechnical and technical individuals as to what the wildlife fighting system will protect against and the criteria by which the system will perform. For each goal designated by the system designer, design objectives must be stated that specify how the system will achieve its goal. These objectives are intended to expand on what the system needs to do during a wildfire scenario. The three intentions chosen to better explain survivability goals include; interior, exterior, and structural survivability. Interior survivability included protecting the contents of the structure such that an occupant may move back into the structure safely after a wildfire. Exterior survivability accounts for the survivability of a structure's weatherproofing and for its ability to continue protecting an occupant and the interior after the wildfire event. A system that achieves structural survivability was intended to ensure no structural or load-bearing members of the structure were weakened, cracked, burned, or disfigured after the wildfire event. Performance criteria that demonstrate how a system will meet the objectives follow the objective creation. These performance criteria are required to include the quantifiable thresholds that, if exceeded, result in the failure of a system's goals. Any assumptions regarding the structure, structure surrounding, or environment, both planned and current, should be stated and considered by the system designer when creating systems goals, objectives, and criteria.

Chapter five is intended to make the system designer define what the wildfire threat is that they will be protesting against. The system designer is required to clearly identify, quantify, and state the wildfire threat(s) the system is intended to protect against. These threats are broken down in the annex to three main types; firebrands, direct flame contact, and radiant heat in order to simplify the quantification by the system designer. The designer is also required to consider the location of other adjacent and local fuel sources. These fuels can add additional threats, such as firebrands or direct flame contact, during a wildfire event. The duration of the wildfire must then be defined. The three segments used in the definition of this time include the time from system activation prior to the arrival of wildfire threats, the time the wildfire flame front takes to progress through the system’s zone of influence, and the time after the wildfire progresses through the system’s zone of influence but the system is still required to meet the goal and objectives.

Chapter six requires that the system, it's devices, its components, and its materials be qualified for their intended protective purposes by the manufacturer for the stated wildfire threats and non-fire exposures and approved for use by the authority having jurisdiction. The method used to qualify components is required to also be presented and approved by the authority having jurisdiction. A method for allowing the use of used discharge devices is required to be set up by the system manufacturer. Piping is required to be protected from the stated wildfire threats and non-fire exposures. Pumps are required to meet the pressure and volume demands of the system. Additionally, a list of spare parts and the standardization of parts is required by the system designer.

The device discharge chapter, chapter seven, requires that discharge device performance shall be quantified and documented by the manufacturer. The requirements of discharge,

discharge characteristics, and the methods used to test the discharge are required to be stated by the manufacturer. The manufacturer is also required to state the spacing requirements of the devices and provide an installation specification for each device.

Chapter eight requires documentation to be submitted to the AHJ detailing the layout and calculation method used to ensure all protected assets receive the required discharge density. The required discharge density is determined by the system designer and based on the distance from the protected asset to the nozzle, the orientation of the protected asset, the effects of wind, and the effects of other discharge devices. The system layout chapter also contains the requirement for a hydraulic calculation to be performed in order to ensure that the select piping sizes are sufficient for the system. The hydraulic calculation may either be completed through the hydraulic calculation procedure for NFPA 13 the available pressure equation for NFPA 13 D, or a calculation method provided by the manufacturer approved by the AHJ. The location of the system pumps and agent storage containers are required to be protected Piping, attachems, and pumps are required to be protected from the stated wildfire threats and non-fire exposures.

Chapter nine is broken into two parts, the first contains all of the requirements for activation including requiring the system designer to fully detail the sequence of system activation. This sequence is required to explain the times and conditions for automatic and/or manual system activation, when each specific discharge device is activated and what event activated the device, and the delay between system activation and device discharge. The second half of the chapter requires the system designer to fully define the system operation which would include when the system evaluates the threat or when the system shuts down. The calculation of the resource requirements or limitations to the system is required of the system designer. These resources may include electricity, wifi, cellular service, agent, fuel or backup power.

The system acceptance chapter, chapter ten, requires documentation to be submitted to the AHJ that details how the acceptance testing was accomplished. This testing is intended as a quality check to make sure the system was installed correctly. This chapter utilizes NFPA 16: standard for the installation of foam-water sprinkler and foam-water spray systems.

Chapter eleven, system resilience, addresses the long term performance of the system once installed. This chapter requires the system designer to consider the weathering effects on the long-term performance of the system. Additionally, the system designer is required to ensure that there is not a combination of incompatible materials within the system that would degrade the system over time. In areas where the ambient temperature of the systems surroundings cannot be maintained above 40 degrees centigrade, as per the NFPA requirements, the system designer must state how the system will prevent the effects of freezing.

Chapter twelve, inspection, testing, and maintenance, contains all of the requirements for further ensuring the system maintains the ability to operate as installed. These requirements are distributed between the system designer and the manufacturer, depending on the requirement. The system designer is required to provide an inspection, testing, and maintenance plan outlining the procedures necessary to ensure proper system function. The designer must also state any system hazards in order to better protect the system user. The manufacturer is required to state the shelf life and cautionary information in relation to the agent, or the life cycle when referring to a system component. This chapter also contains the qualifications for inspectors, detailing the requirements for personnel who inspect and work on the systems.

7.4 Application of the Standard to Two Test Cases

After the completion of the standard, it was applied to two sample cases of systems currently on the market, Roof Saver and Platypus. Each requirement was evaluated, and a decisive verdict on code compliance of "yes" or "no" was attributed to each requirement for each system. Roof Saver passed 15 of the 53 requirements. Platypus was compliant with 10 requirements. An assessment was then performed on the results from the platypus system. Each requirement that was unsatisfactory in terms of the standard was provided an example pathway to compliance. These pathways were categorized into three types. "Easy Fix" refers to any deficiency that can be solved by quantifying, stating, or clearing up some ambiguity. An example of this is the "pumps" requirement where the system designer did not explicitly state appropriate locations for the fire pump. The easy fix, in this case, would be a statement for the system designer detailing properly protected locations for any pumps used. "Design creation" refers to the need for the system designer or manufacturers to create some product, method, or documentation to further explain their thinking or criteria. "Perform Testing" refers to the need for an additional test or qualification of system parts or components. A depiction of the Platypus results is shown below, Figures 13 and 14.

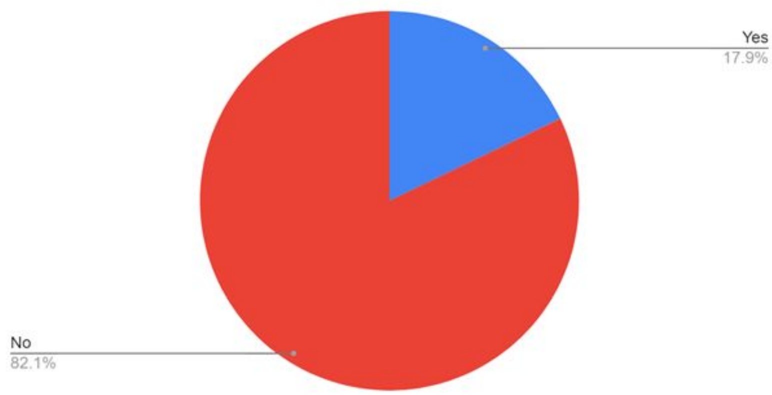

Figure 13: Platypus Compliance to the Standard: Each Requirement

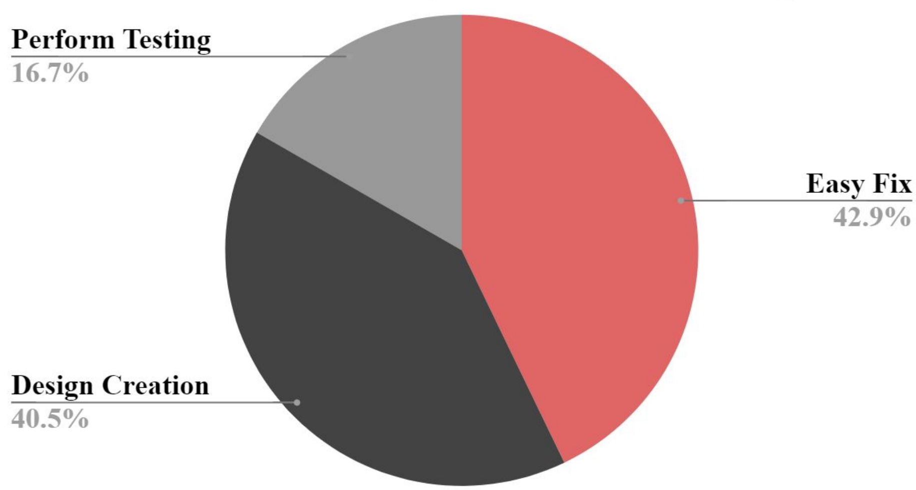

Figure 14: Distribution of Pathways to Standard Compliance.

The set of full results including the rationale of why each verdict was rendered can be found in Annex D of the Standard. These results were then utilized when identifying what future work can be done to better the standard and the fire protection community as a whole. While a majority of the fixes were labeled as an “easy fix”, these changes would create significant work for the fire protection market. These fixes would require the system designers to clearly state any implied assumptions and provide reasoning for their statement. Furthermore, the “preform testing” portion of the failed requirements represents a larger hole in the understanding of the interactions between structure and wildfires. Most of the “Design Creation” requirements were failed because of the lack of instructions from the manufacturer or a method to prove the decisions and components used on the system were suitable for use.

8.0 FUTURE WORK

Our team originally intended to seek professional input in alignment with the NFPA standards creation process. While we received assistance from our project advisors, Professor Puchovsky and Professor Simeoni, we would have liked to have received feedback on our Standard from sources outside of the sphere of the standards development process. These individuals would have included system designers, manufacturers, and other standard council members. The intent would be to present our standard and receive feedback that would better tailor our standard for practical application. While we did not intend to seek feedback from the public as the NFPA standard creation process would. We decided against this early on due to the timelines and scope of our project. The additional feedback from the public should primarily consist of residence owners and system users at the WUI.

We asked the system designer and manufacturer to define and quantify complex phenomena. Additional studies should be conducted to assist the quantification of the wildfire threat, discharge device performance, and necessary discharge density for a protected asset. The quantification of the wildfire threat may be the most important. Current research is starting to provide more information about wildfire dynamics, but the simplified system between a wildfire and a single structure needs to be further defined in order to better evaluate the performance of protection systems. The hope is that the publication of this standard and the need to define these interactions in order to identify the wildfire threat will assist in obtaining resources for this topic.

While agencies such as NIST and IBHS have working scale model firebrand generators with variable flux, calibration of these machines to a specific wildfire threat would greatly boost the quantifiability of systems and system components. As of now, quantification of discharge devices is performed in house by the manufacturer and system designer. A standardized test method should be developed that allows a discharge device to be tested by an agency similar to UL199. This test method should test for the criteria in or standard to ensure that the discharge device is able to provide enough agent to a protected asset under wildfire conditions. Once a device is linked to a specific discharge density for a specified threat, the system designer will be able to easily select a device that is capable of protecting the asset.

The last major addition that we would like to add to our standard is a tabulated or simplified method for obtaining the necessary discharge density for the protected asset. This table would essentially be answering the question "how much agent is needed to protect a portion of the structure."A lot of factors go into how much of an agent an asset will need in order to be protected from a wildfire threat. This agent density requirement will likely be dependent on fire dynamics characteristics such as material properties, orientation, geometry, and threat. This table in conjunction with a streamlined certification process for discharge devices would allow the system designer to design a system in a more efficient manner such as identifying the asset in need of protection based on the design goals and objectives, identifying the assets discharge density requirement, and selecting a device that applies this amount of discharge.

9.0 CONCLUSIONS

The team researched and investigated the national of the wildfire crisis and various wildfire scenarios to understand the nature of wildfires and the risk at the wildland-urban interface. As the threat progresses and continues to damaged property, it is fair to assume that people are going to search for solutions to this problem for protecting their property. The solution includes and has included the innovations of many systems that are intended to protect the homes that are at high risk of wildfire, particularly located in the wildland-urban interface. The problem that the team faced, however, was the gaps in system limitations we found and the trust that consumers placed on these systems to protect their belongings. In researching current systems on the market, there was a consistent lack of communication between stakeholders, including manufacturers, system designers, and system users. Many of the existing systems' designers neither completely nor clearly inform its users of its specific objectives and criteria for specific threats that the system is intended to oppose. Consumers are also not provided with documentation that proves that the purchased system will perform as the system designer claims. In response to this, our team created a standard that requires manufacturers/system designers to communicate all performance criteria, goals, and components of the system to their consumers. The Standard for Fixed Wildfire-Fighting Systems, for the structures that the wildland-urban interface, is a standard that consists of twelve detailed chapters and four explanatory and advisory annexes similar to the structure of NFPA documentation to bridge the aforementioned gap of communication. This standard was also applied to two of the existing systems as a guide for system designers and manufacturers in the annex.

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VI. THE STANDARD

The Standard for Fixed Wildfire-Fighting Systems at the Wildland Urban Interface

2020 EDITION

A WPI MQP

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4 System Performance……………………………………………………...	Zimak
5 Wildfire Event………………………………………………………………	Zimak
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7 Device Discharge…………………………………………………………....	Zimak
8 Design - System layout…………………………………………………...	Zimak
9 System Activation and Operation………………………………………...	Zimak
10 System Acceptance………………………………………………………..	Fawcett
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12 Inspection, Testing, and Maintenance………………………………….…….	Mitchell

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1. Administration

1.1. Scope*

This standard shall provide a means of evaluation for fixed firefighting systems designed for structures at the Wildland Urban Interface (WUI).

1.2. Purpose*

The purpose of this standard shall be to provide the minimum necessary guidelines for wildfire fighting systems that are designed to respond to and mitigate the threats and non-fire exposures from wildland fires to improve the protection of the structure and mitigate property loss.

1.3. Units and Formulas

All units and formulation shall be stated in both international standard and English standard units.

1.4. Enforcement

The administration and enforcement of this standard shall be done by the authority having jurisdiction designated by the governing authority

2. Definitions

The definitions contained in this chapter shall apply to the terms used in this standard. Where terms are not defined in this chapter, they shall be defined using their ordinarily accepted meanings within the context in which they are used. Merriam-Webster's Collegiate Dictionary, the 11th edition, shall be the source for the ordinarily accepted meaning.

2.1. NFPA Official Definitions*

2.1.1. Approved*

Acceptable to the authority having jurisdiction.

2.1.2. Authority Having Jurisdiction (AHJ)*

An organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, an installation, or a procedure.

2.1.3. Shall*

Indicates a mandatory requirement.

2.1.4. Should*

Indicates a recommendation or that which is advised but not required.

