WEEDS: Firebrand Defense for the “Typical Catastrophe”

The California “Fire Siege” of October 2003 destroyed over 4000 homes, and took 24 lives. Being able to prevent destruction of this magnitude will requires two major changes in the way that the fire community and public think about wildland fire. These can be summarized as follows:

- The catastrophic is typical
- Most homes destroyed in wildland fires are ignited directly or indirectly by firebrands

There are a number of ways to address the firebrand threat, and this article will address them, as well as propose a novel method that hopefully can be added to their ranks. Called WEEDS (Wind-Enabled Ember Dousing System), it is an external water spray system that uses the winds associated with catastrophic fire events to distribute water on the structure. This system was used to protect my own home during the Cedar fire, and evidence indicates it helped to save it.

The Catastrophic as Typical

Events as large as the Cedar fire are exceedingly rare, so in what sense can they be called "typical"? Some scientists view wildland fire as what physicists call a *self-organized critical phenomenon*, a classification shared with other events such as earthquakes and avalanches. Such phenomena are driven by a build-up/release mechanism and are inherently unpredictable. Most importantly, the greatest amount of environmental change that they cause is driven by rare, catastrophic events, rather than the gradual accumulation of change brought about by smaller events.

If we look at the statistics on home losses due to wildland fire, we can see what this means. Home losses during the California "Fire Siege" equaled the total combined US losses between 1999 and 2002. Looking more closely, for instance at the year 1999, we see that over half of the losses for that year occurred at the Jones fire near Redding, California – another wind-driven catastrophic fire. This is a characteristic of *self-organized critical phenomena* – big events dominate the statistics over a wide range of scales.

What a "typical" wildland fire is to a fire professional is therefore very different than the wildfire experienced by a "typical" home about to be destroyed. In order to understand this, one has to stop thinking as a wildland fire professional and start to think like a house. Statistically, the last thing the "typical" lost home would see before it burned would be a massive, catastrophic, wind-driven wildland fire, and hardly a fire professional in sight. And firebrands – thousands of horizontal embers carried in gale-force winds.

Since Ramsay's classic 1987 forensic study of 1100 burned homes after the 1983 Ash Wednesday fires, Australian fire authorities have acknowledged that firebrands are the primary cause of structure ignitions. A paper published in 2004 analyzing two Australian wildfires found that there was a 50% destruction probability for homes 100 feet and 200 feet, respectively, from the fire front. This clearly implicates firebrands. Studies most commonly quoted in the US, however, indicate that a house with a non-flammable roof has a 90% chance of survival if it is over 100 feet from fuels. This claim contradicts numerous Australian studies, and the reason for this is not clear. It should be pointed out that our own Mussey Grade corridor in Ramona, which had no professional fire assistance, suffered 60-70% losses, more in line with the Australian figures.

Brand-induced ignitions have several distinguishing features:

- They often start in the attic or on the roof without visible damage elsewhere
- They can lead to ignitions significantly after (or before) the fire front passes
- There is a high probability of self-saves by modestly equipped civilians
- They can occur more than 100 feet from the fire front
- Vegetation around the structure survives, or is charred only on the structure-facing side

The Cedar fire that struck our community was one of these cataclysmic fires. Official reports of the fire indicate that spotting from and density of brands was of a greater intensity than that usually encountered by firefighters. The Ramona Municipal Water District (RMWD), which is responsible for fire protection in our community, held hearings to gather information regarding the Cedar fire. Fifty citizens who were affected by the Cedar fire gave testimony at these hearings. In only one reported case was an observed structure ignition concurrent with the fire-front passage. Of the six citizens who reported staying through the fire (or returned to residences within one hour), all contributed to saving at least one structure without any professional assistance. Four residents reported having cleared in excess of recommended defensible space requirements, and three of their four homes burned. These observations suggest that a large fraction of the homes lost in Ramona during the Cedar fire were ignited by firebrands and secondary ignitions.

