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SPRAY SYSTEM DESIGN FOR EMBER ATTACK

RESEARCH FINDINGS AND DISCUSSION PAPER

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Spray system design for ember attack - Research findings and discussion paper

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1 Introduction

This research report has been developed to provide background support for areas of the AFAC guideline. AFAC members and CSIRO have developed the AFAC guideline "Bushfire spray systems for the protection from ember attack" to provide guidance to the Australian community when considering or installing a bushfire spray system.

This report has been developed to provide a science basis and discussion for positions taken in the draft guideline. The analysis will address those sections of the guideline where concern has been raised during the drafting process as to its appropriateness. The areas requiring analysis are:

- Water supply duration
- Combustibility of tanks
- Automatic activation requirements
- Pump performance under adverse conditions
- Pipe material selection
- Pipe location
- Water source/quality
- Spray nozzle design and performance
- Spray system to protect against surrounding infrastructure ignition

2 Discussion General

Understanding the destruction of a specific house needs to take into account the bushfire event and all the individual elements between the bushfire and the house that could contribute to the risk of structural loss. Previous studies have shown that the majority of houses destroyed in bushfires survive the passage of a fire front, but burn down during the following hours either due to direct ember attack or by attack from surrounding elements that were ignited by an ember attack [0,1,3,4,9,13,15,16,17,18,20,22].

In understanding the mode of attack we utilise a spatial approach to determine the likelihood that internal ignition of the house will occur, as well as incorporating the known behaviour of associated elements around the structure. This approach can link the defined modes of bushfire impact (attack) with the observed performance of building elements (vulnerability). Further details on these specific elements as well as an insight into human behaviour aspects for past bushfire events can be found in references [0,3,7,13,16,18,20]. Figure 1 depicts the complex interaction between the bushfire attack and various elements in and around the house.