2.1.5. Standard*

An NFPA Standard, the main text of which contains only mandatory provisions using the word "shall" to indicate requirements and that is in a form generally suitable for mandatory reference by another standard or code for adoption into law. Non-mandatory provisions are not to be considered a part of the requirements of a standard and shall be located in an appendix, annex, footnote, informational note, or other means as permitted in the NFPA Manuals of Style. When used in a generic sense, such as in the phrase “standards development process” or “standards development activities,” the term “standards” includes all NFPA Standards, including Codes, Standards, Recommended Practices, and Guides.

2.2. General Definitions*

2.2.1. Acceptance Criteria*

Measurable threshold values based on quantified performance criteria for damage or wildfire effects developed by the system designer.

2.2.2. Discharge Device*

Any system appliance used to apply, spray, or release fire protection solutions.

2.2.3. Duration of the Fire Event*

The time set by the system designer quantifying the amount of time the system

2.2.4. Non-Fire Exposure*

Any daily, seasonal, or natural non-wildfire phenomenon that changes the environment or physically interacts with the system.

2.2.5. Firebrand*

A piece of combusting material that travels via wind and lofting effects from the wildfire.

2.2.6. Goal*

The overall qualitative safety outcome of the fire scenario set by the system designer.

2.2.7. Manufacturer*

The groups who are responsible for the manufacturing of the components used for wildfire-fighting.

2.2.8. Minimum Specified Output Value*

Quantitative values for discharge devices, specified by the manufacturer, that correlate to the minimum conditions discharge devices need for proper function.

2.2.9. Objective*

The quantified actions or outcomes that detail the maximum allowable level of damage.

2.2.10. Protected Asset*

The portion of the structure or surrounding structure that the agent is applied to.

2.2.11. Stated Wildfire Threat*

The specific aspects of a wildfire the system will protect against.

2.2.12. Strong Working Knowledge*

Knowledge, experience, or training in such systems.as designated by the system designer or manufacturer.

2.2.13. Structure*

A usually roofed and walled structure built to protect inside contents from an exterior environment.

2.2.14. System Designer *

The person or group of persons responsible for the design of a wildfire fighting system.

2.2.15. System User*

Any person who uses a wildfire fighting system.

2.2.16. Threat*

Any material or activity that can negatively affect a structure.

2.2.17. Wildfire*

An uncontrolled fire spreading through vegetative fuels, exposing and possibly consuming structures.

2.2.18. Wildfire Fighting System*

Any system which is intended to mitigate the effects of wildfire.

2.2.19. Wildland*

An area where developments are essentially nonexistent, except for roads, railroads, power lines and similar facilities.

2.2.20. Wildland Urban Interface (WUI)*

A geographical area where structures and other human development meets or intermingles with wildland and vegetative fuels.

3. Referenced documents

- NFPA 13: Standard for the Installation of Sprinkler Systems, 2019 Edition
- NFPA 13D: Standard for the Installation of Sprinkler Systems in One- and Two-Family Dwellings and Manufactured Homes, 2019 Edition - Chapter 10 Discharge and Hydraulic Calculations
- NFPA 16: Standard for the Installation of Foam-Water Sprinkler and Foam-Water Spray Systems, 2019 Edition – Chapter 8 System Acceptance

4. System Performance

4.1. Protective Goals*

The protective goals shall be explicitly stated by the system designer.

4.1.1. Capabilities of the system*

Goals shall clearly state the capabilities of the system regarding protection from the stated wildfire threat(s) and structural survivability including any system limitations.

4.2. Objectives*

System design objectives, concerning to the goals shall be explicitly stated by the system designer.

4.2.1. Protected Assets*

Objectives shall define the items to be protected which identify the areas of the structure or structural surroundings that require discharge spray to meet the system design goals.

4.3. Criteria*

System criteria detailing an adequate demonstration of the system capabilities, regarding the goals and objectives shall be quantitative and qualitative as stated by the system designer to demonstrate system performance.

4.4. Assumptions*

System designers and manufacturers shall clearly state all relevant assumptions.

5. Wildfire Event

5.1. Threat(s)*

System designers shall clearly identify, quantify, and state the wildfire threat(s) the system is intended to protect against.

5.2. Fuel Sources*

The location of localized and fuel sources adjacent to the protected structure shall be considered when defining the stated wildfire threats and non-fire exposures.

5.3. Duration of the Fire Event*

The duration of the wildfire event and its calculation method shall be explicitly stated by the system designer.

6. System Components*

The system, devices, components, and materials shall be qualified for their intended protective purposes by the manufacturer for the stated wildfire threats and non-fire exposures and approved for use by the authority having jurisdiction.

6.1. Qualification Methods*

The methods used by the manufacturer to qualify components shall be presented and approved by the authority having jurisdiction.

6.2. Health and the Environment

All system components, agents, or materials shall be constituted of materials that pose minimal risk to the health and well-being of the occupants, the wildlife, and/or the local environment.

6.3. Discharge Devices*

Only new discharge devices shall be permitted to be installed except where allowed by 5.2.1

6.3.1. Used Discharge Devices

Used discharge devices shall be permitted when inspected and tested following the qualification criteria created by the system manufacturer.

6.3.2. Used Discharge Device Criteria*

The manufacturer shall provide the inspection and testing criteria for the application of used discharge devices.

6.4. Piping*

Piping shall be designed and installed to withstand the selected wildfire threats and non-fire exposures.

6.4.1. Attachments*

Attachments affixing system components to the structure shall be designed and installed as per the manufacturer's instructions to withstand the selected wildfire threats.

6.5. Pumps*

Pumps shall be selected and meet the system pressure and water flow demands.

6.6. Spare Parts

A list of necessary spare parts for proper maintenance and system operation shall be provided by the system designer.

6.6.1. Standardization*

Parts shall be standardized for the systems for ease of maintenance and repair.

7. Device Discharge

Discharge device performance shall be quantified and documented by the manufacturer.

7.1. Requirements for Discharge *

The minimum specified output values shall be provided by the manufacturer.

7.1.1. Discharge Testing *

The minimum specified output values shall be derived from testing. Testing shall ensure that an adequate amount of agent reaches the desired protected asset under the conditions of the stated wildfire threat and non-fire exposures.

7.2. Device Output Characteristics *

The device output characteristics shall be quantified through testing by the manufacturer

7.3. Device Spacing and Location *

The device spacing and location requirements derived from testing shall be stated by the manufacturer.

7.4. Installation

Discharge devices shall be installed per the manufacturer's instructions.

7.4.1. Manufacturer's Installation Instructions*

The manufacturer shall provide an installation manual detailing the steps of component installation.

8. System layout

Documentation shall be submitted to the AHJ detailing the layout and calculation method used to ensure all protected assets receive the required discharge Density.

8.1. Required Discharge Density*

The required discharge density to meet the goals of each protected asset shall be determined by the system designer.

8.2. Adequate Coverage*

Devices shall be located such that the device discharge density adequately and uniformly covers the entire surface area of the protected assets with a discharge density equal to or greater than the required discharge density.

8.3. Obstructions*

Devices shall be located such that obstructions or other devices do not hinder the agent path to the protected asset.

8.4. Piping*

The calculation method utilized to select pipe sizes ensuring that sizes are sufficient enough to supply agents to the discharge devices at a value no less than the minimum specified output value shall be stated by the system designer. One of the following methods shall be used to confirm the piping size is adequate for the system.

(1) The hydraulic calculation procedure for NFPA 13.
(2) The Available Pressure Equation for NFPA 13 D
(3) A calculation method provided by the manufacturer approved by the AHJ

8.5. Hangers and Attachments*

System components mounted to a structure shall be affixed to the structure with components that are suitable for the selected wildfire threats and expected non-fire exposures.

8.6. System Controllers*

System control mechanisms shall be located in an area that is easily accessible by the user and is protected from wildfire threats and selected non-fire exposures.

8.7. Pumps*

Pumps and equipment required for pump operation shall be protected from the selected wildfire threats and expected non-fire exposures

8.8. Agent Storage Containers*

Containers used to hold agents shall be protected from the selected wildfire threats and expected non-fire exposures.

9. System Activation and Operation

9.1. System Activation*

The system designer shall fully detail the sequence of system activation.

9.1.1. Automatic and/or Manual System Activation*

Times and conditions for automatic and/or manual system activation shall be specified by the system designer.

9.1.2. The Sequence of System Activation *

The sequence of system activation shall include when each specific discharge device is activated and what event activated the device.

9.1.3. System Delay *

The delay between system activation and device discharge shall be quantified and its calculation method provided by the system designer.

9.2. System Operation*

The system designer shall fully define system operations.

9.2.1. Resources*

The system designer shall state any resource requirements or limitations to the system.

10. System Acceptance*

Documentation shall be submitted to the AHJ acceptance testing conducted on the system after installation that demonstrates that the system meets its defined performance criteria (See Section 4). Fixed exterior wildfire-fighting systems shall be tested per the manufacturer's instructions. Sections 10.1-10.2 provide examples of approaches for water-based and foam-based systems.

10.1. Water-based System Acceptance Testing*

System designers for water discharge systems shall submit to the AHJ acceptance testing per NFPA 13 Chapter 10.

10.2. Foam-based System Acceptance Testing*

System designers for foam discharge systems shall submit to the AHJ acceptance testing per NFPA 16 Chapter 8.

11. System Resilience

The components installed for a firefighting system shall be designed to address proper operation throughout the long-term performance of the system.

11.1. Weathering Protection*

System component weathering capability shall be considered in the long-term performance of the system.

11.2. Incompatible Components *

The system shall be designed, installed, and maintained such that reagents and system components are compatible, with no potential for inadvertent reaction.

11.3. Protection from Freezing*

The system shall be designed to account for the effects of freezing in areas where the temperature cannot be maintained at or above 40°F (4°C).

11.4. Wildfire Protection*

The system shall be designed to withstand the wildfire threats for the duration of the wildfire event.

12. Inspection, Testing, and Maintenance

12.1. Responsibility*

Systems shall be inspected, tested, and maintained following the instructions provided by the entities provided in this section.

12.1.1. Manufacturers*

Clear product maintenance instructions shall be provided by the manufacturer.

12.1.1.1. Shelf Life and Cautionary Information *

The shelf life and cautionary information of the agent(s) shall be disclosed and quantified within the instructions by the manufacturer.

12.1.1.2. System Life Cycle

The life cycle of the system shall be clearly quantified by the manufacturer and its derivation explained.

12.1.2. System Designers

The system designer shall provide an inspection, testing, and maintenance plan outlining the procedures necessary to ensure proper system function.

12.1.3. Hazards *

Any system hazards shall be explicitly stated by the system designer.

12.2. Inspection and Testing*

Any component of the system found to be damaged, corroded, or showing signs of damage shall be replaced with a new component of like properties.

12.2.1. Ensuring Proper System Performance

After part replacement, the system shall be tested per the designer's specifications and shall be visually inspected for leaks and any other criteria specified by the system designer to ensure proper system performance.

12.3. Acceptance Inspection and Testing*

The electrical and mechanical systems utilized during the fire event, along with the system's agent source, shall be inspected and tested before project completion to evaluate a system's ability to withstand and defend the protected assets against the stated wildfire threats and non-fire exposures.

12.3.1. Qualifications for Inspectors

Inspections shall be performed by personnel with a strong working knowledge of the system operation.

Annex A - Explanatory Material

A.1.1 Scope

This standard is appropriate for fixed exterior wildfire-fighting systems intended to protect structures at the WUI from the effects of wildfire. The standard will create a common understanding and language between all stakeholders and is intended to address the variety of different wildfire threats, non-fire exposures, and exterior protection goals. The interior of the building should be protected as per NFPA 13 or 13D where appropriate.

This standard was designed with the manufacturer and system designer in mind, providing a pathway for system acceptance to this standard. Once accepted, the system will be quantified for a selected wildfire threat and protection level, which can be used to communicate the system functions to the user.

Stakeholders include but are not limited to:

(1) System Designers
(2) Manufacturers
(3) Homeowners
(4) Insurance companies
(5) Landlords
(6) Tenants

A.1.2 Purpose

This standard will assist the system manufacturers and designers in the quantification of system capabilities and performance for the duration of the system life with the main purpose of preventing the loss of property from wildfires. By explicitly stating these criteria, the operator will be fully informed with the capabilities and limitations of their system in regard to protection of the structure.

While there are several major code organizations with internationally accepted standards and guidelines for wildfire protection, no organization has a methodology to compare the variety of systems and approaches for protection of the structural at the WUI. Additionally, while other major code organizations have traditionally looked to accomplish the wildfire protection of a structure task with noncombustible construction and a vegetative dead zone of defensible space; this standard looks to utilize an exterior agent application system for added wildfire protection.

This code should be used in conjunction with other local and international codes that concern themselves with the protection of structures at the WUI. They include but are not limited to the following.

(1) The International Wildland-urban Interface Code or IWUIC published by the International Code Council
(2) NFPA 1144 -Standard for Reducing Structure Ignition Hazards from Wildland Fire

A.1.3 Enforcement

The term "authority having jurisdiction," or its acronym AHJ is intently used in a broad manner in order to account for the militia of manners that jurisdiction treat these individuals. The AHJ may be a local fire marshal, wildfire fighting chief, or other regional official designated by others with the authority.

Local legislation is permitted to add additional system requirements to better suit a more specific wildfire threat. In some cases, certain threats, non-fire exposures, protection goals, objectives, or criteria may be set to create a common level of protection across a variety of systems and approaches. These specifications should then be presented in a manner that allows the manufacturer and system designer to efficiently take the guidance from the local legislation and create a system that accomplishes these goals.

A.2 Definitions

Standard text quoted from NFPA 13D 2019 edition.

A.2.1 NFPA Official Definitions.

The definitions from this chapter are sourced directly from NFPA documentation as NFPA's definitions and are sourced from NFPA 13D 2019 edition. Exact definitions complying with the preexisting NFPA framework were used to minimize confusion and maintain alignment with other NFPA codes and standards.

A.2.1.1 Approved

Standard text quoted from NFPA 13D 2019 edition.

A.2.1.2 Authority Having Jurisdiction (AHJ)

Standard text quoted from NFPA 13D 2019 edition.

A.2.1.3 Shall

Standard text quoted from NFPA 13D 2019 edition.

A.2.1.4 Should

Standard text quoted from NFPA 13D 2019 edition.

A.2.1.5 Standard

Standard text quoted from NFPA 13D 2019 edition.

A.2.2 General Definitions

Definitions in this section were influenced by definitions contained in the SFPE handbook 5th edition, Merriam-Webster's Collegiate Dictionary, 11th edition, the ICC International Wildland-Urban Interface Code 2018 edition, and a multitude of NFPA codes and standards including

NFPA 101 2018 edition, NFPA 13 and 13D 2019 editions, and NFPA 1144 2015 edition. The following definitions were stated to provide clarity and consistency throughout the standard and create a common language for this standard. The following annex text also states when these definitions are sourced directly from or inspired by adjacent NFPA and ICC codes and standards, the Merriam-Webster's Collegiate Dictionary, or SFPE documentation.

