Research Report

Fire-Retardant Gels: Effects of Weathering on Dehydration and Fire Performance

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Summary

In a study conducted in collaboration with the University of North Carolina at Charlotte, IBHS evaluated the long-term effectiveness of two fire-retardant gels when applied to a wood-based substrate. Gels are a type of coating meant to provide protection for a short period, a few hours, and are typically applied manually just prior to the arrival of a wildfire. The gels act as a protective heat sink on the material they are applied to, reducing the impact of the thermal exposure and therefore potential to ignite.

The operating principle of these fire-retardant gels is based on hydration. Therefore, their effectiveness is reduced as the gels lose moisture. Fully hydrated, both gels tested can increase the time-to-ignition from 15 seconds to over 7 minutes. However, in a realistic wildland fire scenario of 15 percent relative humidity and a wind speed of 10 m/s (approximately 22 mph) both gels reach 50 percent dehydration in less than 1.5 hours and full dehydration[1] in 7 hours.

Introduction

Fire-retardant coatings such as paints and gels can be applied to exterior surfaces of buildings and, if effective, could provide relatively inexpensive protection from flame and radiant heat exposure. This additional protection may reduce the ignition potential of a building and lessen the severity of damage. One type of coating is intumescent paint which is applied to a building like a typical paint coating. Based on marketing information, these coatings are intended to provide protection for a number of years. In 2015, IBHS conducted a study in collaboration with the University of North Carolina at Charlotte to evaluate the long-term effectiveness of intumescent paints when applied to a wood-based substrate as they weathered outdoors. The results indicated weathering reduced the effectiveness of all five commercially available intumescent coatings evaluated by that study. Each coating tested claimed enhanced performance for up to five years, but they all performed no better than uncoated wood after only one year of weathering.

Gels are another type of coating meant to provide protection over a shorter time period, a few hours, and are typically applied manually just prior to the arrival of the wildfire. After hydration occurs during the application process, the gel acts as a protective heat sink on the material it is applied to, reducing the impact of the radiant heat exposure and therefore potential to ignite.

The operating principle of these fire-retardant gels is based on hydration. As the gels lose moisture their effectiveness is reduced. IBHS, again in collaboration with the University of North Carolina at Charlotte, recently completed a research project to evaluate the effectiveness

[1] Full dehydration is when the mass loss had reached a steady-state, where no further reduction in mass was observed with additional weathering time.

of commercially available fire-retardant gels as a function of weathering (i.e., exposure to wind and a low humidity environment).

How We Tested

Two products were tested in this study:

- Gel A used a vegetable cooking oil-based mixing agent
- Gel B used a petroleum-based mixing agent

Both gels were applied to 100 mm x 100 mm (approximately 4 in. x 4 in.) samples of T1-11 plywood siding according to the manufacturer's instructions (Figure 1). The initial target thickness of the gel coating was 6.35 mm (¼ in.).

Figure 1: Application of a gel product to the T1-11 plywood samples.

Samples were weathered in an environmental chamber using three different relative humidity setpoints:

- 15 percent
- 40 percent
- 70 percent

at three wind speeds:

- 0 m/s (no wind)
- 5 m/s (11 mph)
- 10 m/s (22 mph)

To evaluate dehydration of the gel coating, samples were removed from the conditioning chamber hourly and weighed. At each interval, wet film thickness was also measured (Figure 2).

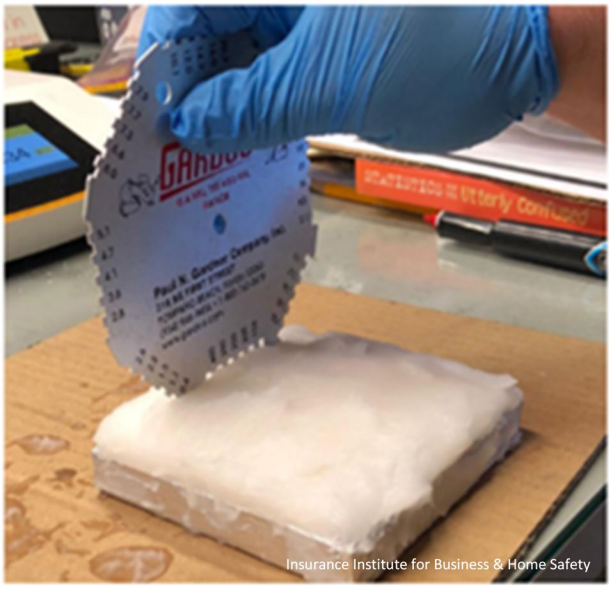

Figure 2: Measuring the wet film thickness of a gel product.