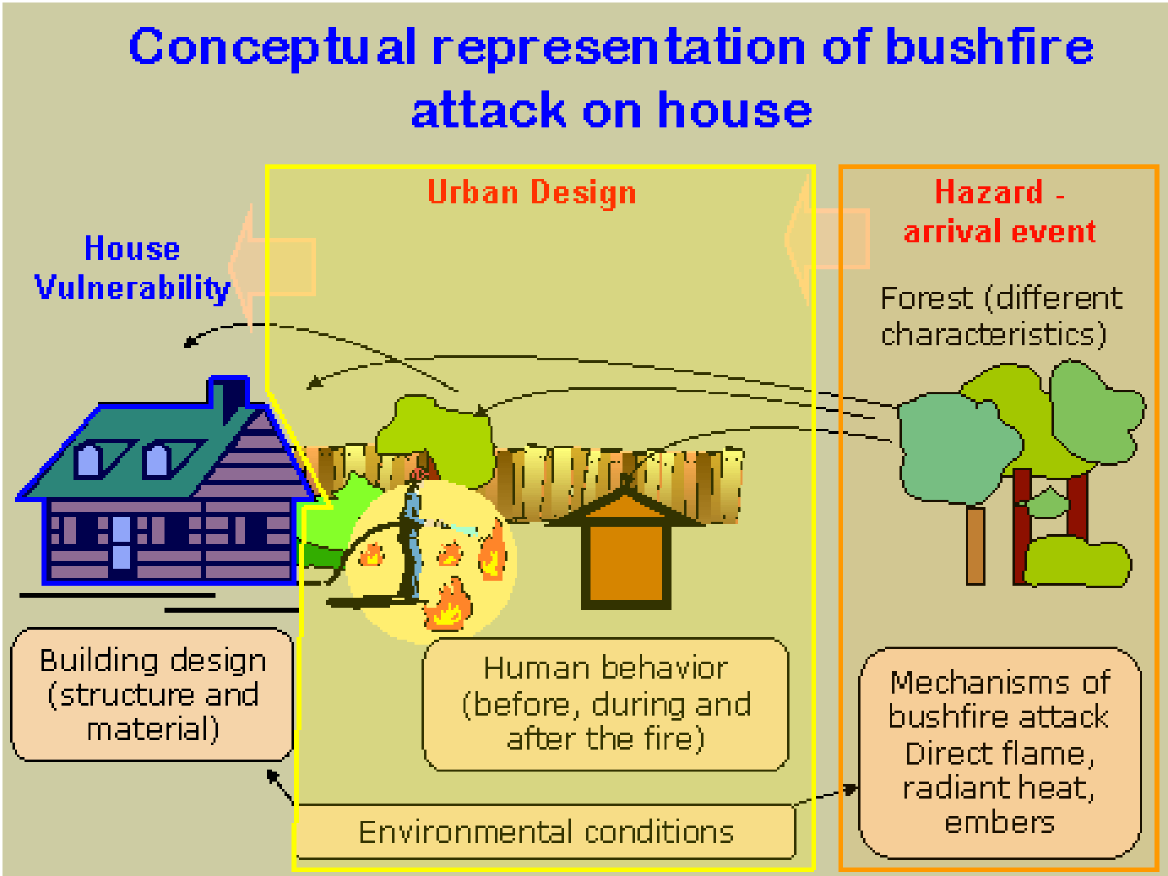

Figure 1 Conceptual Risk Framework

2.1 Characteristic of the bushfire event

The bushfire attack can be defined in three categories, these being flame, radiation and ember/debris. Previous studies identified ember attack as the predominant ignition mechanism. The significance of ember based attack and its interaction with surrounding combustible elements is a clear theme throughout previously analysed fires [0,1,3,4,9,13,15,16,17,18,20,22]. These papers focus on ember attack specifically and relate these conditions with the level of 'BAL 12.5' in the Australian standard for building in bushfire prone areas (AS3959). This category defines the range of impact from low level ember attack which may be experienced by a house some distance from the fire event, to ember attack and up to 12.5 kW/m^2 of radiation experience from the bushfire front itself. In reality houses in this region of the bushfire interface are subject to the risk of additional ember, radiant heat and flame impingement from surrounding infrastructure elements. Some studies highlight the significance of unchecked house to house ignition, a mode exacerbated by close proximity of structures and a lack of occupant and brigade presence [16,17]. In other cases a combustible fence or vehicle may provide a significant escalation of risk.

Each mode of impact has a unique range of properties as detailed below:

2.1.1 Embers / Wind born Debris

Embers and wind born debris are by far the most prevalent attack mechanism on houses in Australian bushfires. When considering how a fire event impacts on an urban area well over 90% of houses are ignited in the absence of direct flame attack or radiant heat (exceeding 12kw/m^2) from the main fire front.

The risk from ember attack is influenced by a number of factors:

- The number of embers.
- Quality of embers.
- The amount of combustible windborne debris present during the ember attack.
- The duration of the ember attack.
- The environmental conditions, under which the embers may land on, near or enter the structure.

2.1.2 Characteristics of flame

Flame impingement on the structure can occur through either direct flame contact from the main fire front or by smaller localised flame impingement from localised fuel sources (vegetation, shed or fences). Either way the external building elements may ignite or the flames may act on the envelope until an aspect of it opens up to allow ignition of buildings contents. Suggested key parameters for which flame attack can be categories are:

- the duration for which this occurs
- the area on which the flame attacks (on structural elements)

It is the authors' opinion that the area impacted and duration of the flame attack are the overriding characteristics for consideration.

2.1.3 Radiation

Radiation impact on a house is synonymous with flame impact, as the flames themselves are the radiation source. From a house's perspective, it is at risk from the level of radiant heat exposure as well as the time for which this exposure occurs. The relationship between radiation and time is very important as some elements may not be affected by high radiant heat exposures for very short times while being affected greatly by long duration exposures at considerably lower levels. Hence a simple peak radiation level is not sufficient to define the type of exposure a house may be affected by except when talking about a specific element whose behaviour is well known.

The most appropriate method is to use a time/radiation curve. A wide range of radiation predictive tools exist for generating these curves, it is most important to determine how sensitivity various elements are to changes in radiation profile so that an appropriately detailed approach for determining the radiation curve can be utilised.

2.1.4 Synergistic effects

One of the key considerations for house ignition is how the above mentioned mechanisms work synergistically. The most prevalent synergistic effect is that of radiation as it alters a materials temperature and moisture content hence likelihood of ignition and flame propagation are increased when exposed to continuous ember attack and or flame impingement.

Yet another significant influence is that of abnormally low humidity and high temperatures associated with major fire events. The same weather conditions that lead to days of high fire danger also affect the moisture content and temperature of the elements of a house. These influences can not be ignored when considering the overall risk posed by the bushfire event.

2.2 Effect of fire on the elements around the house

Previous research conducted by CSIRO, Bushfire CRC and others have highlighted the elements around the house most susceptible to ignition [0,1,3,4,9,13,15,16,17,18,20,22]. The following section describes the behaviour of these elements according to the data obtained in field surveys of past bushfire events. These elements after ignition, increase risk of total house loss unless human intervention is immediate. Spray systems installed to mitigate the risk of ember attack would be required to address the influences of these elements.