A.2.2.1 Acceptance Criteria

These criteria should be scientifically derived and adequately represent the protection goals and objectives. Inspired by the SFPE Handbook performance-based design chapter, 2016 edition.

A.2.2.2 Discharge Device

Intended to apply to any variation of nozzles that discharge agent from the system with the goal of providing protection.

A.2.2.3 Duration of the Fire Event

Intended to allow the quantification of the wildfire with respect to time. This time serves as a quantification of the systems capabilities. This standard requires that the system designer define this time period based on the wildfire threat in order to assess the ability of the system to protect a structure.

A.2.2.4 Non-Fire Exposure

Definition inspired by the Merriam-Webster's Collegiate Dictionary, 11th edition and the need to distinguish the simplified term "exposure" from its traditional Fire protection definition. These none-fire exposures related to all the other factors that will affect the wildfire system once installed.

A.2.2.5 Firebrand

Inspired by a multitude of available definitions and intended to refer to combusting particles that travel from the wildfire.

A.2.2.6 Goal

Definition inspired by the SFPE Handbook performance-based design chapter, 2016 edition.

A.2.2.7 Manufacturer

May also be the system designer. Intended to represent all groups that fabricate components used in the system.

A.2.2.8 Minimum Specified Output Value

The minimum specified output value is intended to ensure the device operates as stated by the system manufacturer and provides the stated protection within its tested boundaries. These values may take the form of the below values.

(1) Minimum operating pressure
(2) Minimum operating flow
(3) Minimum requirement of agent

Regardless of the type of system, each discharge device will have a minimum requirement in order to ensure the device can function as intended to by the manufacturer.

A.2.2.9 Objective

Definition inspired by the SFPE Handbook performance-based design chapter, 2016 edition.

A.2.2.10 Protected Asset

Intended to apply to any item that the gent is specifically applied to. Usually specified by the system designer but can include input from any of the stakeholders. May include any of the following.

(1) Decks
(2) Roofing materials
(3) Exterior siding or wall materials
(4) Exterior columns and beams
(5) Windows and window assemblies
(6) Foliage located proximal to the house

A.2.2.11 Stated Wildfire Threat

The wildfire is quantified by the system designer. The intent of defining the wildfire is hold the system accountable for its intended protection purposes.

A.2.2.12 Strong Working Knowledge

Intended to quantify the requirements for all personnel that install or perform inspections, tests, and maintenance on a specific system. When defined by the system designer, these persons can interact with the system. The manufacturer may further define more stringent requirements for personnel that perform services on specific parts of the system

A.2.2.13 Structure

Definition inspired by the Merriam-Webster's Collegiate Dictionary, 11th edition.

A.2.2.14 System Designer

The system designer is responsible for combining multiple components and devices in a way that meets the design goals. May also be the same entity that manufacturers devices or components of the system.

The separation between the system designer and manufacturer is to account for the difference in responsibility of these two groups. The manufacturer will focus should be on quantifying components for wildland fire protection use and the protection provided by these components for the general case. The system designers focus should be on the combination of these components to accomplish the fire protection goals for the specific structure being protected.

A.2.2.15 System User

System users include but are not limited to the following.

(1) Residence owners
(2) Residence operators
(3) Tenants
(4) Landlords

A.2.2.16 Threat

Definition inspired by the Merriam-Webster's Collegiate Dictionary, 11th edition.

A.2.2.17 Wildfire

Definition sourced directly from ICC International Wildland-Urban Interface Code, 2018 edition.

A.2.2.18 Wildfire Fighting System

Intended to refer to any system that interacts with the exterior of the structure and has a goal of protection of the structure.

A.2.2.19 Wildland

Definition sourced directly from ICC International Wildland-Urban Interface Code, 2018 edition.

A.2.2.20 Wildland Urban Interface (WUI)

Definition sourced directly from ICC International Wildland-Urban Interface Code, 2018 edition.

A.4.1 Protective Goals

The goals selected by the designer should communicate the overall system performance and expectations. Goals should consider multiple stakeholder interests. Stakeholders may include the following

(1) Homeowners
(2) Tenants
(3) Insurers
(4) Neighbors
(5) Emergency first responders

Goals should be specific, measurable, and easily understood by the common homeowner and state any assumptions. Example goals may include.

(1) Prevent structural ignition from firebrands assuming the wildfire does not penetrate the 100-foot defensible space perimeter around the structure.
(2) Extinguish spot fires that may occur proximal to the structure due to localized vegetation and deadfall collected on a roof.
(3) Control the ignition of organic materials and structural components 30 feet out from the structure in order to prevent wildfire progression towards the structure which would result in radiant heat damage to structural members.

A.4.1.1 Capabilities

Each goal should be defined in a way where the intended capabilities of the system are defined. Design goals should clearly indicate to a user the intended application of the system in relation to wildfire protection which may include the following.

(1) Controlling
(2) Suppressing
(1) Extinguishing

When structural survivability is head paramount, goals should consider the following

(1) Interior protection
(2) Exterior protection
(3) Structural member protection

A.4.2 Objectives

Sample objectives include but are not limited to

(1) Interior survivability

(2) Exterior survivability
(3) Structural survivability

Where survivability may be defined by
(1) A certain threshold for fire damage
(2) Protection from radiant heat
(3) Smoke infiltration thresholds
(4) Exterior charging thresholds

Example objectives for a goal of controlling exterior combustion due to firebrands from a fire that comes no closer than 100 meters away from a structure in compliance with NFPA 1144 may be the following.
(1) Preventing the destruction of the exterior deck
(2) Extinguishment of all firebrands that collect on the exterior of the structure before exterior combustion
(3) Prevention of smoke penetration to the interior of the building

A.4.2.1 Protected Assets

Protected assets are any portion of the structure or anything the system is designed to protect through the application of the agent. These assets will need to be within the application distance of the discharge device.

While it may be easier to define the whole structure as a protected asset, the individual exterior components on the structure should be individually selected to provide for better protection as different structural components may require varying levels of protection based on the goals and objectives.

Protected assets may include the following.
(1) Decks
(2) Roofing materials
(3) Exterior siding or wall materials
(4) Exterior columns and beams
(5) Windows and window assemblies
(6) Foliage located proximal to the house

Items located inside the structure that discharge devices do not explicitly discharge onto are not considered protected assets.

A.4.3 Criteria

System performance criteria include any values that once exceeded indicate a failure of the system. These criteria will then be used in trial designs to demonstrate the adequate performance of the system. Criteria may include the following

(1) A specified radiant heat flux value on protected assets
(2) Temperatures of protected assets
(3) Percentage of protected assets damaged, charred, or burned
(4) Concentration or quantity of collected firebrands
(5) Interior or structural damage thresholds

Example performance criteria include the following for the objective of protecting the destruction of a wooden exterior deck

(1) Prevent firebrands from accumulating such that there is no flaming ignition
(2) Maintain a moisture content of greater than 20% to decrease the necessary radiation energy intensity for combustion of wooden members to less than 1 cal/cm^2/sec (sourced from the Fire Protection Handbook, 6-67)
(3) No more than 10% of the deck is charred

The designer must quantitatively present the result of the system capabilities in the context of the system goals and objectives. Demonstrations of quantitative system capabilities include but are not limited to.

(1) Hydraulic calculations
(2) Fire model testing
(3) Full-scale fire tests

A.4.4 Assumptions

Many Structures at the WUI comply with NFPA 1144 (Standard for Reducing Structure Ignition Hazards from Wildland Fire). The system designer should check with the user to ensure that there is defined defensible space on the property. Any deviations, both planned and current, should be considered by the system designer when creating systems goals, objectives, and criteria. The assumptions should include at a minimum the following.

Assumptions should be derived for empirical data or be derived from calculations and may include the following.

(1) Wildfire HHR based on fuel sources
(2) Wildfire speed based on vegetation, slope, and expected wind conditions
(3) Wildfire direction of attack based on geographical data

(4) Total occupant evacuation
(5) Compliance with NFPA 1144

A.5.1 Threat(s)

It is the system designer's job to quantify what the fire that the system will protect against. Threats should be selected to best represent the level of protection of the system. Specific quantification is important to ensure the system is tested to a predesignated standard and adequate in its protection. Example wildfire threats may include the following.

(1) Firebrands
(2) Direct flame contact
(3) Radiant heat

It should be noted that these threats may be from either the wildfire flam from or adjacent fuels such as plant matter on a roof, localized vegetation, adjacent structures, or other man-made items.

The quantification of the fire is perhaps the most important yet most difficult task for the system designer. The variety of wildfire input parameters prevents the simple calculation of an expected heat release rate or firebrand generation rate. The intent in quantifying the fire threat is to require the system designer to investigate what the expected specified wildfire threat would be. The designer will then have a specified wildfire event for them to model and test their system against. If the system meets the design goals and objectives, then the system can be considered qualified for the specified wildfire threat. It is also important to note that the wildfire event must either be modeled or tested against the system. There is a possibility that the necessary information to quantify the wildfire threat is unavailable to the system designer or the technology necessary to specify a specific threat is not yet available. The system designer would in that case either need to create this technology, calculation method, or test, or revise their wildfire threat to be within the limitations of the technology and wildfire science available. All assumptions should be made in a scientific manner, and the methodology used to make these assumptions should be stated.

If the designer attempts to quantify a wildfire event for a firebrand protection system, the "firebrand storm" should be quantified. This "storm" could be defined as a flux of firebrands expected including expected firebrand characteristics. Data to quantify firebrands is available from the Angora Fire and the NIST Dragon family of firebrand generators (Manzello & Foote, 2007). The data received from the Angora Fire can support the quantification of firebrand size for a wildfire. It should be noted that while these results only represent one set of data from an area surrounding unburns and damages homes that were in the path of the wildfire.

From the Angora Fire, almost all firebrands (85%) were less than 0.5 cm^2 in size (Manzello & Foote, 2007). The system designer may then choose to physically represent this wildfire threat within a replicable manner by utilizing a firebrand generator. Most recently, work at NIST utilizes the NIST Dragon for firebrand production as it can effectively replicate this size distribution.

The number of firebrands per area over time, or mass flux, is dependent on the fuel characteristics and size of the wildfire. As the firebrand flux is dependent on a mass feed rate, a worst-case firebrand flux can be ascertained by the system designer and utilized for testing (Manzello, et al, 2012).

When a NIST style firebrand generator is used, the blower speed sets how many firebrands are ejected from the apparatus. This value should be selected and be representative of the expected wildfire threat. Other bench-top and full-scale firebrand tests have used blower speeds in the range of 7 m/s. In the case that a similar device is used, and the ejection criteria are unknown, a quenching system that catches firebrands to be later dried and studied should be used to quantify the firebrand generation.

Where threats as can include localized vegetation that is not in accordance with NFPA1144, values for rates of heat release should be identified. The heat release rate (HRR) of coniferous vegetation is well documented for Christmas tree type vegetation. Plastics and other manmade materials may be taken from literature. For specialize foliage, a botanist or another qualified expert with knowledge of how vegetation burns may be required to categorize local fuels. When unable to specifically quantify a specific threat, an engineering estimate with a provided safety margin can be used. This estimate should be backed up with relevant theory and assumptions that lead to the estimate.

Radiant heat is typically not the main concern when it comes to wildfires as the effects of firebrands and direct flame contact typically are the main pathways for structural ignition. However, radiant heat is one of the most well studied and understood products of wildfire (Caton, et. al. (2016). While defensible space and proper vegetation selection help prevent the direct effects of radiant heat on a structure, the second and third-order effects result in hotter and drier environments that the structure and surrounding environment will be in. These effects should be considered when assessing the criteria of the structure and may include the following.

(1) A dryer atmosphere
(2) A rise in ambient temperature that will pre-warm fuels.

(3) A loss in water content at exposed structural components
(4) Lower water content of adjacent vegetation

A.5.2 Fuel Sources

In a wildfire event, all localized fuel sources should be considered as potential threats to the structure. Adjacent structures and fuel sources may include.

(1) Adjacent structures such as other houses, sheds, barns, detached garages, or outhouses
(2) Flammable materials near the structure such as vegetation, debris, firewood piles, anything stored under the decking, and other materials that may catch fire easily and facility flame spread to the structure
(3) Trees or overhanging branches adjacent to the structure
(4) Materials identified by NFPA 1144

Threat(s) should incorporate the fire effects of adjacent fuel sources including but not limited to

(1) Additional firebrands' generation
(2) Additional radiant heat
(3) Additional opportunities for direct flame contact

A.5.3 Duration of the Fire Event

The fire event duration starts at the time of system activation and lasts until the structure is safe from the wildfire threat and no longer requires the system. The calculation method is required to be stated by the system designer to communicate how this value was calculated and to better inform the user of the limitations of their system.

The duration of the wildfire event timeline can be broken down and thought of the addition of three main pieces, below.

(1) The time from system activation prior to the arrival of wildfire threats
(2) The time the wildfire flame front takes to progress through the system's zone of influence
(3) The time after the wildfire progresses through the system's zone of influence but the system is still required to meet the goal and objectives.

Depending on the goals and objectives of the system, additional segments may be necessary.

<u>System Activation Prior to the Arrival of Wildfire Threats</u>

System activation should occur early enough to allow the agent(s) to be applied in a timely manner. This amount of time will differ between agent(s) and the protection goal(s). For example, a system designed to pre-wet mulch and wooden exterior features such as a deck will need to start sooner than systems designed to extinguish spot fires. This information will need to be quantified by the system designer and should be derived from scale fire tests of mathematical models. Test or model methods to identify the necessary amount of time between system activation and discharge may include the following

(1) Scale or full-size testing with a section of the protected asset against the quantified wildfire threat demonstrating achievement of design criteria such as protected asset water content under the conditions specified by the quantified wildfire threat.
(2) A model that demonstrates with input parameters that equate to the quantified wildfire threat that can calculate the time inclusive of some safety factor is enough to meet the design criteria.

These tests or models should ensure that once the system has adequate time to discharge agents before the arrival of the first effects from the wildfire threat. In the case where the system's goals are prewetting, the system designer should state the necessary time the system must be activated before protection is achieved.

In cases where the system operates in a reactionary mode, such as the extinguishment of spot fires, the difference between detection of a fire threat and discharge should be stated by the system designer. This value will be affected by the goals and objectives, the quantified wildfire threat, and the detection technology used. The system designer should in this case state how the wildfire threat is to be detected, and the calculated response time to that threat.