A catastrophe-dominated model has implications for strategy and tactics. Strategically, it means that the “shelter-in-place” strategy as currently being implemented (“Hide and wait for the fireman”) is likely to lead to a mass-casualty incident. During catastrophic events, firefighting resources are spread very thin and are often unable to keep up with the rapidly moving fire front. “Sheltering” residents are likely to panic and flee if the fire-front arrives before professional assistance does. As was the case during the Cedar fire, it is during such panicked evacuations that the majority of casualties occur.

There are a number of tactics that can be effective against brands under high-wind catastrophic conditions, and all have one thing in common:

No structure-protection technique that is effective during catastrophic fires depends on the presence of fire professionals. While professional intervention is very effective, there will never be enough professionals to protect all structures during catastrophes.

Stopping Brand Ignitions

There have been great strides in recent years in the development of techniques that make the likelihood of direct flame and radiant heat ignition much less likely. Addressing brand ignitions will not require change to current accepted practices, but will instead require that additional practices be adopted. Effective techniques are described in the following sections:

Construction Techniques and Materials

Fire-safe construction is the firebrand protection method currently recommended by the professional fire community, and is described in both the NFPA 1144 and IUWIC wildland fire codes.

The most fundamental problem with them is that there can be no breaches in the integrity of the structure. Wind-driven brands can be very penetrating. The curved tile roofs, ubiquitous in Southern California, must be sealed underneath with fireproof material or they can act as ember-collectors. The greatest vulnerabilities may not be obvious except in post-mortem, as the following quote from the RMWD hearings demonstrates:

"the first thing I saw… was a house with 100% of the roof in flames, nothing else burning, just the roof. This is an all tile roof, a new house with every fire prevention technique known to the construction industry...
What effort did I take before the fire? It was a new home there were no vents on the east side of the house. The eves were entirely stucco, tile roof... I had quarter inch tempered glass windows on the fire side of the house... The architect came back from a trip that next week and my wife, a realtor, wanted to take him on a tour to show him what happened and his comment was, 'I know one house that didn't burn, it was my house'. She said when they got there his jaw hit the floor because everything was done to protect that house from fires."

Self-saves

Many Australian fire authorities, as described in last year's *Wildfire* article by Keith Harrap, discourage evacuation by able-bodied people. Instead, they are encouraged to remain with their structure through the fire and protect it themselves. Statistics gathered by Australian fire authorities [] indicate that the probability that an occupied structure survives a wildfire is over six times higher than for an unoccupied, unprepared structure. This technique presupposes defensible space, available water, minimal but proper equipment, and residents who understand the obligations and risks and are willing to assume them.

Barrier Foams and Gels

Foams and gels are designed to provide a thermal barrier around the protected structure. How well they will protect a structure under "typical" catastrophic conditions depends upon how well they seal open gaps and niches, and how long this seal endures under high winds.

Their main disadvantage is that they currently require manual application. Any proposed automated system will have to compensate for intense wind conditions. They also take time to apply, and training or technical competency to apply properly.

Rethinking External Sprinklers

Using external water systems to protect structures is an old idea, and has spawned many patents and some commercial ventures. None of these has gained wide acceptance by the public or fire protection agencies. The main arguments against the use of external sprinklers have been:

- The spray pattern will be severely disrupted by the high winds associated with large wildland fires
- Most designs apply water to the roof, but roofing materials approved in WUI areas are fire resistant anyway.
- These systems require a large amount of water to be effective, for which a municipal supply cannot be depended upon.

The main problem with these early approaches is that they assumed the spray system would provide thermal protection. Design requirements are less rigorous if the primary system goal is to extinguish brands.

There are three main ways that sprinklers can provide protection from brands:

- Direct extinguishing – if the spray density exceeds a critical value, the embers will be extinguished by the spray. Crib experiments yield spray densities between 1 and 4 gm/m^2-sec for this value. One would naively expect the lower values, since brands tend to have high surface-to-volume ratios and tend to be light, but I know of no experimental work in this area.
- Water accumulation on all flat surfaces on and near the structure will create a "moat" which can extinguish brands that either roll towards the base of the structure or that strike vertical fascia and fall to their base.
- Hydration of light fuels both by spray and by vapor. Only light fuels such as leaves and small twigs can have their water content changed by humidity within a few hours. Claims of a "vapor bubble" advanced by some patents and companies, however, do not make sense in the light of the extreme wind conditions experienced in catastrophic wildland fires.