2.2.1 Vegetation

The categorisation of flammability of gardens is complex as many different aspects of garden design can contribute to its ‘flammability’. Weather plays a major role in predisposing all vegetation types to be more readily ignited. Long durations of hot dry conditions lower moisture levels in plants as well as ground litter surrounding the structures [17]. The presence of vegetation in the immediate vicinity of structures (less than 20m) can be used as a ‘measure’ of garden flammability because it usually provides extensive low level direct flame attack. Continuous forest fuels that extend to less than 100m from your structure also requires attention as significant radiation, flame and ember attack may occur depending on the forest type, slope and weather conditions possible in your area.

2.2.2 Outbuildings

Previous studies have highlighted the fact that outbuildings are more readily lost compared to the main structure and represent a significant secondary impact mechanism for main structure loss. Outbuildings like garages and sheds present more openings in their structure and are more susceptible to ember-based ignition of their contents compared to conventional house design. These features then become localised flame, radiation and ember sources presenting a significant additional risk to the main structure. The issue of how much risk these outbuildings pose to the main structure becomes a function of proximity, outbuilding design, size, orientation and material existing within the outbuilding [1,3,14,17]. Spray system design would need to consider these hazards and the potential impact of an outbuilding fire near the main structure if the outbuilding is not constructed to the same bushfire resistant level.

2.2.3 Fences

Fencing systems contribute to the risk of house loss in a similar way to outbuildings. Burning timber fences adjacent to the main structure have the potential to break windows and ignite combustible features [21]. The fences can also be responsible for spreading flame up between houses. Fences with adjacent vegetation are particularly susceptible to ignition and combustion. On the other hand, non-combustible fences or fences that are regularly wetted can perform as an effective radiation barrier, thus reducing the potential for fire attack from either the main fire front or the burning of adjacent structures or elements.

2.2.4 Other

Other combustible elements around the house could contribute to house ignition; eg. Cars, wood heaps, rubbish, garden furniture, gas bottles etc. It is often desirable to protect or retain these external objects as well as to protect the house from the effects of these elements. Strategic placement of spray system's in areas such as carports may be required to mitigate these risks.

2.3 Impact of fire on the house structure design and material

The characteristics of a house design, and materials used in construction, can influence the ability for a house to survive a bushfire [0,1,3,4,9,13,15,16,17,18,20]. Research shows that the following design features, presented below, significantly contributed to the vulnerability of a house under attack:

- Flooring systems and wall cladding can allow ember entry and/or could allow the accumulation of wind-borne debris that is readily ignited by ember attack.
- Gap and entry points in the building envelope are a key area for ember attack. Window elements are particularly susceptible to radiation attack, and soon lead to an opening for ember entry into the structure. Vents and roofs present points of entry. The presence of combustible material in door and window frames increases the risk of ignition and spread.
- Small ignitions on timber decks or verandas, if left unattended can grow to a point where they threaten building elements such as facades, windows and doors, thus threatening the building envelope and causing eventual total structural loss.

2.4 Human activities

Given that ember attack has been identified as the most prevalent attack mechanism leading to house loss it is not surprising to also observe that the presence of occupants or brigade members has a significant influence on house loss risk.

Fire service intervention is an important aspect of this influence as they are significantly better equipped and have the ability to actively defend against more aggressive bushfire attack scenarios including more heavily involved house fires. Understandably, the number of brigade members tends to be substantially lower than the number of occupants in a given area. This highlights the importance of occupant activities and/or active spray systems especially in the many hours after the fire front has passed when ember attack persists and surrounding elements continue to burn.

Human intervention is related to the following parameters:

- Timing
- Capability
- Knowledge
- Critical decision making ability
- Tools, protective equipment and systems

Human intervention remains the single biggest influence on house loss statistics according to previously collected data.

3 Discussion – Spray system components

As identified in the introduction a number of areas within the draft guideline require some form of assessment to ensure they are appropriate and will contribute to a spray-systems effectiveness.

3.1 Water supply duration

2 parameters – functional distance to the source

- wind threshold that the functional distance relates to (the further you are from the source the higher the wind threshold at which significant ember attack will occur.

Ember attack is the most persistent mode of bushfire attack; surveys of past incidents have highlighted examples of building ignitions from ember attack for a period of 12 hours after the initial fire front had impacted [16,17]. These building ignitions can occur either through a new ember landing on or in an area where flaming ignition can result or from an area that is experiencing smouldering combustion from an ember attack some time earlier. These ember may have originated from the heavy fuels burning in the forest or from combustible objects within the urban environment. Either the source or the susceptible areas on the structure require frequent wetting in order to mitigate these risks.