<u>Wildfire Flame Front Progression.</u>

The system's zone of influence refers to the area the system protects plus the area surrounding the system where wildfire threats may be generator and progress into the protected area. This area is likely to fall in the range of 100 feet away from the structure, as per the defensible space requirements of NFPA 1144. During this time, the system will be providing protection for the structure and can be fully activated

There are several main variables that affect the forward spread of wildlife. The effects of expected fuels, wind speeds, slope should all be considered when designing the expected wildfire event. Additionally, the geographical location of the structure at the WUI will greatly affect how long the wildfire threats will be near the structure. All these factors should be considered, along with historical data, when setting the Wildfire flame front progression time.

Wildfire prediction models and methods should be used to figure out this time and account for the multitude of variables. The input variables and calculation methods are required to be presented to the AHJ for review.

After the Wildfire Progression

The end of the wildfire event should represent the time where the system is no longer needed for protection of the structure. This time may be long after the wildfire passes, as additional firebrands, reignition of localized fires, or delayed burning effects may still threaten the structure. This time should be calculated considering the goals and objectives as well as the started wildfire threat.

One method to calculate this value is by modeling the effect of localized combustibles after the wildfire has progressed past the house. Large fuels are likely to still be smoldering and may have the potential to ignite smaller localized fuels or create firebrands.

When not possible to clearly define the length of time necessary for the duration of the fire event time, another option is to protect the structure for as long as possible given the local resources. Based on the system discharge requirements and resource needs, the length of time stored resources will last the system can be calculated.

For instance, if there are 10,000 gallons of stored water on site, and the system discharge requires 500 gallons per hour, the stock will last 20 hours from system activation. While this method does not actually quantify the wildfire, it does communicate to the user how long the system will last which will allow for better system quantification.

A.6 The System Components

The components of the system will need to withstand a multitude of natural and wildfire effects while maintaining the ability to operate. It is the job of the system designer to select appropriate parts for the system to ensure proper operation. It is the job of the manufacturer to verify that the components designed for the wildfire system can withstand these effects through testing and quantification of the components' capabilities.

A.6.1 Qualification Methods

There exists a variety of tests published and performed by internationally recognized listing laboratories. These tests are intended to be used as an equivalency to the qualification requirements in this section. When not available the manufacturer will be required to provide test methods to quantify the effects of the products of combustion on fire protection components. These components may be tested and qualified for the following products of combustion in relation to the specified fire threat.

(1) Radiant heat
(2) Combusting material such as firebrands
(3) Direct flame contact
(4) An increase in ambient temperatures
(5) A decrease in atmospheric water content

In systems intended only to prewet the surface of protected assets, the system components may only need to withstand the effects of firebrands, an elevated ambient temperature, and lower atmospheric water content. The components should then be tested and qualified for use in this environment. However, if a system is to be designed to actively suppress an approaching wildfire flame front, the system components will need to be tested to a much more robust standard potentially including the effect of radiant heat and direct flame contact. While the manufacturer oversees qualifying the use of their products, it is the role of the system designed to ensure that the qualifications of the system components match the intended use.

Components must be able to withstand both the products of the wildfire and routine non-fire exposures due to the location of exterior components. The protection of components due to routine non-fire exposures is detailed in section 10.

A.6.2 Health and the Environment

As the motivation for the creation of this standard was driven by the need for structure at the border with wildlands, negative environmental impacts were always intended to be mitigated. While it at times be necessary to meet the protection goals to utilize a component, agent, or material that can negatively impact the local ecosystem, this should be avoided whenever possible.

A.6.3 Discharge Devices

The intent in restricting the use of used discharge devices is to ensure that all devices installed qualified for protection against the wildfire threats over the system lifespan. When the manufacturer allows, used discharge devices can be used as long as they meet the inspection and testing criteria set forth by the manufacturer.

A.6.3.2 Used Discharge Device Criteria*

The inspection and testing criteria developed by the system manufacturer should prove that the device is able to perform the same discharge criteria as a new device over the same system lifespan. These criteria may include the following

(1) A visual damage inspection
(2) Pressure tests
(3) Waterflow tests performed by the system manufacturer

A.6.4 Piping

When piping is installed on the exterior of a structure, the effect of the selected wildfire event and non-fire exposures should be considered on this piping. Piping may be installed under the roof a protected structure or enclosed in a protective component. In these cases, the piping should still be accessible for maintenance.

A.6.4.1 Attachments

The selected wildfire threat will define what the system attachment should be tested against to quantify their use in a wildfire protection system. The manufacturer should then define the installation method necessary for the selected wildfire threat. This may include quantifying the attachment and installation methods for a specified wind speed.

A.6.5 Pumps

The system designer should select a pump that adequately fulfills the needs of the system including providing the necessary pressure and volumetric flow. Before properly selecting a pump, there must be a calculation of the necessary flow and pressure at the inlet. This calculation and its method should be presented by the system manufacture and consider pressure losses due to a change in height, pressure losses due to friction, and other discharge device pressure and flow losses.

Care must be taken to ensure the system provides a net positive suction head available that is greater than the Net Positive Suction Head in order to avoid pump cavitation. This can be accomplished through implementing process controls that prevent low pressure at the pump inlet or through design controls that locate pumps where the available pressure head will always be greater than the pet positive suction head.

A.6.6 Spare Parts

The list of necessary spare parts should include all the parts necessary for system maintenance. This list intended to contain all the parts the system user should have on hand in case of a system malfunction or break. This list may include the following.

(1) Replaceable components for discharge devices
(2) Replacement fittings
(3) Extra O-rings
(4) A pipe or tube leak sealing kit

A.6.6.1 Standardization

When possible, the system components should be on a standardized size for ease of maintenance and emergency repair. Standardization may include common fitting sizes, connections, treads, or pipe diameters.

A.7 Device Discharge

Discharge devices are required to have a prescribed discharge and spray criterion provided by the manufacturer. The manufacturer must develop the criteria and acceptable test methods to prove that the device operates as stated. This testing will also help the manufacture quantify and verify that device design such as nozzle and orifice sizes are adequate and backed by a provided test method.

The quantification of the discharge and spray criteria is necessary for the system designer to select an appropriate device to protect the selected protected asset in relation to the goals, objectives, and fire threat.

A.7.1 Requirements for Discharge

The minimum specified output values are intended to ensure the device operates as stated by the system manufacturer and provides the stated protection within its tested boundaries. Discharge devices are required to maintain an adequate rate of agent application described by the manufacturer for the selected protected asset. These values are required to be derived from the qualification testing performed by the manufacturer.

A.7.1.1 Discharge Testing

Discharge device testing is required to ensure the discharge is sufficient to meet the goals and performance criteria in relation to the stated wildfire threat. These tests should occur under the conditions the device is designed to protect against and may include the following.

(1) Scale model fire testing
(2) Waterflow testing
(3) Pan tests
(4) Water droplet size quantification tests
(5) Hydraulic modeling

An example test that a manufacturer may want to run to quantify the spray pattern is a pan test such as the test provided in UL 199. This test, or a variation thereof, can be used to confirm that the spray radius stated to be utilized in device installation and system design is correct. Typically, this radius would also be accompanied by a minimum required pressure or flow to ensure that the system is able to provide adequate agent to the discharge device.

A.7.2 Device Output Characteristics

The output characteristics of the discharge device are required to be quantified for the system designer to properly design the system to meet the protection goals. Discharge criteria testing data may include the following.

(1) Spray radius
(2) Discharge density
(3) Volumetric flow rates
(4) Spray patterns
(5) Spray coverage
(6) Droplet size
(7) The maximum distance between adjacent devices

A.7.3 Device Spacing and Location

Spacing and location requirements are required to be set by the manufacturer to allow the system designer to properly locate discharge devices. The manufacturer is required to perform testing in order to qualify the spacing criteria. The testing should take into consideration the geometry and orientation of the protected asset. This testing may take the form of the following.

(1) A full water flow test on a model structure that can demonstrate adequate coverage of the protected asset.
(2) A hydraulic model input with discharge and output characteristics that can model the discharge spray in relation to the structure

The manufacturer will need to consider many factors when specifying the spacing and location requirements for discharge devices. It is recommended that an equation be utilized that considers the factors that affect the discharge spray such as distance from the discharge devices to protected asset and output values.

A.7.4.1 Manufacturer's Instructions

The installation manual should detail each aspect of device installation. This manual should also contain the spacing and location requirements, output characteristics, and discharge requirements. Additionally, an overview of the methods used to service these values should be provided including any relevant assumptions and constraints of testing.

A.8 System Layout

The intent of the design section is to provide the system designer with a process to document how and why the system components were combined in the manner specified by the designer to protect the structure. Calculation methods and diagrams are required to be presented to the AHJ with the intent of confirming that all protected assets receive adequate discharge spray. The design of the system should include the following

(1) The layout and location of each discharge device overlay on an engineering document of the structure.
(2) The location and description of each protected asset
(3) The amount of agent required to protect the asset, required discharge density, and the calculation method used to derive this amount
(4) The amount of agent expected to contact the protected agent and the calculation method used to derive this amount

A.8.1 Required Discharge Density

The system designer is required to select the discharge density required to protect the assets from the selected wildfire threats over the duration of the wildfire event. This density should be derived from the thermodynamic properties or tests of the asset and relate back to the protection goals, objectives, and criteria.

Each protected assist will require a different discharge density for protection. When a specific required density cannot be derived, an engineering judgment should be made. This judgement should be based on scientific methods that are reproducible. Options include the following.

(1) A scale fire test
(2) Calculations utilizing data derived from a listing laboratory or other recognized testing authority that quantifies the fire characteristics of the protected asset
(3) Consulting an expert (such as a botanist or manufacturers engineer) to derive an amount of agent discharge that would be adequate to meet the system goals.

A.8.2 Adequate Coverage

Device discharge should generally equally cover the entire protected assist. Device discharge patterns should overlap when necessary to provide the required discharge density.

One method of confirming adequate coverage if the system is the utilization of s spray overlay on an engineering document. This overlay should show the location of each discharge device and the devices spray radius based on the device manufacturers information. Care should be taken to account for variables that may change the spray characteristics, including the following.

(1) Distance from the protected asset to the nozzle
(2) Orientation of the protected asset

(3) The effects of wind
(4) The effects of other discharge devices

A.8.3 Obstructions

Devices should be located far enough in distance from obstructions such as gutters, poles, other devices, roof peaks, and other structural components. When not possible, multiple devices should be used in conjunction to cover the protected compound.

A.8.4 Piping

Piping selected by the system designer must supply the discharge devices with adequate agent. The system designer must take into account a variety of losses throughout the system. Pressure losses that should be accounted for during this calculation method include the following.

(1) Pressure losses due to a change in elevation.
(2) Pressure frictional losses as agent flows through the piping and connections
(3) Pressure losses as agent flows through other system devices
(4) Pressure losses from discharging devices.

Regardless of the calculation method used, all values should be appropriately sourced. These sources may include values presented in NFPA publications, manufacturers documents, or scientific publications. If values are unavailable for a given piping type, the system designer may provide a test method that ensures that the system provides a discharge equal to or greater than the Required Discharge Density.

<u>The Hydraulic Calculation Procedure for NFPA 13.</u>

The intent of allowing the full NFPA 13 hydraulic calculation procedure is twofold. First, the procedure is widely utilized in the fire protection community. The second is that there exist a multitude of software applications that can be utilized to perform these calculations.

The hydraulic calculation procedure for NFPA 13 accounts for a multitude of variables and frictional losses. The methods locate the most hydraulically remote sprinkler and works back to the agent supply. The hydraulically most remote sprinkler should be either clearly defined through the calculation method as the furthest sprinkler may not always be the most remote.

If the agent is not predominantly water or if the agent's hydraulic behavior deviates from that of water, these deviations should be accounted for in the calculation method. The Hazen–Williams formula used to calculate the frictional resistance, or pressure drop per foot, accounts for the flow of agent, pipe diameter, and a frictional loss coefficient. The Hazen–Williams C factor may be either calculated through methods provided in the hydraulic calculation procedure for NFPA

13 or from the manufacturer's documentation. The K-Factor formula may be used to determine the k factor for the discharge device. Equivalent pipe lengths and valves or other devices may be used from either the provided tables in NFPA 13 provided they are corrected for pipe schedule and type or documentation provided by the manufacturer.

When all the discharge devices are intended to discharge at the same time, all devices should be calculated. A hydraulic calculation sheet or program may be used by the system designed to assist in the calculation when using this method.

This method utilizes a variety of equations to calculate head losses throughout the system. Some of these equations sourced from NFPA 13: 2019 edition - chapter 27 Plans and Calculations are presented below.

The Hazen–Williams formula

$$P = \frac{XQ^{1.85}}{C^{1.85}d^{4.87}}$$

Where
X = 4.52 for empirical and 6.05 in SI units
p = frictional resistance (psi/ft of pipe) or (bar/m of pipe)
Q = flow (gpm) or (L/ min)
C =friction loss coefficient
d = actual internal diameter of pipe (in.) or (mm)

K-Factor Formula

$$K_n = \frac{Q}{\sqrt{P}}$$

where
K_n= equivalent K at a node
Q =flow at the node
P =pressure at the node

The Available Pressure Equation modified from NFPA 13 D

The intent of calculating the available pressure through the available pressure equation is to allow a simplified calculation method for simple systems. This method subtracts a variety of pressure losses from the available pressure provided by the supply. A total available pressure is then calculated which represents the available pressure for frictional pipe losses. If the frictional pressure losses are larger than the available pressure, a large diameter pipe must be used. The calculation procedure should follow the methodology provided in NFPA 13 D chapter 10.

A modified version of this equation from NFPA 13D, 2019 edition - Chapter 10 Discharge and Hydraulic Calculations is presented below.

$$P_t = P_{sup} - PL_{suc} - PL_d - PL_e - P_{sp}$$

P_t= available pressure
P_{sup} = pressure available from the water supply source
PL_{suc}= pressure loss in the water supply pipe
PL_d = pressure loss from devices
PL_e = pressure loss associated with changes in elevation
P_{sp} = maximum pressure required by a sprinkler

<u>A calculation method provided by the manufacturer</u>
The manufacturer should derive the calculation method for hydraulic testing. This method, at a minimum, should identify the major losses in pressure due to the following.

(1) Friction losses between the agent and piping
(2) Elevation losses
(3) Losses from devices

Additionally, this method should be approved by the AHJ and checked by a third part in order to ensure the validity of the calculation method.

A.8.5 Hangers and Attachments
Hangars and attachments should be firmly mounted to a sturdy portion of the structure. Attachments should be spaced in a manner that supports the weight of the system components multiple by a safety factor. The suggested use of safety factor is greater than 5 (NFPA 13).

The methodology utilized in the 2019 edition NFPA 13 chapter 17: Installation Requirements for Hanging and Support of System Piping may be utilized provided appropriate provisions are taken account for the special circumstances presented wildfire protection. As an example, the hangers and attachments must be able to withstand the shear forces from wind.

