Effect of Fire-Retardant Coatings and Weathering on the Flammability of Wood-Based Materials in WUI Communities

Laura Dubrulle, Mauro Zammarano, Douglas Fox, Rick Davis

Flammability Reduction Group
Kathryn Butler, Erik Johnsson, Alexander Maranghides

Wildland-Urban Interface Fire Group

May 19-22, 2019
San Antonio, TX
Disclaimer

It is NIST policy that all technical manuscripts and research communications receive a thorough internal review before publication.

This review ensures that these communications are of high quality and conform to NIST and Department of Commerce policies.

Some of the data in this presentation hasn’t been through this review process and should be considered experimental / draft results.

However, the data has been analyzed by subject matter experts within the research team and is believed to be scientifically sound and consistent with the integrity expected of NIST research.
What is the problem?

“Wildland-Urban Interface (WUI) is the area where houses meet or intermingle with undeveloped wildland vegetation”

What is the problem?

WUI communities threatened by wildfires

Texas, USA, 2011

Corsica, France, 2017

Sokcho, South Korea, 2019

Victoria, Australia, 2009

California, USA, 2018
What is the problem?

WUI fire exposure from:

• Wildland

• Detached combustibles

• Structures and attached combustibles
What is the problem?

WUI fire exposure from:

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• Structures and attached combustibles
What is the problem?

WUI fire exposure from:

- Wildland
- Detached combustibles
- Structures and attached combustibles

Fences act like “fire highway”
Generate embers

A. Maranghides et.al, 2016. NIST Note (1909)
What is the problem?

©Courtesy of WUI Fire Group NIST
What and how?

1. Identification of commercial solutions

   - Fire-retardant coatings
   - Top-coatings

2. Evaluation of fire-retardant/aging properties - Cone Calorimetry/QUV

Accelerated weathering “QUV”
8 h UV – 0.25 h spray – 3.75 h condensation

Selection best candidates

After aging in QUV

Commercial solution for WUI communities
Identify commercial products

Coatings

⁻ Easy to apply (for old or new fences) affordable price
⁻ Aging, weather/mold resistance require several coats + top-coating

1. Market research

- 10 Fire-retardant coatings – 6 film-forming and 4 penetrating stains (all classic intumescent chemicals)

- 5 Top-coatings
Identify commercial products

Coatings

- Easy to apply (for old or new fences) affordable price
- Aging, weather/mold resistance require several coats + top-coating

1. Market research

- **10** Fire-retardant coatings – **6** film-forming and **4** penetrating stains (all classic intumescent chemicals)

- **5** Top-coatings

2. Properties and Application

- Solid contents (ATSM D2369), densities (ASTM D1475 and D792)

- Application on western red cedar (10 x 10 x 1.25 cm). Manufacturer’s recommendation for the dry film thickness

- Conditioning at 25 ℃ and 55% RH.
Flaming properties of fire-retardant coatings

Cone calorimetry (ASTM E1354) – Horizontal configuration – $\dot{Q} = 50 \text{ kW/m}^2$ – distance 60 mm
Flaming properties of fire-retardant coatings

Cone calorimetry (ASTM E1354) – Horizontal configuration – $\dot{Q} = 50 \ kW/m^2$ – distance 60 mm

3 possible scenarios:

Start test  Ignition  1 min  Flame-out  2 min  Stop test
Flaming properties of fire-retardant coatings

Cone calorimetry (ASTM E1354) – Horizontal configuration – $\dot{Q} = 50 \, kW/m^2$ – distance 60 mm

3 possible scenarios:

1. Start test → Ignition → Flame-out → Stop test
2. Start test → Ignition → Flame-out → Stop test
3. Start test → Ignition → Flame-out → Stop test
Flaming properties of fire-retardant coatings

**Cone calorimetry** (ASTM E1354) – Horizontal configuration – $\dot{Q} = 50 \text{ kW/m}^2$ – distance 60 mm

3 possible scenarios:
Flaming properties of fire-retardant coatings

Cone calorimetry (ASTM E1354) – Horizontal configuration – $\dot{Q} = 50 \text{ kW/m}^2$ – distance 60 mm

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Average results – 3 tests – S.Dev < 15%
Flaming properties of fire-retardant coatings

Cone calorimetry (ASTM E1354) – Horizontal configuration – \( \dot{Q} = 50 \, kW/m^2 \) – distance 60 mm

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**Table: Average results – 3 tests – S.Dev < 15%**

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Cone calorimetry (ASTM E1354) – Horizontal configuration – $\dot{Q} = 50 \text{ kW/m}^2$ – distance 60 mm

![Graph showing HRR vs time for Red Cedar and samples 3, 5, 7, 8](image)

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Worst fire-retardant properties:

Film-forming 3 and 5 (2/6)

Stains 7, 8, 9 and 10 (4/4)
Flaming properties of fire-retardant coatings

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Best fire-retardant properties:
Film-forming 1, 2, 4 and 6 (4/6)
Aging of fire-retardant coatings

Rainwater solubility tests

ASTM D3132 - Coatings disks soak in simulated rainwater for 7 days

\[ \text{mass loss} = f(t) \]
Aging of fire-retardant coatings

Rainwater solubility tests

ASTM D3132 - Coatings disks soak in simulated rainwater for 7 days

\[ \text{mass loss} = f(t) \]