Areas where this is straight forward are decks and facades, more problematic areas are gaps and cavities that are not designed to be wetted. In terms of the duration in which a spray system may be required to operate, it is important to mitigate the risk of ember ignition or entry for the entire duration of the incident ember attack.

Each fire scenario is different, some may involve brief localised high winds that quickly abate, others involve winds that persist for many hours after the main fire event. For a spray system to mitigate the risk of ember ignition it would need to wet the required areas until the winds that carry embers and leaf debris to the structure abates.

It is a reasonable assumption that wind speeds in excess of 20km/h are capable of transporting fine fuels and embers onto structures. Using the Canberra 2003 [17]fires as an example where on the 18th of January at approximately 3pm a bushfire front impacted the suburb of Duffy, embers were observed to impact the suburb at a similar time as the fire front reached the suburb perimeter. Figure 2 below indicates the wind speed at Canberra airport (measured at 10m above ground level) during the day of impact and the following day. The graph clearly shows a persistence of winds above 20km/hr until 9:30pm in the evening. This is consistent with observations that structure ignition through to the late evening in the Duffy area.

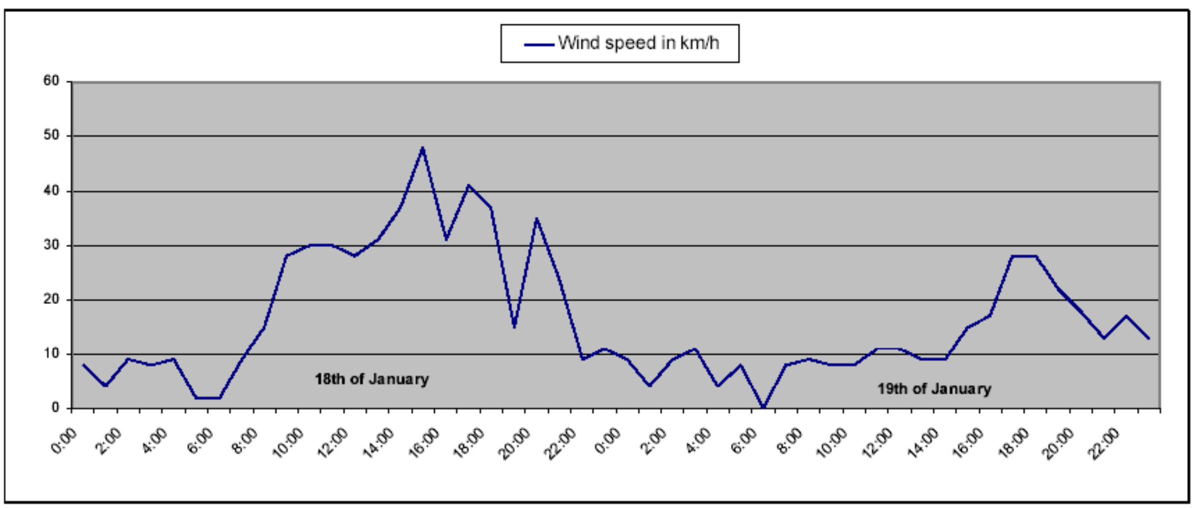

Figure 2 Hourly wind speed plot for Canberra Airport January 2003

In considering this event the danger period for short distance spotting is from 3pm till 9:30pm and also for an additional few hours from this time for smouldering material that may develop into flaming ignition under the lower wind conditions. Long distance spotting would have been prevalent from the time of the fire event until around 9pm.

Ash Wednesday 1983 is also another iconic event where significant house loss occurred. Using the weather station at Mt Gambier (SA) as an indicative indicator of wind-speed during the event (see Figure 3) it can be observed that from the onset of high wind conditions at 4pm which is also the approximate time when significant house loss began to occur, wind speeds remained above 20km/h until 3am.