The manufacturer should state where components can be used and under what conditions. These conditions should be derived from a test method created by the manufacturer that includes these wildfire factors.

A.8.6 System Controllers

The system controller may be mounted on the exterior of the structure and is constructed and installed in a manner that protects the device.

A.8.7 Pumps

Pump protection may include the following

(1) Classification of the pump as a protected asset and the installation of a wildfire fighting system.
(2) Installation within a protected enclosure

A.8.8 Agent Storage Containers

Protection for these containers may include the following

(1) Classification of the containers as a protected asset and the installation of a wildfire fighting system.
(2) Installation within a protected enclosure

A.9.1 System Activation

The sequence for system activation is required with the intent that the system designer states the key information necessary to qualify the system. This information should include how many devices and what times in the activation cycle will discharge, how fast the devices can discharge, and how the system designer arrived at these values.

System activation refers to the process of initiating the supply of agents to discharge devices. In some cases, the user may choose to "arm" or prepare the system such as turning on a power source or by providing the first of a two-factor activation sequence as the user leaves the structure. This action is not considered activating the system.

A.9.1.1 Automatic and/or Manual System Activation

System activation should start with a clearly definable interaction such as a sensing device reaching a predetermined threshold or input from the user. The times and conditions for activation should be explicitly stated for the user so that they are able to effectively interface with the system.

Manual system activation may be initiated by the following.

(1) The user activates the system through physical interaction such as pushing an "activation" button or flipping a switch
(2) The user activates the system through a communication network such as sending a text message
(3) The user elects to delay activate the system and after a pre-programmed time, the system activates.

Automatic system activation may be initiated by a detection device such as heat, flame, or video identifies a fire threat and activates the system.

A.9.1.2 The Sequence of System Activation

Each discharge device is required to be assigned an activation event. In cases where the whole system activates at once, the sequence of system activation is required to specify that the whole system including all the devices will be activated at once at the same time. In cases where portions of the system activate at different times, each discharge device is required to be assigned the event that will activate it. This may take the form of devices 1-20 on the west side of the structure activate one an automatic heat detector reaches a predetermined temperature and signals to activate the west side discharge devices. The other devices are also required to have assigned activation criteria.

A.9.1.3 System Delay

The delay between system activation and the time between device discharge may include the following.

(1) Time for the agent to fill the system piping which can be hydraulically calculated by dividing the volume of the system piping by the input flow rate in the dry pipe type system. In systems utilizing a pump, the input flow rate is equal to the pump flow rate. In systems connected to a residential water outlet such a hose, a flow rate test should be completed to identify the inlet flow rate of the residential water outlet.
(2) The time between system alarm and pump activation dependent on pump startup operations and set by the pump manufacturer

A.9.2 System Operation

The systems designer should detail every part of the systems operation process including, but not limited to the following.

(1) When and under what conditions the system will discharge the agent.
(2) When the system re-evaluates the wildfire threat
(3) If and when discharge criteria changes
(4) Any notification, alarms, or communication to the system user
(5) When or during what conditions the system shuts down

A.9.2.1 Resources

Resources necessary for successful system operation should be calculated to be available at least as long as the duration of the fire event from system activation to system shutdown. A variety of resource may need to be available based on the system and the system operations. Some resources include the following

(1) Electricity
(2) Backup power
(3) Wi-Fi
(4) Cellular service
(5) Fuel
(6) Agent

That calculation to ensure that resources are available may include calculating the demand of the system per a unit time, multiplying this value by the duration of the wildfire or duration of necessity for proper operation, and then ensuring the resource demand is less than that of the available resources.

The following should be considered when planning for resources.

(1) Other draws on the resources
    (a) What other users will be utilizing and how much from the same lake or water main?
(2) Reliability of resource availability
    (a) Will and when will the lake, pool, holding tank, or other agent source be exhausted?
(3) Reliability of the supply system used to get the resource to the system if any
    (a) How much fuel can the pump hold and how long will this last?
    (b) How long can the pump continuously operate?
(4) Will power be available, or must it be provided?
    (a) What is the reliability of power?
    (b) Are batteries present and properly sized in order to ensure the system can operate for the duration of the wildfire event.
(5) Will the internet, cellular, or phone coverage be available and what is its reliability?

Additionally, the environmental impact of the use of these resources should be questioned. When agents are drawn from natural sources such as lakes, rivers, or ponds, an environmental impact assessment should be performed as to mitigate any potential environmental damages.

A.10 System Acceptance

Performance test methods that system manufacturers must conduct on the installed system should be specific to the wildfire threats the system is designed to address. For instance, a system designed to address the threat of wildfire firebrands should be tested for its efficiency of preventing spot fires, managing firebrand build up, etc.

A.10.1 Water-based System Acceptance Testing

NFPA 13 addresses the following acceptances testing for interior factors.

(1) Acceptance Requirements
   (a) Hydrostatic Tests for Pressure of System Piping
   (b) Test Blanks
   (c) Dry Pipe and Double Interlock Preaction System(s)
(2) System Operational Tests
   (a) Waterflow Devices
   (b) Dry Pipe Systems
   (c) Deluge and Preaction Systems
   (d) Pressure-Reducing Valves
   (e) Backflow Prevention

System designers should consider how NFPA 16 match components of their system design.

A.10.2 Foam-based System Acceptance Testing

NFPA 16 addresses the following acceptance testing for interior factors.

(1) Hydrostatic Pressure Tests for Pressure of Concentrate Lines and System Piping
(2) Acceptance Tests
   (a) Approval of System by System Installer
   (b) Proportioning System Testing
   (c) Rate of Discharge Computed from Hydraulic Calculations
   (d) Post-operation System Flushing

System designers should consider how NFPA 16 match components of their system design.

A.11 System Resilience

The system components must be rated to address the long-term performance within the system. The phrase "long term" refers to the approximate lifetime of the component. These components must be able to withstand the standard daily conditions in addition to performing in response to a wildfire event.

A.11.1 Weathering

Weathering should be considered to assist in the evaluation of system capabilities over time and the long-term resilience of the system. System manufacturers should state the resistances to exterior weathering non-fire exposures for the components utilized in the system design. Examples of exterior weathering non-fire exposures include the following.

(1) Wind
(2) Natural heating or freezing ambient temperatures
(3) Sunlight exposure
(4) Local wildlife

A.11.2 Incompatible Components

Components and reagents should be selected by the system designer in order to prevent the combination of incompatible materials within the system. Examples of incompatible components include the following.

(1) Agents that are corrosive to selected system components
(2) Systems components that are incompatible with each other.
(3) Bonding agents that damage system agents.

A.11.3 Protection from Freezing

The suggested method of freezing protection is the use of a dry pipe type system with drains that allow for system purge. Where wet pipe type components and piping are installed on the exterior of a structure or in areas that cannot be confirmed to prevent temperature drops, any of the following can also be used to prevent system freezing. NFPA 13D, Standard for the Installation of Sprinkler Systems in One- and Two-Family Dwellings and Manufactured Homes, should be used in addition to this standard when applying any of the below provisions.

(1) Antifreeze systems
(2) Heat tracing
(3) Dry pipe segments extending out of heated areas containing a wet pipe system

A.11.4 Wildfire Protection

System components and layout should be able to withstand and perform for the full the wildfire event. The system designer should consider the following elements of a wildfire event.

(1) Radiant heat on the system discharge devices and other exposed system components.
(2) The presence of firebrands and other combusting materials in proximity to the system
(3) Wind effects on exterior system components.

A.12.1 Responsibility

A system manufacturer and system designer can be the same entity, in which case they are to have both the responsibilities stated in 10.1.1 and 10.1.2. These individuals are to be clear of all instructions and procedures that the user must follow as well as if and/or when experienced personnel is required.

Experienced personnel include but is not limited to the following:

(1) System manufacturer(s)
(2) System designer(s)
(3) System cleaners
(4) Contractors
(5) Plumbers
(6) Installers
(7) Field testers
(8) Inspectors

A.12.1.1 Manufacturers

The format of how the instructions and what is expected of stakeholders are both conveyed by the manufacturer, whatever the method, it must be clear for the understanding of any possible stakeholders.

Clear instruction formats include but are not limited to:

(1) Visual aids within instructions
(2) Online assistance guide
(3) Telephone instruction
(4) Instructional video
(5) Instruction book, guide, or pamphlet

A.12.1.1.1 Shelf Life and Cautionary Information*

Dispensed agents' properties include but are not limited to the following:

(1) The chemical make-up of the agent
(2) All hazards of the chemical
(3) Any harmful or non-harmful byproduct of the aged agent
(4) Its effect on any parties stated in 6.1.2

A.12.1.3 Hazards

Hazards include but are not limited to the following:

(1) Choking hazards
(2) Electrical hazards
(3) Sharp edges, components, or pieces
(4) Poison hazards
(5) Pressure, weight, and/or ergonomic hazards

A.12.2 Inspection and Testing

Inspection, testing, and maintenance include but are limited to the following:

(1) Periodic testing of the agent performance
(2) Periodic testing and inspection of the system's set up
(3) Periodic testing and inspection of performance, agent flow, and agent source
(4) Cleaning procedures
(5) Repairing and replacement procedures
(6) Code enforcers

A.12.3 Acceptance Inspection and Testing

Personal qualified to be considered knowledgeable and trained in such systems may include Installers or system designers that are trained and certified by discharge device manufacturers for application of the manufacturers' products. System designers should also be knowledgeable of the localized wildfire threats and non-fire exposures.

Annex B - Wildfire Protection System Compliance: Roof Saver

Application System: Roof Saver Sprinklers	System Statements
System Goal	Roof Saver Sprinklers is a highly effective tool to protect a residential property
System Objective	Roof Saver Sprinklers is a highly effective tool to help a property survive a wildfire
System Criteria	Roof Saver Sprinklers are temporary fire suppression components, designed to prevent ignition, not to put out a fire
System Threats	Wildfire (not specified)
Stated Non-Fire Exposures	Not specified

Criteria #	Section Title	What Roof Saver Says?	Standard Compliance	Comments
4	**System Performance**			
4.1.	**Protective Goals***	"Roof Saver Sprinklers® are a highly effective tool to help survive a wildfire – together with defensible space and other fire safe measures your home will have a much better chance of survival!" and "Roof Saver Sprinklers® are a temporary fire suppression system, they are not designed to put out a fire, but help prevent ignition."	**YES**	The protective goals are broad and stated but do not clearly state how the device will be able to operate in accordance with what the manufacturer claims it will. To improve this statement or its clarity, the system designer or manufacturer would need to specify how the device is able to operate. This will come up in later sections.
4.1.1	**Capabilities of the System***	"Roof Saver Sprinklers® are a temporary fire suppression system, they are not designed to put out a fire, but help prevent ignition." and "Due to the unpredictable nature of wildfires it is impossible to guarantee against property loss or personal injury."	**NO**	The system's capabilities and limitations are broadly stated but lack specificity of wildfire threats to be protected against. For example, specific wildfire threats can be explained to improve this.
4.2	**Objectives***	"Roof Saver Sprinklers® are a highly effective tool to help survive a wildfire – together with defensible	**NO**	This objective is too vague and does not help quantify the protection goals. the terms "insure", "maximum", and "fire

		space and other fire safe measures your home will have a much better chance of survival!" and "Roof Saver Sprinklers® are a temporary fire suppression system, they are not designed to put out a fire, but help prevent ignition."		protection" need additional definition. The suggestion would be to change this statement to "extinguish firebrand that collect on the exterior of the structure before structure exterior combustion"
4.2.1	**Protected Assets ***	"Roof Saver Sprinklers® thoroughly wets roofs, gutters, decks, surrounding trees, and shrubs making these fuels less susceptible to ignition."	**YES**	Protected assets are the assets that are expected to soak by water to decrease the chance of ignition. However, it is worth mentioning that the effectiveness is based on how the system user maintains the defensible space.
4.3	**Criteria***	"Roof Saver Sprinklers® thoroughly wets roofs, gutters, decks, surrounding trees, and shrubs making these fuels less susceptible to ignition." and "they are not designed to put out a fire, but help prevent ignition" and "this soaking of the roof and landscape also releases moisture into the air lowering ambient temperatures and increasing humidity levels."	**NO**	There is no statement that elaborates on a performance criterion attached to the system or system design. The statement of the house's ignition being prevented is not specific enough in defining the threat that the sprinkler is protecting against. The performance criteria for the system should be explicitly stated and in terms of the stated wildfire threat(s). Performance criteria for this system may include "prevention the flaming ignition of any component attached to the structure “or "Prevent firebrands from accumulating to a quantity necessary to produce flaming ignition of structural components." or "protect the exterior of the structure by extinguishing any firebrands in the vicinity of open vents or openings"
4.4	**Assumptions***	This company relies on partially on how the systems user maintains the defensible space. This company provides links and tips in order to do this, but they assume the maximum effectiveness from this.	**NO**	Defensible space links are provided but the maintenance of this space is not explicitly stated.

5	**Wildfire Event**			
5.1	**Threat(s)***	None Stated, although this company could be implying "flying embers" and "burning particles" based on a picture that is shown. The evidence and statements still lack in this area	**NO**	Nothing about the wildfire is specified, defined, or quantified. The system designer should consider the following questions, How big of a wildfire? How many firebrands and will the wildfire create that they system will have to protect against? What size or type of firebrand? What about the effects of radiant heat or flame contact? How close is the wildfire going to approach the structure? All these questions and more should be addressed by the system designer when defining the wildfire event, the system is intended to protect against. An example wildfire threat statement may be "a surface burning wildfire that comes within 100 feet of the structure and produces firebrands from local ponderosa pine at a flux of no more than 100 firebrands per square meter per minute and an initial horizontal velocity of no more than 8 m/s".
5.2	**Fuel Sources***	"Over 90% of homes that ignite in a wildfire (except home to home ignition) are due to flying embers and burning particles up to a mile ahead of the main fire. The roof is the most vulnerable part of any home during a wildfire. Wood shake shingles, leaves, pine needles, on roof or in gutters is usually the first thing to ignite." and "Roof Saver Sprinklers® thoroughly wets roofs, gutters, decks, surrounding trees, and shrubs making these fuels less susceptible to ignition."	**YES**	Even though the threats of the wildfire are not specified. The fuel sources from the property and around it are considered and are, in fact, expect to be affected by the sprinkler system.