Radiant heat flux from wildland fire to homes depends on the intensity of the fire and distance between the flame and building. Experimental crown fires generated heat fluxes of 80 kW/m^2 to buildings 30 feet away (Cohen 2004). The maximum estimated exposure for a firefighter wearing wildland firefighter clothing and head and neck protection is 7 kW/m^2 over a period of approximately 90 seconds (Butler and Cohen 1996). Fire performance of each gel was evaluated using a cone calorimeter with a fire exposure of 50 kW/m^2 which represents the radiant exposure from a spreading wildfire at 3 different dehydration conditions:

- Freshly applied: These specimens were tested using the cone calorimeter immediately following application and not exposed to any weathering
- 50% dehydration: These specimens were tested once the mass of the applied gel reached 50% of its initially applied mass.
- Fully dehydrated: These specimens were tested when the mass loss had reached steady state i.e. no further reduction in mass was observed with additional weathering time[2]

Table 1 provides the average time-to-ignition for each of the dehydration conditions from three samples, including for untreated T1-11 plywood control. The time-to-ignition decreased linearly with dehydration of the gel. When freshly applied, both gel coatings increased time-to-ignition from 15 seconds for the untreated case to 467 and 440 seconds (7.7 and 7.3 minutes), respectively, for coatings A and B. When the specimens were tested in the fully dehydrated condition, Gel A had a similar time-to-ignition as the untreated specimen. The specimen with Gel B (the petroleum-based gel) had a shorter average time-to-ignition than the untreated

[2] It is possible that some moisture (water) could be retained within the gel material at this dehydration condition.

specimen, indicating that once dry, material coated with Gel B may be more susceptible to ignition.

Table 1: Average time-to-ignition for samples

Condition	Gel A	Gel B	Untreated T1-11 Plywood
Freshly applied (100% hydrated)	7.7 min.	7.3 min.	—
50% dehydrated (mass loss from initial)	4 min.	2.8 min.	—
Fully dehydrated	0.3 min. (18 sec.)	0.07 min. (4.2 sec.)	0.2 min. (12 sec.)

As shown in Table 1, the hydration of the gel coating is critical to enhanced fire performance. Table 2 provides the time required under the different drying environments to reach the 50 percent and fully dehydrated. As expected, higher wind speeds and lower relative humidity causes the gels to dehydrate faster. Even under ideal conditions not typical for severe wildfires, no wind and high relative humidity (70 percent), both gels reached 50 percent dehydration in less than 19 hours. The worst-case conditions, 15 percent relative humidity and 10 m/s wind speed, are consistent with the National Weather Service red flag warning conditions that could lead to severe wildfires. During the Tubbs fire (2017) in Northern California relative humidity was measured at 17 percent with sustained surface wind speeds of 21 m/s (Nauslar 2018). Under these more realistic conditions both gels were found to reach the 50 percent dehydrated state in less than 2 hours.

Table 2: Dehydration time, measured as time to 50 percent and 100 percent dehydration, based on impact of conditioning (wind and relative humidity).

Conditioning Environment	50% dehydrated (hrs.)		100% dehydrated (hrs.)	
	Gel A	Gel B	Gel A (acrylic)	Gel B
15% relative humidity @ 10 m/s	1.4	1.3	5.0	7.0
40% relative humidity @ 5 m/s	4.3	2.2	9.0	8.0
70% relative humidity @ 0 m/s	18.8	16.9	70.0	55.0

Time to full dehydration indicates the point when the mass of samples did not change after three measurements. In worst case conditions (red flag weather), both gels reach full dehydration in less than 7 hours. Under the favorable weathering conditions, the gels lasted 2–3 days before full dehydration. The substrate sample material for Gel A in these tests was acrylic, representing window glass. Figure 3 shows a summary of the data.