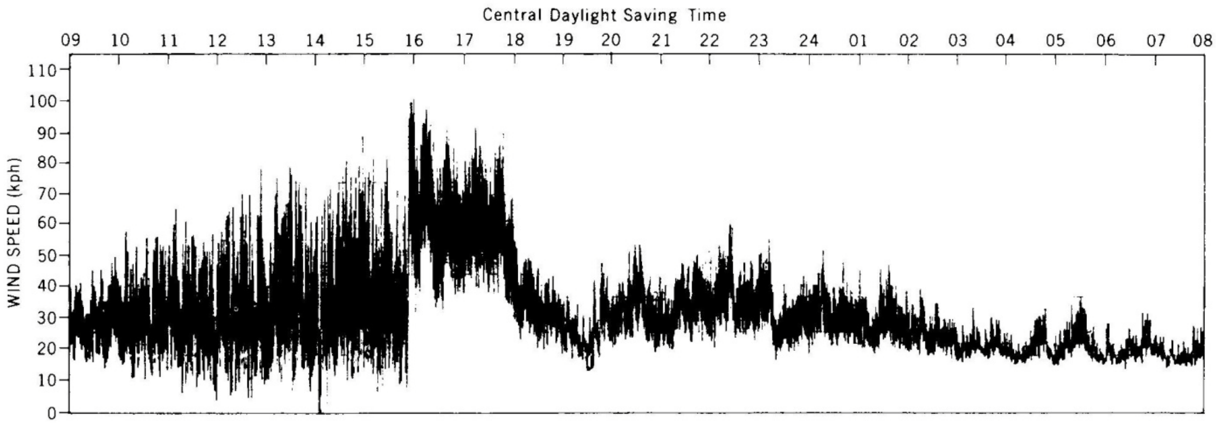

Figure 3 - Ash Wednesday hourly wind data

Ember attach is most prevalent during and immediately after the fire front has passed and are created and driven by fine fuel combustion. After the fire front has past heavy fuels burn slowly burn out over many hours, causing a slow decay of in ember density. It is a qualitative risk judgment as to when it is most appropriate to require spray system activity. It important to have constant spray delivery for 10 minutes prior to arrival, during and for at least 1 hour after the fire front has passed. After this time intermittent spray delivery is most appropriate, and ideally should persist for as long as the winds provide ember transport onto the structure. For spray system design it is recommended that intermittent sprays should remain active for at least 5hours after the main front, and continue to operate if water supply available for up to 12 hours.

3.2 Combustible Tanks

Recent research on combustible and non combustible tanks [19] has provided the following guidance:

- There is little evidence to suggest that metal, concrete and subterranean tanks are not suitable for providing water supply during a bushfire event.
- Polyethylene (PE) tanks are readily ignited when exposed to radiation and/or ember attack. If radiation persists the tank will eventually catastrophically fail. If the tank is only exposed to the effect of a moving fire front and has no heavy fuel elements which provide continued radiation impingement or feedback after the tank has been ignited then the tank is likely to self extinguish and maintain its role of providing a fire fighting water supply.
- The proximity of a PE tank to a well protected house does not present a high risk provided that tank and any combustible facades or elements on the house are protected by the spray system or other means.
- Sitting two PE tanks in close proximity is also undesirable as the combustion of either tank may impose the necessary radiation on to the adjacent tank to ensure that both tanks burn until failure. This may also be true for tanks placed close to a surface that can reflect the radiation produced by its combustion thus allowing the tank to continue to burn until failure even though the original heat source has subsided (example elements include fences and sheds).
- Stored combustibles near a PE tank may provide the necessary flame and radiation to promote the PE tank to continue to burn and fail. Excessive fine fuel build up around the base of the tank could also cause failure.

- PE tanks should not be placed near combustible vegetation or other combustible elements eg fences, sheds, motor vehicles, etc.

It conclusion, PE tanks can be utilised for ember attack spray systems however, the above conditions should be met and maintained.

3.3 Automatic activation

The ember attack guideline in most cases recognises the benefits of passive construction measures in accordance with AS 3959 when compared to a Bushfire Spray System. However, it also recognises the difficulties with retrospectively installing passive protection measures on to existing houses. With this in mind an automatic activation method would be desirable to ensure the Bushfire Spray System is activated prior to or at the same as time as ember attack occurring.

The concept of automatic activation is important as it is recognised that the majority of homes lost in bushfires are unoccupied and often present a significant risk to neighbouring structures.

Prior to any discussion about what mechanism will activate a Bushfire Spray System, a thorough analysis of how the BSS will fit into a homeowner's Bushfire Safety Plan is required. This will then determine the most effective method of activation. The concept of a bushfire safety plan is supported by post fire research such as Blue Mountains and Eyre Peninsula where those occupants who had a plan clearly performed better than those who hadn't considered bushfires as a risk.

Unfortunately automatic activation of bushfire spray systems to offset the impact of ember attack is one that has not been considered in the past. This is due to the dynamic nature of ember attack. However, this is not a reason to obstruct a homeowner's desire to develop a system that will activate automatically.

If it is decided or required to pursue an activation system that is automatic then the following considerations should be addressed:

- The type of vegetation that exists around the property and the density of embers that it will produce. E.g. rough bark trees will produce more embers than smooth bark trees.
- The local environmental conditions including wind speed and direction.
- The time duration for the ember attack. This could be influenced by the type and quantity of vegetation surrounding the home.