5.3	**Duration of the Fire Event***	"If possible, run sprinklers for several hours prior to the arrival of the fire." and "If for any reason your area loses water pressure, or electricity for wells, our stage 1 and stage 2 systems will not be able to work as designed. Stage 3 systems operate independently from your house water supply and will continue to operate." and "Roof Saver Sprinklers® are a temporary fire suppression system"	**NO**	The system is expected to last during a fire based on a few statements, none of which provide how these conclusions were made. The pre-wetting of the structure is assumed action that must be accomplished before the arrival of the wildfire. The system designer must research the local environment to identify how much time the system will need to actively protect against a wildfire progressing through the area proximal to the structure.
6	**System Components***			
6.1	**Qualification Methods***	None Stated	**NO**	The suggestion is to mention all components such as the braces, pumps, controllers, initiating devices, or valves that will also be used in the system and how they have been qualified for use in.
6.2	**Health and the Environment**	None Stated	**NO**	
6.3	**Discharge Devices***	None Stated	**NO**	The system designer never explicitly states when used discharge devices are allowed. The manufacturer should state that a used discharge device should never be installed if that is the intent of making replacement discharge device available through the manufacturer.
6.3.1	**Used Discharge Devices**	None Stated	**NO**	If the manufacturer is intending to allow used or refurbished discharge devices, a qualification criterion must be created. These criteria should detail when it is acceptable to use these types of discharge devices and how these criteria were derived.
6.3.2	**Used Discharge Device Criteria***	None Stated	**NO**	If the manufacturer would like to allow used discharge devices to be a part of the system, then a methodology for ensuring proper

				discharge device quality will be required.
6.4	**Piping**	Installation guidelines are presented within an instructional video available on the product website. Piping in this case happens to be a garden hosing	**YES**	The recommendation is adding a readable installation guide that details where piping can be placed to protect the piping from the wildfire threats in addition to the instructional video. As the selected piping is tested for fire exposures, the statement "piping is permitted to be exposed to the wildfire threat as long as it is securely attached to a structural member on exterior of the structure"
6.4.1	**Attachments**	For the attachment of the hose to the roof, a sprinkler base and ridgeline hose holder is used to attach the system to the roof without the use of nails	**YES**	No Comment
6.5	**Pumps**	Pumps are not applicable for this system	**NO**	No Comment
6.6	**Spare Parts**	All necessary parts are available on the system's site for purchase.	**YES**	There are very few parts for the proper operation of this system.
6.6.1	**Standardization**	All necessary parts are available on the system's site for purchase. All these parts are standard except for the patented Roof Saver ridgeline holder and the galvanized steel base of the sprinkler.	**YES**	The parts are standardized and available
7	**Device Discharge**			
7.1	**Requirements for Discharge ***	Not stated	**NO**	This information is not stated, and this information is vital when ensuring that an adequate amount of agent is discharged in the spray pattern stated by the manufacturer and used in the designer by the system designer.
7.1.1	**Discharge Testing ***	Not stated	**NO**	The discharge devices need to be put under more testing than just varying the pressure. These devices should be tested against

				an actual specified threats and non-fire exposures against a representative portion of the structure so that the discharge devices can be quantified for use in these systems.
7.2	**Device Output Characteristics ***	Not stated	**NO**	The discharge devices need to be tested against conditions similar to those expected in the stated wildfire threat. This test may take the form of observing the spray pattern, droplet size, discharge density map, or spray radius under the wildfire conditions (such as a firebrand storm and sustained wind specified by the manufacturer).
7.3	**Device Spacing and Location ***	Not stated	**NO**	Testing of the discharge devices was not conducted to begin with.
7.4.1	**Manufacturer's Installation Instructions***	In addition to an installation video, a diagram of where and a scale for however many sprinkler heads are needed.	**YES**	The installation instructions should outline the proper installation of a discharge device including how far away from the structure the device head should be placed, the steps for assembly or connection to the system, the orientation the device is to be installed in based on the protection goals
8	**Design - System Layout**			
8.1	**Required Discharge Density Derivation***	Not Stated	**NO**	As the protected assets are not explicitly stated by the system designer, it is impossible to locate an adequate discharge density for each protected asset. The suggestion would be to detail the surrounding environment in one of the example layouts that shows the location and description of all the protected assets and how the system is arranged in the context of these protected assets. Additionally, in the systems that are "ridgeline only", the designer must state exactly what this system will protect against, such as preventing the combustion of built up debris on the roof.

8.2	**Adequate Coverage***	A diagram of where and a scale for however many sprinkler heads are needed, exemplifying the coverage expectation	**NO**	Devices are located at the spacing tested and provided by the manufacturer ensure a uniform layer of agent is applied to the assumed protected asset. However, there is no confirmation that the discharge density is equal to or greater than the required discharge density.
8.3	**Obstructions***	All discharge devices are located along the ridgelines, eves, or gutter lines of the roof	**YES**	Based on the provided example drawings and layout specifications, there are no obstructions to the discharge spray. For good practice, all future structure drawings should also show the locations of any other nonstructural obstructions that may be proximal to the structure.
8.4	**Piping**	No system hydraulic calculation method stated	**NO**	As the selected piping is tested for fire exposures, the statement "piping is permitted to be exposed to the wildfire threat as long as it is securely attached to a structural member on exterior of the structure" in addition to a statement why this assumption can be made should be explicitly made by the system designer if that is their implied intent.
8.5	**Hangers and Attachments**	For the attachment of the hose to the roof, a sprinkler base and ridgeline hose holder is used to attach the system to the roof without the use of nails	**NO**	Even though attachments are referenced on the system's website, they are not proven to be suitable for selected wildfire threats and selected non-fire exposures.
8.6	**System Controllers**	The system controller is the same controller that activates a water hose and it is typically easily accessible by the user.	**YES**	No Comment
8.7	**Pumps**	No pumps required	**NO**	No Comment
8.8	**Agent Storage Containers**	The system agent storage container is the water supply of the user's house.	**YES**	Because the water supply of the system is from the house's water supply, the storage of the agent is protected from the most wildfire threats as long as the house is not

				infiltrated, or the interior of the house is breached and destroyed
9	**System Activation and Operation**			
9.1	**System Activation***	"Roof Saver Sprinklers® thoroughly wets roofs, gutters, decks, surrounding trees, and shrubs making these fuels less susceptible to ignition. This soaking of the roof and landscape also releases moisture into the air lowering ambient temperatures and increasing humidity levels. If possible, run sprinklers for several hours prior to the arrival of the fire. The wetter the better, but any run time will increase your home's chance of survival. Turn on your sprinklers and prepare to evacuate!"	**YES**	The system activation is free form as the activation is manual and is recommended any time before the fire event. There is only a twostep process for this system and the designer/manufacturer does make them clear. As an improvement, the designer of the system should be specific and tabulated in a way that consumers can map out when they choose to activated their systems.
9.1.1	**Automatic and/or Manual System Activation***	If possible, run sprinklers for several hours prior to the arrival of the fire.	**YES**	The system activation is free form as the activation is manual and is recommended any time before the fire event. There is only a twostep process for this system and the designer/manufacturer does make them clear. As an improvement, the designer of the system should be specific and tabulated in a way that consumers can map out when they choose to activate their systems.
9.1.2	**Sequence of System Activation ***	A sprinkler system operation is almost simultaneous to manual activation.	**NO**	The comment above covers this.
9.1.3	**System Delay ***	A sprinkler system operation is almost simultaneous to manual activation.	**NO**	The comment above covers this.
9.2	**System Operation***	"Due to the unpredictable nature of wildfires it is impossible to guarantee against property loss or	**YES**	System designer clearly states how the system is operated.

		personal injury. Roof Saver Sprinklers® are a temporary fire suppression system, they are not designed to put out a fire, but help prevent ignition. If for any reason your area loses water pressure, or electricity for wells, our stage 1 and stage 2 systems will not be able to work as designed. Stage 3 systems operate independently from your house water supply and will continue to operate."		
9.2.1	**Resources***	If for any reason your area loses water pressure, or electricity for wells, our stage 1 and stage 2 systems will not be able to work as designed. Stage 3 systems operate independently from your house water supply and will continue to operate.	**YES**	The system states that the source of the water comes from the home's water supply and the designer also states the design limitations of the system, which depends on the stage of the systems.
10	**System Acceptance**			
10	**System Acceptance**	Not Stated	**NO**	Due to a lack of clear criteria and detailed objectives; the system acceptance criteria are not available from the system designer Once the performance criteria for the system have been defined, the acceptance criteria of the system can be derived. This criterion should quantify the success of a system's performance. This objective should be tested in the context of the stated wildfire threat and the non-fire exposures. It is the job of the system designer to provide this criterion.
10.1	**Water-based System Acceptance Testing***	Not Stated	**NO**	Refer to the comments above.

10.2	**Foam-based System Acceptance Testing ***	Not Stated	**NO**	Refer to the comments above
11	**System Resilience**			
11.1	**Non-Fire Exposures***	Not Stated	**NO**	The system designer in the provided general cases does not explicitly state the other non-fire exposures for the system over time. These non-fire exposures will be based on the geographic location and will vary from area to area. A sample non-fire exposure statement may be stated as "intense sunlight, wind guests up to 75 MPH, intense rain, hail up to 1/4 of an inch" and should be based off the local climate.
11.2	**Incompatible Components ***	Not Stated	**NO**	The system designer explicitly stated what components and where to source these components.
11.3	**Protection from Freezing***	Not Stated	**NO**	Protection from freezing was not explicitly stated by the system designer. Many water hoses survive the elements, but the metal and sprinkler heads are to be considered by the system designer when being weathered.
11.4	**Wildfire Protection***	Not Stated, other than a comment in the installation video that states that the ridgeline holders for the water hose can withstand 100 mph winds. (There is still no evidence or testing of this tabulated and provided to the user).	**NO**	As the wildfire was not quantified by the system designer, the effect of the wildfire on the system are not stated. The system designer should indicate what specifically the effects of wildfire will be on the system based on the expected wildfire threat. As testing of the discharge devices are unknown, a determination on the effect of the stated wildfire threat cannot be made. While the system designer does reference products that are tested and listed for other protection purposes, no components are list for wildfire use. The system designer should explain how the component listings and certifications make

				they suitable for use in the wildfire environment.
12	**Inspection, Testing, and Maintenance**			
12.1	**Responsibility***	Not stated	**NO**	There is no mention of how the system was designed to ensure long term performance and protection for the structure against the stated wildfire threat(s) over the lifetime of the system. There is no quantification of acceptance testing or what an acceptance test would look like. As the system designer does not provide the details necessary to evaluate a system once installed on a structure, there is no guarantee that the system will continue to meet its specific goals and objective as the system ages. A combined performance criteria and field testing of the system to ensure proper activation, performance, device discharge, and device spray is recommended.
12.1.1	**Manufacturers***	Not stated	**NO**	The Roof Saver system lacks any clear maintenance instructions. Required maintenance should be provided in an educational manner in a form that is clear. The suggestion would be a product data sheet that is given to the user when the system is commissioned. The maintenance person in this scenario is the user of the system.
12.1.1.1	**Shelf Life and Cautionary Information**	Not stated	**NO**	Because the system user is the maintenance individual for this system, the system designer should specify any harmful agents and components that the user would be dealing with for installation and proceeding maintenance. Water, in this case of being the agent for this system, can collect harmful bacteria when not in use for a considerable

				amount of time or can even react with certain materials. It is up to the system designer and/or manufacturer to know, quantify, prove, and communicate this information to the user/maintenance individual.
12.1.1.2	**System Life Cycle**	Not Stated	**NO**	The system and components life cycle should be stated by the designer and/or manufacturer. It is up to these individuals to know, quantify, prove, and communicate this information to the user/maintenance individual.
12.1.2	**System Designers***	Not Stated	**NO**	The system designer needs to explicitly state what is required of the user for proper system operation and proper ITM procedures. It is up to the system designer to create and provide a maintenance plan for the individual responsible for the maintenance of the system.
12.1.3	**Hazards**	Not stated	**NO**	Because the system user is the maintenance individual for this system, the system designer should specify any harmful agents and components that the user would be dealing with for installation and proceeding maintenance.
12.2	**Inspection and Testing***	Not stated	**NO**	The system designer should state that the system is required to be tested and inspected, whether this ITM process is conducted by experienced personnel or not. Every component of the system should be tested. The system designer should consider the water pressure's compliance.
12.2.1	**Ensuring Proper System Performance**	Not stated	**NO**	The system designer should state that the system is required to be tested and inspected after part replacement to ensure proper system operation.
12.3	**Acceptance Inspection and Testing**	Not stated	**NO**	The system designer should state that the system will be tested after installation before handoff to the user. While this aspect may have

				been implied, it is crucial that the designer state what they are looking for during this test and why they are looking for it.
12.3.1	**Qualifications for Inspectors**	Not stated	**NO**	For the purposes of this standard, the average user is not considered a person with a strong working knowledge. Although the user may be trained by the system designer to perform minor maintenance or part replacement, the user will not have the same working knowledge as trained personal. The designer also needs to add a statement that quantifies when and how often trained personal interacts with the system and for what reason.

Annex C –Wildfire Protection System Compliance: Platypus

C.1 Methodology

The standard can be broken down into 53 distinct requirements spread across 9 chapters for the system designers and manufacturers. The following assessment of the platypus system evaluates each requirement based on literature and documents provided by Platypus both from their online platform and documents provided by the Platypus system designers. The evaluation criteria were absolute; ether the system was able to fully meet the requirements of the standard or no. in the cases where the system was able to fully meet the requirement, the system was labeled as compliant in that regard. In the cases where the system was unable to meet the full requirement, it was labelled as not compliant. In cases where the compliance could not be adequately measured such as installation criteria, the requirement was considered to be not applicable in this example. Regardless of the compliance, standings, comments were provided as to why or why not the requirement was compliant. When not compliant, these comments also included aspects that may have been complaint and options to reach compliance with the standard.