The Fire Protection Association of Australia published a study in 2000 in which they analyzed the potential efficacy of a number of sprinkler designs as to their capability to protect structures from brands. They concluded that a "drip" system in which the water runs down the walls is the best system due to its higher resistance to wind disruption.

WEEDS: A Wind-Enabled Ember Dousing System

I would like to propose another principle to be considered for use in external spray systems. Called WEEDS (for Wind-Enabled Ember Dousing System), it simply consists of under-eave irrigation-type sprinkler heads directed *outward.* The idea is that in the high winds that are characteristic of catastrophic destructive fires, the spray will be blown back onto the structure. The outward direction gives the coarse spray time to disperse laterally from the central axis, allowing overlapping coverage between spray heads to persist up to high wind speeds. We constructed a prototype system on our own home in Ramona, California, and this structure survived the Cedar fire. Structures on all adjacent properties were destroyed.

Characteristics of the system are:

- 32 outwardly-directed irrigation nozzles spaced 8' apart under the boxed-in eaves, protruding 4-6" and delivering between .5 and 1 gpm.
- 360 degree protection
- Low flow rate – a 5000 gallon tank lasts 3 to 4 hours.
- Electric 2 hp pump operating at gauge pressure of 63 psi.
- 12 kW propane-fueled generator with automatic transfer switch

A schematic of the system can be seen in Figures [] and []. This concept is being placed into the public domain, and is free for use.

The system operated according to expectations on the night of the Cedar fire. Winds were over 30 mph, and full surface wetting was obtained, including wetting of the roof. The system was operated intermittently until evacuation at 4:15 am. Because municipal water was still flowing, estimated operating time for the system was around five hours. Based on RMWD transcripts and other eyewitness accounts, the fire front passed through between 6:30 and 7:30 am. The structure was accessed 30 hours later, and was found to be intact.

While it isn't possible to conclusively prove that the system protected the structure, there is some evidence to suggest it. First, there is evidence that ember attack was significant on the property. Aside from extinguished brands found about the property, I also observed (as shown in Figure [],

- partial ignition of railroad ties, without significant charring
- small burn marks on citrus leaves
- contents of a metal shed ignited, while a *chamise* (primary component of the local chaparral and notoriously flammable) six feet away suffered no damage

Some computer modeling has been done on the WEEDS spray pattern for an upcoming academic publication. While a number of approximations have been made, most of these lead to the results being overly conservative. Figure [] shows the spray density on the ground and walls at two different wind speeds. For low wind speeds, WEEDS can lay down enough spray density to extinguish brands and wet materials up to 12 feet or so from the structure. As the wind speed increases, a greater fraction of the spray is blown back onto the structure. The spray overlaps until the wind speed at the nozzle is over 60 km/hr. Gusting and chaotic wind conditions, though, will tend to prevent persistent gaps in coverage. At higher wind speeds, in the present configuration, approximately 40% of the spray will go onto the roof, which can be important if there are gaps under shingles or tiles, or the possibility of gutter debris. The model supports the assertion that any collection of brands on or near the structure, including attic vent screens, would receive sufficient spray density to extinguish them.

There are some advantages of WEEDS over a drip system. Because the spray is carried by the wind, it can reach recesses and voids that a drip system cannot. Places where brands are likely to be deposited are the same places that spray is likely to accumulate. Also, during lulls in the wind, protection extends several meters out from the structure, covering vegetation and other ignitable materials.

Conclusion

WEEDS is a specific solution to a general problem – that of protecting structures from brands. There are a number of solutions to this problem, some more appropriate than others depending on conditions, and more solutions can be developed. These will only be applied, though, if the following is realized:

Significantly reducing WUI home losses will require addressing brand ignitions under high-wind conditions in which professional fire assistance is unavailable