3.3.1 Sensors

A recent review of bushfire spray systems in New South Wales and Victoria identified the following possible solutions for automatic activation:

- Smoke detectors placed on the external walls of the house, and
- Heat sensors placed around the house and/or property.

The concept of using smoke detection technology is one that is supported as it operates on the principle that smoke will be present when embers are attacking, this is certainly the case for aggressive wind driven fire events where house loss is most prevalent. However it is not completely true when embers fall from a convention column onto an urban environment. Once the embers have landed on surrounding fine fuels, the smoke produced is likely to activate the smoke detector. Provided that false alarms causing activation of the spray system is capable of causing minor inconvenience it appears to be the most viable option. For situations where false activation is undesirable, multiple sensors may be used, spray activation only occurs when a threshold for each sensor is achieved. The most appropriate variables being smoke, temperature and wind speed. Approximate threshold of temperature and wind speed could be set appropriate for local conditions.

Smoke detectors are not designed for external conditions, it is likely that there will be some problems with the external installation, smoke detector suppliers would need to be consulted regarding the most appropriate design for this task.

Unfortunately the downside to using smoke detection technology is that a system will activate at the first sign of smoke. This has the potential to substantially increase the amount of water required to protect the home. However, a smart system may be developed whereby the detector has the ability to activate and deactivate the spray system depending on the levels of smoke present. This area is one where further research and development would need to occur to better define the requirements for a smoke detector.

3.4 Pump performance

3.4.1 Context

Measures should be taken to ensure the pump can operate under the conditions found during extreme bushfire events with the understanding that pumps, piping and water supply may be placed in areas that receive a much higher impact from the bushfire event than the structure it is attempting to protect.

It is a suitable assumption that main electricity and water supply may be interrupted during the fire event.

3.4.2 Expectations

The pump is expected to start and operate effectively and meet the requirements of flow rate, duration, intermittent flow demand, auto prime, service life, safe operation, and flexibility for other uses.

3.4.3 Water supply options

There is a wide range of water pressure supply options for an effective spray system. A system can be designed for either low or high pressure depending on the preferred water supply option :

3.4.3.1 Gravity feed supply

One of the most reliable approaches is to have a fixed gravity feed water supply of sufficient capacity, pressure head and pipe flow capacity to operate the spray system for its entire duration.

This system overcomes the need for pump operation during the event, but requires a water tank at a location where sufficient pressure head is provided. Placement and type selection of tank to ensure it is not susceptible to catastrophic failure is discussed in section 3.2. Tank installations of less than 15m of pressure head would require to use of low pressure swirl or spray heads. Installations great than this height would allow for a wide range of heads, including impact. Further research is planned to investigate the minimum water pressure required to provide an effective spray delivery system.

Advantages:

- This approach lends itself to areas with appropriate elevation on the property.
- Synergy with cases where gravity feed water systems is the preferred system for domestic or farm use.
- Negates the requirement for high capacity water pumping system.

- Negates the requirements for pump systems that can operate in absence of mains electricity and water supply.
- Mechanically simplistic, intrinsically reliable.
- Can be easily activated and cycled as required.

Disadvantages

- Considerations with this system include ensuring adequate tank level during times of high bushfire risk.
- Water storage must be at an elevated point.
- Pressure delivery is limited by initial tank installation.

3.4.3.2 Electric motor supply

In certain cases electric motor supply is a preferred option.

This system relies on an electric motor served by a generator or other backup power supply. This system may be suitable where there is an existing need for a domestic system water and power supply system. Typically these systems are not as powerful as a petrol or diesel driven pump and are more suited to low pressure low volume supply requirements. However they could be designed for high volume and pressure operations with a significant up front cost.

Advantages

- potential for dual purpose usage of pump and generator (or alternative or source)
- Normal usage of the pump ensures constant monitoring of reliable pump operation.
- Simplistic start and stop operation of pump.
- Advantages of this approach is easy stop and start of the electric pump as required, and the generator can be used to provide power during all instances mains power supply is not available. In the occasional instance where mains power is not lost during the bushfire impact the generator may not be called upon. Adding redundancy into this solution.
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Disadvantages

- A backup generator is necessary to ensure pump operation during power failure which is common during bushfire events.
- Spray system may require significantly greater power requirements than an existing domestic supply requires. Adding significant initial purchase and running cost.
- A reserve capacity must be maintained for spray system operations during times of high bushfire risk.
- Generators or backup power source require regular checks and servicing.

Figure 4 - Photo showing the importance of suitable protection being provided to pumps.

3.4.3.3 Petrol driven pressure pump

When a duel purpose design cannot be identified, a petrol internal combustion engine coupled with an appropriate water pump can in many cases be the most cost effective method of providing sufficient water pressure when a gravity feed water supply is not available.