C.2 Graphical Results

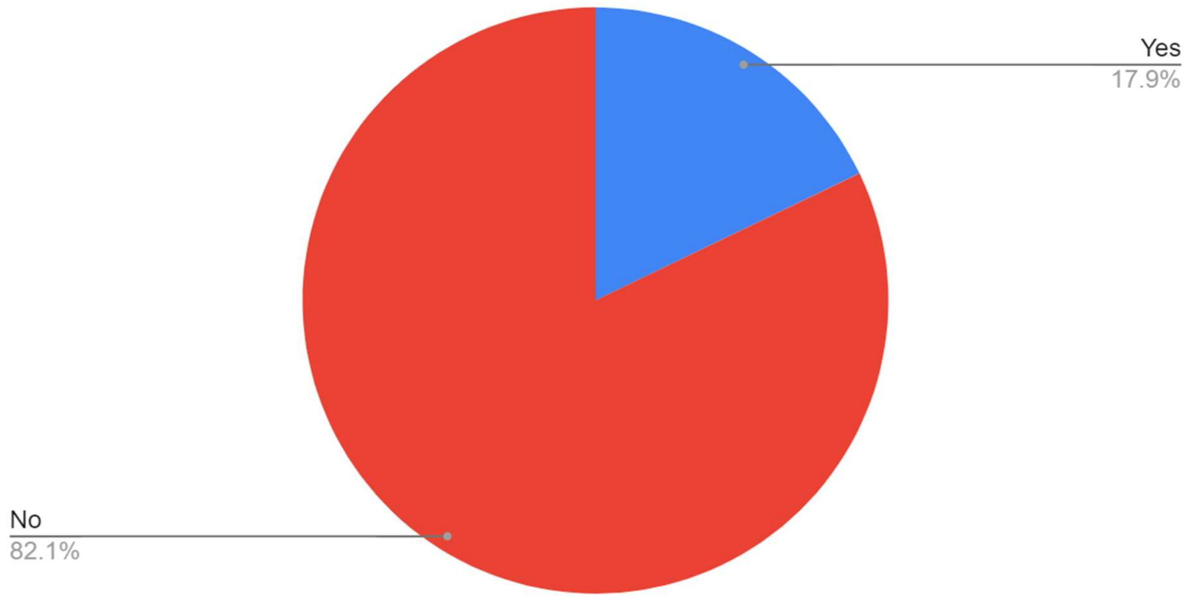

Figure C1: Platypus Compliance to our Standard: By Each Requirement. Overall compliance of the Platypus system to our standard. Each standard requirement was individually addressed in the context of the Platypus system. A “yes” is defined when the provided documentation of the system as provided by the designer met the requirements of the standard and was considered compliant. A “no " is defined when the provided documentation of the system as provided by the designer does not meet the requirements of the standard and was not compliant.

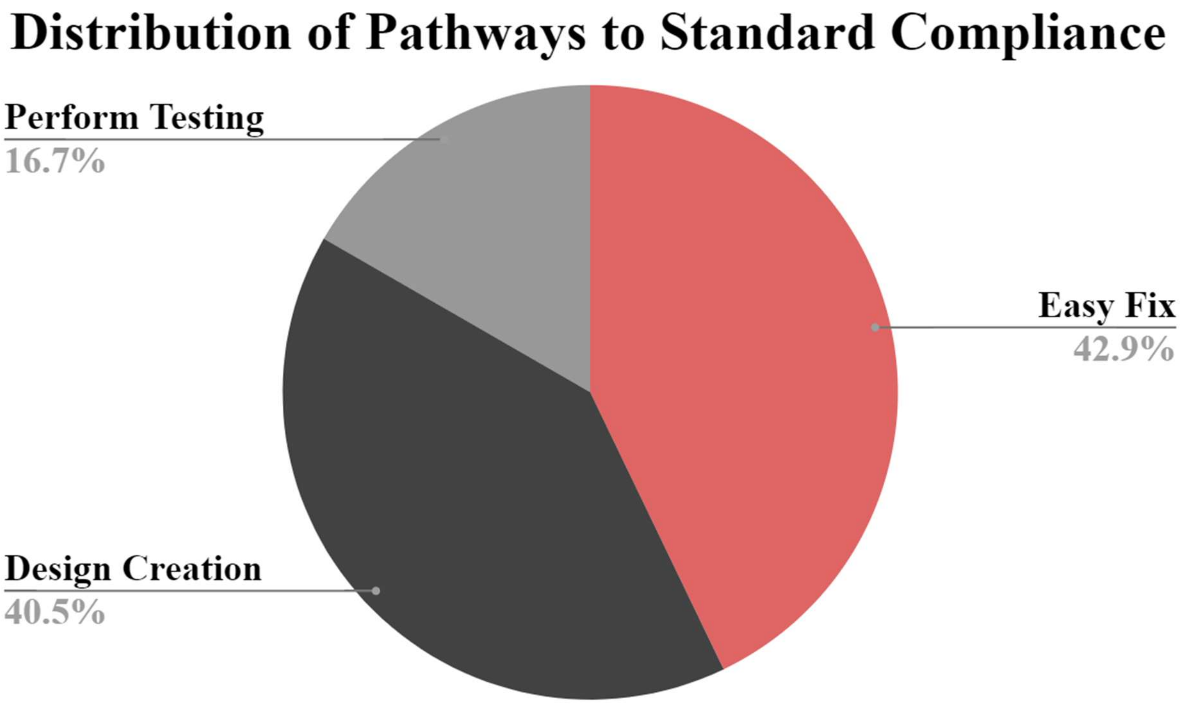

Figure C2: Distribution of Pathways to Standard Compliance. Each requirement that was unsatisfactory in terms of the standard was provided an example pathway to compliance. These pathways were categorized into three types. “Easy Fix” refers to any deficiency that can be solved by quantifying, stating, or clearing up some ambiguity. An example of this is the “pumps” requirement where the system designer did not explicitly state appropriate locations for the fire pump. The easy fix in this cause would be a statement for the system designer detailing properly protected locations for any pumps used. “Design creation” refers to the need for the system designer or manufacturers to create some product, method, or documentation to further explain their thinking or criteria. “Perform Testing” refers to the need for an additional test or qualification of system parts or components. An example of a requirement that was labeled as “preform testing” is device output characteristics, where the discharge devices must be tested under the expected wildfire conditions.

C.3 Results

C.3.1 Key

i. Each new chapter starts with a grey bar

ii. "NO" means that the system does not meet the specific requirement specified in the standard.

iii. "Yes" means that the system does meet the requirement specified in the standard.

iv. Any requirement that was half or partially met was still listed as "no"

C.3.2 Tabulated Results

	Section Title	What Platypus Says	Standard Compliance	Comments
4	**System Performance**			
4.1.	**Protective Goals**	"Platypus Sprinkler system is designed for maximum protection of your home from ember attack in the event of a bushfire or wildfire."	YES	While this goal is very vague due to the ambiguity in "maximum protection", it would still meet the requirements of the standard as the goal is explicitly stated in terms of a selected wildfire threat.
4.1.1	**Capabilities of the system**	"protection of your home from ember attack"	NO	While the capabilities of the system(protection) in regard to protection from the stated wildfire threat (an ember attack) is stated; the structural survivability is not addressed. Additionally, the term "protection" is too vague to be used in the context of an objective. The suggestion is for the manufacturer to qualify the terms "protection" along the lines of preventing the ignition of the structure exterior. Additionally, the amendment such as "by preventing the accumulation of firebrands' ' could be added after "attack" in order to quantify how the protection will be carried out in context.
4.2	**Objectives**	"ensures maximum home fire protection."	NO	This objective is too vague and does not help quantify the protection goals. the terms "insure", "maximum", and "fire protection" need additional definition. The suggestion would be to change this statement to "extinguish firebrand that collect on the exterior of the structure before structure exterior combustion"
4.2.1	**Protected Assets**	"provides a curtain effect surrounding the building and ground. Installing home fire sprinklers	YES	The stated thinking inspires confidence that the system designer will assess the structural surroundings and structural components that will require protection. As the source of this information was intended to apply to a multitude

		on decking handrails, above gable ends and any other areas at risk of debris build up is also wise" and " Solar panels can also be an area where debris can build up"		of systems, the broad methodology is acceptable. When applied to a specific structure, the protected assist is required to be explicitly stated, such as stating "the asphalt shingle roof, the exposed wooden cross members, the wooden window frames, the wooden deck, the mowed grass surrounding the house, and the brick veneer siding".
4.3	**Criteria**	None stated	NO	There is no statement that elaborates on a performance criterion attached to the system or system design. While the designer does state that the system is intended for protection from ember attack, this statement does not qualify as a criterion. The performance criteria for the system should be explicitly stated and in terms of the stated wildfire threat(s). Performance criteria for this system may include "prevention the flaming ignition of any component attached to the structure “or "Prevent firebrands from accumulating to a quantity necessary to produce flaming ignition of structural components." or "protect the exterior of the structure by extinguishing any firebrands in the vicinity of open vents or openings"
4.4	**Assumptions**	"All data is based on laboratory testing in no wind conditions."	NO	The designer did state that the system performance was quantified under conditions of no wind. However, there are more assumptions that should be stated by the designer and manufacturer. Assumptions for a system like Platypus may include the structure complies with NFPA 1144 and total occupant evacuation occurs indicating only protection of the structure goals.

5	**Wildfire Event**			
5.1	**Threat(s)**	"maximum protection of your home from ember attack in the event of a bushfire or wildfire"	NO	The specific wildfire threat is never quantified by the system designer. While the main threat of firebrands is addressed, the wildfire or bushfire is left completely under defined. The system designer should consider the following questions, How big of a wildfire? How many firebrands and will the wildfire create that they system will have to protect against? What size or type of firebrand? What about the effects of radiant heat or flame contact? How close is the wildfire going to approach the structure? All these questions and more should be addressed by the system designer when defining the wildfire event, the system is intended to protect against. An example wildfire threat statement may be "a surface burning wildfire that comes within 100 feet of the structure and produces

				firebrands from local ponderosa pine at a flux of no more than 100 firebrands per square meter per minute and an initial horizontal velocity of no more than 8 m/s".
5.2	**Fuel Sources**	None stated	NO	The location of any adjacent fuels is not addressed by the system designer. A property with the installed system is shown to not be in compliance with NFPA 1144 on the system designers' promotional platform. The localized vegetation must be quantified and taken into the design calculation so the protection of the structure goals can be accomplished.

5.3	**Duration of the Fire Event**	None stated	NO	The duration of the wildfire event is not stated, and no mention is made of the availability of resources. No time is set for the system activation prior to the arrival of wildfire threats, wildfire flame front progress through the system's zone of influence, or after the wildfire has progressed through the system's zone of influence. As the system is intended for firebrand protection, pre-wetting of the structure is assumed action that must be accomplished before the arrival of the wildfire. The system operates in a cycle between full system discharge for a set time up to one hour and a rest time up to one hour. The worst-case longest cycle from system activation to reactivation is two hours (1 hour on and 1 hour off). Assuming one cycle can accomplish the prewetting goals of the system, the time required before the arrival of the wildfire is assumed to be one hour. The time for the wildfire progression through the zone of influence is variable on local vegetation. The system designer must research the local environment to identify how much time the system will need to actively protect against a wildfire progressing through the area proximal to the structure. After the fire event there are likely few sources of firebrand generation present, however a worse case of one system cycle can be assumed but should be confirmed by the system designer, adding an additional system cycle.
6	**System Components**			

6.1	**Qualification Methods**	"Flow, pressure and stream height data as tested by University of South Australia " and the Copper tube manufactured by Crane is certified by ASTM B88, the UPC, UL 700, and a variety of other international agencies. The fittings used on the system have been tested to UL /ANSI 213: (Standard for Rubber Gasketed Fittings for Fire-Protection Service), the IPC, ASME B31 (Code for Pressure Piping), and multiple other International codes and standards. the discharge device is mentioned to have a glass reinforced nylon head that is flame retardant and VO flame rated	NO	The system piping and fittings have been quantified for explosive environments and industrial use. The system designer fails to equate the testing performed on these components to the expected wildfire threat. The methods used to quantify the sprinkler should also be made available for the AHJ. The use of the VO flame rating should be explained. The suggestion is to mention any other components such as the braces, pumps, controllers, initiating devices, or valves that will also be used in the system and how they have been quantified for use in the wildfire environment.

6.2	**Health and the Environment**	The discharge devices and the agent materials are not discussed -The Crane tube is certified by the NSF/ ANSI 61 for drinking water components. The Viega components are tested by NSF/ ANSI 61 (Drinking Water System Components –Health Effects) and NSF/ANSI 372 (Drinking Water System Components- Lead Content)	NO	All system components are not certified in this regard. The manufacturer should clearly state "the discharge devices are constructed from materials that are not known to cause adverse health or environmental effects' if that is their intent of stating that the piping is certified for drinking water use. Additionally, the agent source should be addressed. If the agent source contains any components that will cause adverse health effects or environmental concerns, it is the systems designer's job to address this issue.
6.3	**Discharge Devices**	Not Stated	NO	The system designer never explicitly states when used discharge devices are allowed. The manufacturer should state that a used discharge device should never be installed if that is the intent of making a replacement discharge device available through the manufacturer.
6.3.1	**Used Discharge Devices**	"A replacement head and bearing kit would be approximately $5.85 per sprinkler "	NO	If the manufacturer is intending to allow used or refurbished discharge devices, a qualification criterion must be created. This criterion should detail when it is acceptable to use these types of discharge devices and how this criterion was derived.
6.3.2	**Used Discharge Device Criteria***	Not Stated	NO	If the manufacturer would like to allow used discharge devices to be a part of the system, then a methodology for ensuring proper discharge device quality will be required.

6.4	**Piping**	No installation guideline stated, piping tested to withstand conventional fires (see above)	NO	There is no mention of installation guides detailing the installation of the piping in relation to the stated wildfire threat. Recommend adding an installation guide that details where piping can be placed to protect the piping from the wildfire threats. As the selected piping is tested for fire threats, the statement "piping is permitted to be exposed to the wildfire threat as long as it is securely attached to a structural member on exterior of the structure"
6.4.1	**Attachments**	Not Stated	NO	There is no mention of piping attachments, hangers, braces, or installation guides detailing the attachment of the system to the structure. An installation guide that details what braces can be made from, what size braces are needed, and what the braces can be safely attached to should be included.
6.5	**Pumps**	Not Stated	NO	There is no mention of the pump, or agent source. The water flow and pressure demands are not stated on the provided sample layouts. The calculation method used to identify the pressure and water flow demands should be presented. After this calculation, a pump can be selected.
6.6	**Spare Parts**	None stated	NO	There is no statement indicating a necessary list of spare parts for the system. A published list and a user manual that the user can keep with the parts to ensure that the system is always operational should be created.
6.6.1	**Standardization**	Various parts available on web pages for purchase including specialty piping, flow controllers, valves, unions, and adapters.	NO	There is no statement indicating a standardization of spare parts on the system designer side. The designer does a good job indicating what manufacturers will make certain components, which will assist in standardization. A statement to the extent of "all spare parts should be compatible with the Veigas and Crane tubing" can also be made.
7	**Device**			

	Discharge			
7.1	**Requirements for Discharge**	Optimum pressure for each nozzle is 300 kPa.	NO	While the optimum discharge device pressure is stated, the minimum flow rate or pressure is not supplied. This information is vital when ensuring that an adequate amount of agent is discharged in the spray pattern stated by the manufacturer and used in the designer by the system designer.
7.1.1	**Discharge Testing**	"Flow and pressure data available on request for 50-350kPa." and "Flow, pressure and stream height data as tested by University of South Australia is also available"	NO	While the discharge devices have been tested over a variety of pressures, the discharge versus the stated wildfire threat is not quantified. The discharge devices need to be put under more testing than just varying the pressure. These devices should be tested against an actual firebrand storm against a representative portion of the structure so that the discharge devices can be quantified for use in these systems.
7.2	**Device Output Characteristics**	Stated nominal flow rates at 300 kPa for a variety of nozzle sizes	NO	While the discharge devices have been tested over a variety of pressures, the discharge versus the stated wildfire threat is not quantified. The discharge devices need to be tested against conditions like those expected in the stated wildfire threat. This test may take the form of observing the spray pattern, droplet size, discharge density map, or spray radius under the wildfire conditions (such as a firebrand storm and sustained wind specified by the manufacturer).
7.3	**Device Spacing and Location**	Stated maximum distance between sprinklers for a variety of nozzle sizes	Yes	While these test methodologies were not available at the time of the writing of this report, testing was conducted by the University of South Australia. These tests can be taken to meet this standard as they quantified the spacing requirements stated by the manufacturer with a provided methodology.
7.4	**Installation**	Not Stated	NO	A set of manufacturer’s instructions are required to be provided to ensure proper installation of

				the discharge devices.
7.4.1	**Manufacturer's Installation Instructions**	Not Stated	NO	It is possible that an installation guide for the sprinkler exists, but at the time of this writing this document was not identified. The installation instructions should outline the proper installation of a discharge device including how far away from the structure the device head should be placed, the steps for assembly or connection to the system, the orientation the device is to be installed in based on the protection goals.