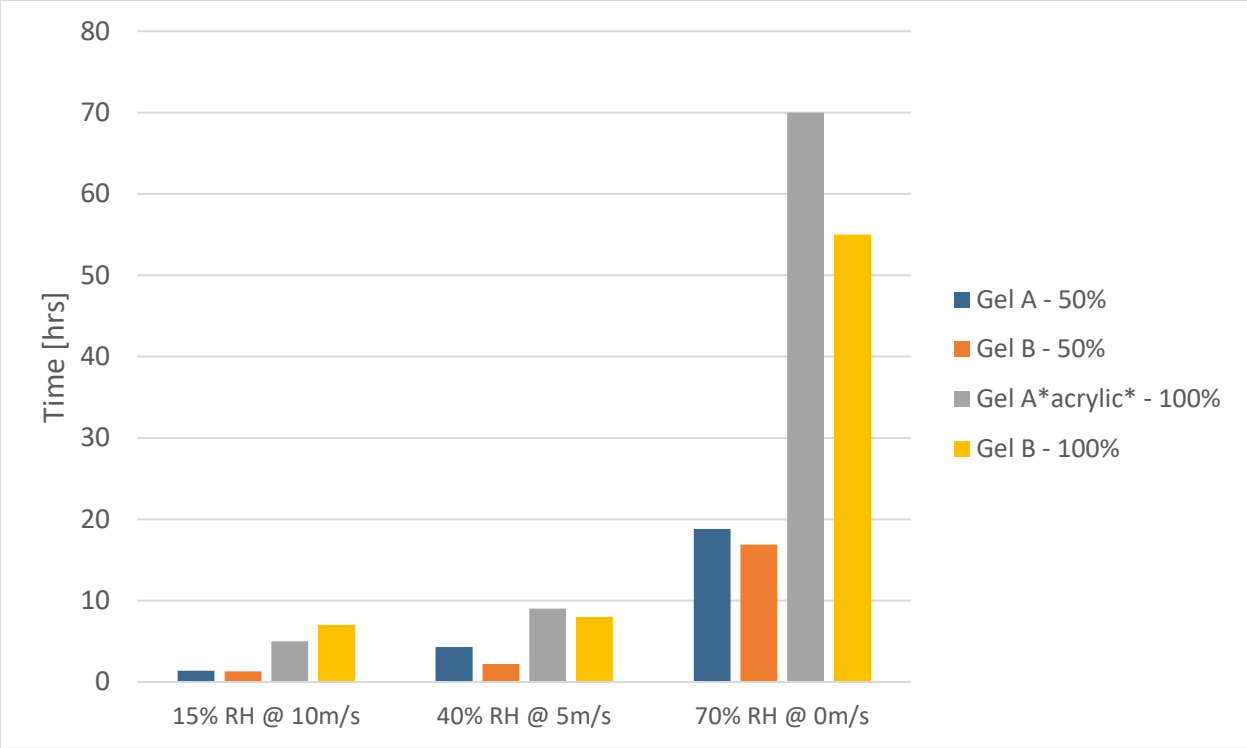

Figure 3: Time to 50 percent and 100 percent dehydration for each gel type. For time to full dehydration, Gel A was applied to acrylic, which has similar characteristics to window glass.

Results

- Fully hydrated, both gels tested can increase the time-to-ignition from 15 seconds to over 7 minutes.
- At 50 percent dehydration, the time-to-ignition was reduced by nearly half from over 7 minutes to 4 minutes for Gel A, and less than 3 minutes for Gel B.
- In a realistic wildland fire scenario of 15 percent relative humidity and a wind speed of 10 m/s (approximately 22 mph) both gels reach 50 percent dehydration in less than 1.5 hours and full dehydration in 7 hours.
- When completely or partially (50 percent) dehydrated, a gel that uses a petroleum-based mixing agent may create a condition more susceptible to ignition than untreated T1-11 plywood.
- The gels also limit the intensity of the fire after ignition (measured as peak heat release rate from cone) by limiting the amount of oxygen available to the ignited wood.
- During application, the gel can clog the spray nozzle which can be difficult to clean and adds additional time to the process.

- Removal and cleanup of fire-retardant gels after a fire has been reported to pose some challenges for homeowners. However, once dehydrated the products tested could be peeled off easily.

Conclusions

The results of this study show that the higher wind speed and lower relative humidity factors associated with more extreme fire weather result in faster dehydration rates. In a moderate weathering condition, it took about 4 hours for the gel to lose 50 percent of its initial mass (dehydration) and wet film thickness. Because protection from gels depends on continuous coverage, surfaces where the gel was not applied or has dried off are vulnerable locations. In that condition, the time-to-ignition was approximately 4 minutes, 13 times that of uncoated wood. In real-world conditions, it is not likely that a structure will experience a long-duration constant heat flux, so the gels would delay or prevent ignition.

IBHS provides extensive guidance and recommendations on decisions regarding building design, construction materials and mitigation practices homeowners can take to make their homes more wildfire-resistant. In the event a wildland fire threatens homes and buildings, IBHS also provides guidance at disastersafety.org that can be used to evaluate their property and take appropriate actions.

While property protection and resistance to wildfire exposures is important, the first priority should always be life safety. Homeowners should have an evacuation plan in place and follow instructions from local officials. Recent fires, including the Tubbs (2017) and Camp (2018), have demonstrated how rapidly wind-driven wildfires can spread, resulting in a short time between fire ignition and the need to evacuate a vulnerable area.

References

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