It is essential to provide regular maintenance to these units, ideally the system may be integrated with other domestic or property maintenance needs to provide an impetus for regular operation and maintenance.

Placement of pump to prevent flame and radiant heat exposure. Use of spark traps for air intakes, use of non combustible filter elements. Is it available in the required manual or auto start requirement? May require spray protection and shielding of pump and motor.

Advantages

- Cost effective compared to electric/generator system for high demand systems
- Potential for multiple uses of motor and pump system.
- Available as ‘off the shelf’ system.
- Reasonable term reliability provided service regime is followed.

Disadvantages

- Requires regular checks and servicing. Fuel conditioner is essential and the replacement or use of fuel on a regular basis to ensure it does not become old and inappropriate for use.
- Engine is susceptible to smoke and high temperatures.
- Auto start and intermittent activation is more problematic than electric or gravity feed systems.
- Extensive thermal protection required, from radiant heat and some means of limiting the peak air temperature experience by the engine

3.4.3.4 Diesel driven pressure pump

A diesel internal combustion engine coupled with an appropriate water pump can in many cases be the most cost effective method of providing sufficient water pressure when a gravity feed water supply is not available, especially where large capacity systems are required.

Considerations are similar to petrol pump systems, except that a diesel driven system is more suitable to high capacity installations, typically larger than a standard house.

Advantages

- Can perform under more extreme conditions than a petrol pump.
- Potential for multiple uses of motor and pump system.
- Available as ‘off the shelf’ system
- Long term reliability provided service regime is followed.
- Improved fuel consumption rate compared to petrol, potentially providing longer operation with standard tank size.
- Fuel is more stable at elevated temperatures and ignition sources.

Disadvantages

- Requires regular checks and servicing. Fuel conditioner is essential; replacement or use of fuel on a regular basis to ensure it does no become too old for use.
- Initial cost is higher for small capacity installations compared to petrol.

3.5 Use of plastic piping

As stated previously in this report a bushfire spray system designed to limit the impact of ember attack is to be designed to a radiant heat exposure of 12.5 kW/m². In addition to this radiant heat exposure, embers may start fires within close proximity to the house prior to the Bushfire Spray System activating. This may generate an increased radiant heat exposure above 12.5 kW/m².

Various forms of plastic are known to not maintain their integrity when exposed to high temperatures. This causes problems with using plastic pipes if consideration is not provided on how to reduce these impacts.

Figure 5 - Photo showing the importance of providing appropriate coverage of plastic pipes when laid on the ground.

Figure 6 - Photo showing use of copper pipe work where the expected radiant heat will be high due to plants located against the house.

Considerations should include:

- Will the water be continuously flowing through the pipes when high temperatures are present?
- Is an auto activation system being utilised that will activate the spray system prior to temperatures being experienced that will potentially damage the integrity of the plastic pipe.
- Will the plastic pipe be installed internally or behind a barrier?
- Will the spray system mitigate the localised flaming activity as a result of combustibles being ignited by ember attack?
- Is the pipe installation such that leaf debris will not accumulate against the pipe

If the answer to the above considerations are sufficient then it could well be expected that plastic piping will be appropriate and will not be damaged by the bushfire. However, as with all other items discussed in this report regular maintenance needs to occur to ensure the plastic pipes are not damaged during the fire event.

3.6 Pipe location

Effective pipe location will ensure that leaf build up against the pipe or structure is not possible unless the spray system is designed to wet these pipes. The guideline states the requirement to ensure all pipe-work when installed onto a roof surface is provided with a 50 mm separation space. This is intended to reduce the build up of leaves and combustible materials against the roof surface and potentially becoming an ignition source.

Figure 7 - Debris accumulation against pipe-work

If the 50mm separation space is removed from the guideline the build up of combustible material against the pipe-work becomes another risk area for the house. This is demonstrated in Figure 7. The 50mm space is supported to reduce the areas of the house that can support an ember developing into a flaming fire.

3.7 Water source/quality

3.7.1 Water recovery and reuse

An effective method of maintaining high levels of water capacity for ember mitigation is to recover a percentage of the water pumped through the spray system. This is often most effectively utilising existing storm water recovery drains where rainwater recovery systems are already in use. If these are to be utilised, consideration must be given to the potential to contaminate the domestic rainwater supply to the house. Otherwise it is a very effective method of ensuring adequate quantities to the spray system.

Water recovery systems are often not suitable when a primary water supply such as a pool is used, unless the storm water can be simultaneously diverted from the rain water supply to the pool and a routine of flushing the system after testing and operation is employed.