8	**Design - System layout**	The platypus systems are all designed in house. Several examples plans detail the location, spacing, and zone of each sprinkler head. Platypus supplies four example structures with sprinklers laid out as an example for their clients, would also be acceptable for a sprinkler layout for a structure. The calculation method is not immediately supplied by the system designer; however, it could be safely assumed that the posted spacing requirements were followed in the completion of these drawings. Additionally, the system designer gives two configurations of the system, a total spray system and a ridgeline only system. The ridgeline only system is less expensive, but only	NO	The designers had a lot of the right pieces, but not enough clarification and explanation regarding how the final design was selected. While sprinkler spacings are provided for a general case, there is no information that confirms that all protected assets will receive the adequate agent from the discharge devices. While providing an alternative system with different protection goals may be beneficial to a consumer who cannot afford the full protection, this additional layout also may cause further confusion for a consumer looking to implement one of these systems. The suggestion is to utilize the provided drawings along with the calculation method and piping diagram as a single final product for both the AHJ and the system user.

		has discharge devices located at the roof crests. It is not explicitly stated what the protected asset or protection goals are of each of the systems.		
8.1	**Required Discharge Density Derivation**	Discharge density not stated	NO	As the protected assets are not explicitly stated by the system designer, it is impossible to locate an adequate discharge density for each protected asset. The suggestion would be to detail the surrounding environment in one of the example layouts that shows the location and description of all the protected assets and how the system is arranged in the context of these protected assets. Additionally, in the systems that are "ridgeline only", the designer must state exactly what this

				system will protect against, such as preventing the combustion of built up debris on the roof.
8.2	**Adequate Coverage**	The provided example system layouts detail the radius of device discharge	NO	Devices are located at the spacing tested and provided by the manufacturer ensure a uniform layer of agent is applied to the assumed protected asset. However, there is no confirmation that the discharge density is equal to or greater than the required discharge density.
8.3	**Obstructions**	All discharge devices are located along the ridgelines, eves, or gutter lines of the roof	yes	Based on the provided example drawings and layout specifications, there are no obstructions to the discharge spray. For good practice, all future structure drawings should also show the locations of any other nonstructural obstructions that may be proximal to the structure.
8.4	**Piping**	No system hydraulic calculation method stated	NO	There is no mention of any calculation method used to ensure that the piping is adequately sized. As the system contains multiple discharge devices that all discharge at the same time, the hydraulic calculation procedure for NFPA 13 is recommended for the Platypus system. The system designer should adequately size the pipes to ensure each discharge device received the agent at the necessary minimum output values.
8.5	**Hangers and attachments**	no reference to system hanger or attachments stated	NO	There is no mention of piping attachments, hangers, braces, or installation guides detailing the attachment of the system to the structure. The addition of an installation guide that details what braces can be made from, what size braces are needed, and what the braces can be safely attached to should be added to the design specifications.

8.6	**System Controllers**	The system controller location is not specified. Platypus states that the controller is in an "IP66 wall mount enclosure" which is ATEX/IECEx Certified and a service temperature up to 80 degrees centigrade	NO	There is no specific location of the panel that is provided (i.e. 4 feet from the ground located on the north side of the structure adjacent to the garage.) The controller is stated to be protected by a wall mounted box that is not explicitly tested for wildfire use. However, the box is certified for use in hazardous conditions such as explosions. The system designer should equate the significance of the testing performed on the protective cover to the started wildfire threats and the selected non-fire exposures.
8.7	**Pumps**	No reference to the location or protection of system pumps	NO	The existence, location, and protection of any fire pumps is not stated. The pump may be located inside a protected structure to maintain protection from environmental non-fire exposures and wildfire threats if this structure is also protected for the wildfire.
8.8	**Agent Storage Containers**	No reference to system agent storage containers	NO	The location and protection of any agent storage is not stated. Potential agent sources may include a nearby lake, swimming pool, river, or city connection if these agent sources can be certified to be protected from the wildfire and available during the wildfire event. (The system designer should still check with the local authority to confirm local water supply is not shut off or redirected in the event of a wildfire incident).
9	**System Activation and Operation**			

9.1	**System Activation**	"The Platypus Sprinkler System can be operated manually by use of isolation valves or automatically activated using our Controller device which starts and stops the system based on a preset ambient temperature. Controllers can also be activated by SMS from a mobile phone." "When the ambient air temperature rises above the set point, the system becomes active."	Yes	The system designer fully details the sequences for system operation. The user defined time up to 60 minutes should be set in conjunction with the system designer to better suit a more specific wildfire threat but is acceptable in this general case.
9.1.1	**Automatic and/or Manual System Activation**	See system activation	yes	When automatically controlled, the system will activate once a set point ambient temperature is reached which can be adjusted based on the protection goals and selected wildfire threats. The manual activation can occur at any time designated by the system user. For additional protective measures, the system designer should train the system user to indicate appropriate times for system activation in terms of the wildfire threat.
9.1.2	**Sequence of System Activation**	See system activation	NO	Specific devices are not required to be individually addressed in the instance that the entire system activates concurrently. However, the manufacturer must state, not just imply, that the entire system activates at the same time.

9.1.3	**System Delay**	Not stated	NO	No hydraulic calculations were provided by the system designer. These calculations should account for the time it takes the pump or agent supply to reach operating pressure and the time needed to charge the system. These calculations should also ensure that pipe diameters are of an adequate size to compensate for frictional losses.
9.2	**System Operation**	"The system will run for an amount of time which is set by the user up to a maximum of 60 minutes. After the run time has expired, the system pauses for an amount of time, also set by the user, up to a maximum of 60 minutes. The ambient air temperature is measured again, if it is still above the set point the controller will run the system again. This cycle is repeated until the ambient air temperature falls below the set point. During this time the controller will send SMS information to the stored numbers advising the status of the system."	YES	The system designer clearly states the cycle of device discharge once activated.

9.2.1	**Resources**	Not Stated	NO	The resource demand for the general case produced by the system manufacturer was not provided. The system resource demand needs to be calculated to ensure that the available resources such as backup power, stored agent, and fuel are sufficient to run the system for the entirety of the wildfire event.
10	**System Acceptance**			
10	**System Acceptance**	Not Stated	NO	Due to a lack of clear criteria and detailed objectives; the system acceptance criteria are not available from the system designer Once the performance criteria for the system have been defined, the acceptance criteria of the system can be derived. This criterion should quantify the success of a system's performance. As the Platypus system is designed for ember protection, the system acceptance may be defined as the prevention of flaming ignition of any exterior structural component. This objective should be tested in the context of the stated wildfire threat and the non-fire exposures. It is the job of the system designed to provide this criterion.
10.1	**Water-based System Acceptance Testing**	Not Stated	NO	Refer to the section comments above.
10.2	**Foam-based System Acceptance Testing**	Not Stated	NO	Refer to the section comments above.
11	**System Resilience**	Not Stated	NO	While periodic inspections to ensure performance are mentioned by the system designer, there is no mention of how the system was designed to ensure long term performance

				and protection for the structure against the stated wildfire threat(s).
11.1	**Non-Fire Exposures**	Not Stated	NO	The system designer in the provided general cases does not explicitly state the other non-fire exposures for the system over time. These non-fire exposures will be based on the geographic location and will vary from area to area. A sample non-fire exposure statement may be stated as "intense sunlight, wind guests up to 75 MPH, intense rain, hail up to 1/4 of an inch" and should be based on the local climate.
11.2	**Incompatible Components**	Not Stated	NO	The system designer explicitly stated what components and where to source these components. However, the agent is not mentioned by the system designer. As the assumed agent, water, can be corrosive to the copper piping, the designer should explicitly state the potential effects and mitigation strategies to prevent corrosion of the system.
11.3	**Protection from Freezing**	Not Stated	NO	Protection from freezing was not explicitly stated by the system designer. As an example "systems were assumed to be located in Australia and an area where the effects of freezing are minor", an official statement such as “when temperatures dip below 5 degrees C, the system should be drained to prevent freezing." should be made if that is the intent of the system designer.

11.4	**Wildfire Protection**	The Copper tube manufactured by Crane is certified by ASTM B88, the UPC, UL 700, and a variety of other international agencies. The fittings used on the system have been tested to UL /ANSI 213: (Standard for Rubber Gasketed Fittings for Fire-Protection Service), the IPC, ASME B31 (Code for Pressure Piping), and multiple other International codes and standards. the discharge device is mentioned to have a glass reinforced nylon head that is flame retardant and VO flame rated	NO	As the wildfire was not quantified by the system designer, the effect of the wildfire on the system are not stated. The system designer should indicate what specifically the effects of wildfire will be on the system based on the expected wildfire threat. As testing of the discharge devices are unknown, a determination on the effect of the stated wildfire threat cannot be made. While the system designer does reference products that are tested and listed for other protection purposes, no components are listed for wildfire use. The system designer should explain how the component listings and certifications make them suitable for use in the wildfire environment.
12	**Inspection, Testing, and Maintenance**			

12.1	**Responsibility**	See below	NO	While periodic inspections to ensure performance are mentioned by the system designer, there is no mention of how the system was designed to ensure long term performance and protection for the structure against the stated wildfire threat(s) over the lifetime of the system. While the system designer does provide maintenance specifications, there is no quantification of acceptance testing or what an acceptance test would look like. As the system designer does not provide the details necessary to evaluate a system once installed on a structure, there is no guarantee that the system will continue to meet its specific goals and objectives as the system ages. A combined performance criteria and field testing of the system to ensure proper activation, performance, device discharge, and device spray is recommended.
12.1.1	**Manufacturers**	"Your installer will provide further advice and or ongoing maintenance." and "We recommend replacing these components (sprinkler heads and bearings) at your 5-year service"	YES	The provided statement clearly addresses product maintenance and lifetime. While this was stated to the user, the additional required maintenance should be provided in an educational manner in a form that is clear. The suggestion would be a product data sheet that is given to the user when the system is commissioned.
12.1.1.1	**Shelf Life and Cautionary information**	Not stated	NO	The system designer does not state any information regarding the agent use. Additionally, there was no instructions regarding system or agent use provided by the manufacturer.

12.1.1.2	**System Life Cycle**	Stated 5 years for the discharge devices, not stated for other components	NO	The life cycle of the whole system is not quantified. While the designer suggests replacing the sprinklers after the 5-year service, the rest of the system components are not addressed. The suggestion would be to add a statement that addresses these components, such as "all system components are assessed at the five-year service by the system designer".
12.1.2	**System Designers**	"Weekly visual checks of the sprinkler system and water supply. Start your pump each week during the bushfire season. Your installer will provide further advice and or ongoing maintenance."	Yes	The system designer explicitly states what is required of the user for proper system operation.
12.1.3	**Hazards**	Not stated	NO	No hazards were stated by the system designer or identified by the system designer. As they listed pool water as a potential agent source, any portions of the pool water agent that can prove hazardous should be quantified and stated by the system designer.
12.2	**Inspection and Testing**	"Weekly visual checks of the sprinkler system and water supply. Start your pump each week during the bushfire season. Your installer will provide further advice and or ongoing maintenance."	Yes	Additional comments provided by the system designer should detail when the system must be inspected by the designer or when they should be contacted for maintenance.

12.2.1	**Ensuring Proper System Performance**	Not stated	NO	The system designer should state that the system is required to be tested and inspected after part replacement to ensure proper system operation.
12.3	**Acceptance Inspection and Testing**	Not stated	NO	The system designer should state that the system will be tested after installation before handoff to the user. While this aspect may have been implied, it is crucial that the designer state what they are looking for during this test and why they are looking for it.
12.3.1	**Qualifications for Inspectors**	None stated	NO	For the purposes of this standard, the average user is not considered a person with a strong working knowledge. Although the user may be trained by the system designer to perform minor maintenance or part replacement, the user will not have the same working knowledge as trained personnel. The designer also needs to add a statement that quantifies when and how often trained personal interacts with the system and for what reason.

Annex D – Informational References

NFPA Publications

- NFPA 13: Standard for the Installation of Sprinkler Systems, 2019 Edition
- NFPA 13D: Standard for the Installation of Sprinkler Systems in One- and Two-Family Dwellings and Manufactured Homes, 2019 Edition
- NFPA 1144: Standard for Reducing Structure Ignition Hazards from Wildland Fire, 2018 Edition

Other Publications

- ICC IWUIC: International Wildland-Urban Interface Code, 2015 edition
- SFPE Handbook of Fire Protection Engineering, 2016 edition
- UL 199: Standard for Automatic Sprinklers for Fire-Protection Service

Other References

- Caton, E. S. et. al. (2016) Review of Pathways for Building Fire Spread in Wildland Urban Interface Part I: Exposure Conditions, Fire Technology, 53, 429-473. DOI:10.1007/s10694-016-0589-z
- Manzello, Samuel L., et al. “Enabling the Study of Structure Vulnerabilities to Ignition from Wind Driven Firebrand Showers: A Summary of Experimental Results.” Fire Safety Journal, vol. 54, 2012, pp. 181–196., doi: 10.1016/j.firesaf.2012.06.012.
- Manzello, Samuel L., and Ethan I. D. Foote. “Characterizing Firebrand Exposure from Wildland–Urban Interface (WUI) Fires: Results from the 2007 Angora Fire.” Fire Technology, vol. 50, no. 1, 2012, pp. 105–124., doi:10.1007/s10694-012-0295-4.
- Merriam-Webster’s Collegiate Dictionary, 11th edition