Important mass loss after 1 week for all FR coatings
Aging of fire-retardant coatings

QUV

ASTM G154

12-hour cycle:

- 8 h UV
  \((E_v = 1.55 \text{ W/m}^2/\text{nm}, 60 \degree \text{C})\)

- 0.25 h Spray
  \((25 \degree \text{C})\)

- 3.75 h Condensation
  \((50 \degree \text{C})\)

Cone Calorimeter
Aging of fire-retardant coatings

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Cone Calorimeter
The need of top-coatings
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A and D, very low rainwater solubility
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Issue = compatibility between FR and top coatings

✓ Cone tests to check the compatibility

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<th>Top-coating D</th>
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1 + D
6 + D

Systems 1+D and 6+D

QUV
ASTM G154 – Cycle of 12 hours
8 h UV-A ($E_o = 1.55 \text{ W/m}^2/\text{nm}$, 60 °C)
0.25 h spray (25 °C)
3.75 h condensation (50 °C)
*Cone Calorimeter*

![Graph showing HRR vs. Time for 1+D system]
**Systems 1+D and 6+D**

**QUV**

ASTM G154 – Cycle of 12 hours
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*Cone Calorimeter*

![Graph showing HRR (kW/m²) vs Time (s) for 1+D samples at 0 h and 24 h]
Systems 1+D and 6+D

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*Cone Calorimeter*
Systems 1+D and 6+D

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*Cone Calorimeter*

![Graph showing HRR over time for different conditions](image)
Systems 1+D and 6+D

QUV
ASTM G154 – Cycle of 12 hours
8 h UV-A ($E_o = 1.55 \text{ W/m}^2/\text{nm}$, 60 °C)
0.25 h spray (25 °C)
3.75 h condensation (50 °C)

Cone Calorimeter

![HRR vs Time Graph](chart.png)

1 + D

- 0 h
- 24 h
- 72 h
- 1 week
- 2 weeks

![Images of Specimens](images.png)

- t_0 h
- t_24 h
- t_2 weeks
Systems 1+D and 6+D

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ASTM G154 – Cycle of 12 hours
8 h UV-A ($E_o = 1.55 \text{ W/m}^2\text{/nm, 60 °C}$)
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*Cone Calorimeter*

Similar results than uncoated red cedar!
Systems 1+D and 6+D

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Systems 1+D and 6+D

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ASTM G154 – Cycle of 12 hours
8 h UV-A ($E_0 = 1.55 \text{ W/m}^2/\text{nm}$, 60 °C)
0.25 h spray (25 °C)
3.75 h condensation (50 °C)

*Cone Calorimeter*

Similar results than uncoated red cedar!

1 + D

6 + D
**Systems 1+D and 6+D**

**QUV**

ASTM G154 – Cycle of 12 hours

- 8 h UV-A ($E_v = 1.55 \text{ W/m}^2/\text{nm}, 60 ^\circ\text{C})$
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**Cone Calorimeter**

**Similar results than uncoated red cedar!**

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**Systems 1+D and 6+D**

<table>
<thead>
<tr>
<th>System</th>
<th>Duration Details</th>
<th>Average Outdoor Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1+D</td>
<td>between 2 and 4 weeks (average ~200 days outside)</td>
<td></td>
</tr>
<tr>
<td>6+D</td>
<td>between 72 h and 1 week (average ~50 days)</td>
<td></td>
</tr>
</tbody>
</table>
Smoldering experiments

Pyrometer, Heitronics KT19.81

$T_{\text{max}} = 1000 \, ^\circ\text{C}$

FOV $\sim 10 \, \text{mm}$

$e = 0.96$

Smoldering experiments

Uncoated Red Cedar
\[ \dot{Q} = 20 \text{ kW/m}^2 \]

Smoldering experiments

Uncoated Red Cedar
\[ \dot{Q} = 20 \, kW/m^2 \]

Glowing ignition

Smoldering experiments

Uncoated Red Cedar

\[ \dot{Q} = 20 \, kW/m^2 \]

Smoldering experiments

Uncoated Red Cedar
\[ \dot{Q} = 20 \text{ kW/m}^2 \]

Glowing ignition

Steady char combustion

Transient glowing ignition

\[ \dot{Q} = 20 \text{ kW/m}^2 \]

Smoldering

Non-smoldering

Conclusion

Commercial systems
- FR coatings, few weeks
- FR coatings + top-coating, few months

Concerns
- QUV conditions, too harsh?
- Standard test methods inappropriate?
Conclusion

Commercial systems
• FR coatings, few weeks
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Concerns
• QUV conditions, too harsh?
• Standard test methods inappropriate?

What next?
• Technology transfer: 2 papers
• Keep an eye on the market for new products
• Scale-up – Burning fences
• Increase flaming/smoldering resistance of wood by:
  – Improving commercial coatings
  – Using new approaches identified in the literature
Thank you for your attention

Questions?

Fire Research Division: https://www.nist.gov/el/fire-research-division-73300
- Flammability Reduction Group: https://www.nist.gov/el/fire-research-division-73300/flammability-reduction-73304
- WUI Fire Group: https://www.nist.gov/el/fire-research-division-73300/wildland-urban-interface-fire-73305