3.7.2 Use of non potable water sources

Water storage of non potable water can raise issues of health and/or corrosion of water tanks. Local council regulation would normally cover these types of water storage issues. Where water treatments such as chlorine or salt are used their corrosive influence must be considered. Fresh water purging of the pump body is essential to minimise the risk of a system failure due to corrosion.

3.8 Spray performance

For the mitigation of risk due to ember attack the range of individual objectives the spray system is attempting to achieve must first be considered. These are generically listed below:

3.8.1 Gaps

Generic gaps whether they be in the roof, walls or underfloor of the structure are susceptible to ember entry if they are of sufficient size (generally considered that 2mm or greater is sufficient to allow embers entry through a simple gap whether it be a round hole or slot) [22]. If a spray system as one of its objective is required to mitigate the risk posed by this gap during bushfire attack then at least one of the following criteria would need to be met:

- **The gap itself must be flooded at all times,** this requirement is obviously quite onerous on a spray system and would not normally be a chosen method to mitigate the risk of ember attack. High water delivery rates would be required to constantly block a gap, unless they were few in number and size. *Often roof spray systems are employed under the pretence they will prevent ember entry into the roof cavity, these roof sprays are likely* *to wet gutters and roof valley where combustible material may collect, however water flow over the roof surface is likely to do little to block the gaps that a roof may have.*

- **The entire occupiable or non occupiable space in which the gap allows entry into is wetted or non combustible**, wetting would need to be at least intermittent as to not allow flaming or smouldering ignition of materials that could lead to house loss. It is rare that an occupiable or non occupiable space is suitable for wetting however this criterion may provide a solution where this is acceptable.
- **Appropriate detection and spray activation systems are installed** as to not allow the occupiable or non occupiable space that the gap reveals to become involved in the spread of flame. Future regulations and designs may include the optional or mandatory fitment of internal domestic sprinkler systems, it may be possible to extend the functionality of this system to include the protection of non occupiable spaces and operate in the absence of mains water supply and mains power.

Figure 8 - Photo showing gaps on the inside of an external wall.

Figure 9 - Photo showing debris entering through the gap under a front door

3.8.2 Window protection

During ember attack windows are susceptible to ember lodgement on the surrounding combustible frame. Glass breakage is also possible due to the combustion of surrounding elements that may provide radiation, flame or mechanical impact on the glassing element. For effective window protection all of the following criteria needs to be met [22]:

- Where combustible window frames are used intermittent wetting of the window frames should occur.
- Where surrounding combustible elements are sufficiently close to cause radiation to exceed 12.5 kW/m² on a plane or laminated window a water film must flow over the entire surface of the glass, unless intermittent spray is provided to the element to prevent its combustion.
- Where surrounding combustible elements are sufficiently close to fall against the window then intermittent water spray on the element to prevent its combustion should occur. An example of this is non spray protected combustible fences that when ignited may fall onto a window, breaking the glass.

Figure 10 - Photo showing the remains of a window frame ignited by ember attack.

3.8.3 External attached elements

External elements attached to the dwelling have the potential to ignite and present significant flame and radiation impact to the main structure. Where these elements are considered combustible the spray system must intermittently wet these elements to ensure they do not ignite and support flame that may impact on the main structure in some way. These external elements may include decks, fences, wood piles and rubbish bins [0,1,3,4,9,13,15,16,17,18,20,22]:

Figure 11 - Photo showing the deck of a house ignited by ember attack

3.8.4 Surrounding Ground Cover

The design including the location and type of sprays should consider the concept of overspray occurring into areas immediately adjacent the house. As stated previously in the report combustible material within close proximity of the house can ignite and generate significant short term radiant heat. This short term radiant heat and possible flame contact has the potential to compromise glass and other house entry areas [0,1,3,4,9,13,15,16,17,18,20,22].

The use of low wind effect watering systems such as an impact head sprinkler is recommended to continuously or intermittently wet combustible ground cover within six meters of the structure. Many irrigation suppliers can provide information as to the level of wind effect different spray heads are susceptible to.

4 RECOMMENDATIONS

As a result of the assessment of a number of areas within the draft guideline the following recommendations are made:

Consideration must be given to the effect on the sprinkler system's performance from other structures including sheds, outbuildings and fences. This could be in the form of a risk assessment.

There are extensive opportunities to proactively investigate the performance of pumping and spray systems under simulated bushfire and wind conditions so that more prescriptive guidance can be provided.

5 CONCLUSIONS

This research report has been developed to provide supporting information for the proposed guidelines and if it can't justify the guidelines to propose additional research requirements. The report has assessed areas of the guideline including spray performance, automatic activation and types of pumping systems.

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