RS Technical Bulletin: 17-010

RS Poles and Fire Shields Fire Performance

Background [1]

High intensity wildfires are fast-moving flame fronts that can damage or destroy utility structures, even when the exposure time is relatively short. Wood utility poles are particularly susceptible to wildfire damage from both large and small fires. While the number of wildfire events over the last 30 years seems to be relatively constant in the continental US, the size of the fires appears to be increasing with time as shown in Figure 1. Although these statistics are from the US, it is likely that trends in Canada will be similar.

RS composite poles are manufactured from polyurethane resin and E-glass fiber to create a fiber reinforced polymer (FRP) laminate. Extensive flammability testing has demonstrated that the RS laminate is self-extinguishing [a]. The RS Fire Shield™ is manufactured using the same composite material as RS poles and can be used to increase fire resistance on a pole of any material type including wood poles. When used with an RS pole, the Fire Shield™ will allow RS poles to survive extreme [b] wildfire events. When used with wood poles, it will protect them from moderate to severe wildfires, which the wood poles would not normally be expected to survive if left unprotected.

Figure 1: Number of and Area Burned by Wildfires per year in the Continental US [1]

[a] Self-Extinguishing: The ability of a material to cease burning once the source of the flame has been removed.

Wildfire Characteristics [2,3]

Conditions within a wildfire are highly variable, depending on the fuel type (grass, shrubs, coniferous trees, deciduous trees or combinations of these). Heat flux at the surface of a pole will depend on fuel type, density, proximity to the pole and duration which may range from <30 seconds for moderate fires in grass fuels to upwards of 90 seconds in high-intensity wildfires fueled by heavier coniferous forest.

Figure 3 and Table 1 are data collected during the International Crown Fire Modeling Experiment (ICFME) in the Northwest Territories (NWT) of Canada, conducted between 1995 and 2001. During this period, 18 high-intensity crown fires (see Figure 2) were created and studied by over 100 participants representing 30 organizations from 14 countries. The ICFME provided valuable data and insight into the nature and characteristics of crowning forest fires, which greatly assisted in addressing fire management problems and opportunities affecting both people and ecosystems.
Utility pole heat flux exposure depends on whether the energy transfer is purely radiative (surface not contacted by flames) or a combination of radiative and convective and may peak at upwards of 250 kW/m². Wildfire gas temperatures can range from 800 to 1,200°C [1,472 to 2,192°F] with most fires below 1,000°C [1,832°F] and exposure durations rarely above 90 seconds.
Wildfire Intensity | Exposure Duration | Gas Temperature
---|---|---
Moderate | 30 to ≤ 90 Seconds | 800 - 1,200°C [1,472 - 2,192°F]
Severe | 91 to 120 Seconds | 800 - 1,200°C [1,472 - 2,192°F]
Extreme | 121 to ≤ 180 Seconds | 800 - 1,200°C [1,472 - 2,192°F]

Table 2: Wildfire Intensity Characteristics with Corresponding Exposure Time and Gas Temperatures

**Fire Exposure Test Setup** \[1,2,4,5,6\]

To evaluate the fire performance of RS composite products, Mark Ackerman, P.Eng. from MYAC Consulting Inc. in Sherwood Park, Alberta, Canada, was contracted to conduct wildfire exposure tests. Mr. Ackerman has been involved in wildland fire research for over 20 years, focusing on energy transfer from high-intensity, fast moving fire fronts and how wildland fire workers can be protected in the event of entrapment. He has developed specialized equipment for the measure of energy transfer and fire spread rates in grass and forest fires for over 20 years. As a result of his work, he was asked to sit on NFPA 1977 (NFPA standard committee dealing with wildland fire) and was a principal on the team driven by the US Forest Service to develop a new fire shelter for fire-fighting personnel. Between 2011 and 2018, Mr. Ackerman conducted over 25 fire exposure tests on a variety of RS composite poles, both with and without the RS Fire Shield™. During the same time period, he also conducted fire exposure tests on wood poles, again testing both unprotected wood poles and wood poles protected by the RS Fire Shield™.

The generic test setup was as follows: Each pole was stood in a vertical position, guyed or embedded to hold it in place, instrumented to measure temperature and heat flux and then exposed to propane fueled diffusion flames for durations that simulated severe to extreme wildfire conditions. Wildfires in undisturbed coniferous forests are not expected to exceed 90 seconds in duration. Exposure durations in maintained overhead line right-of-way areas would not typically exceed 60 seconds. RS poles and the RS Fire Shield™ were exposed to beyond worst-case durations of 120 seconds (defined as Severe) and 180 seconds (defined as Extreme). To ensure flame contact with the pole wall surface, shrouds were constructed using 20-gauge steel spiral duct of 0.60 - 0.91 m [24 - 36 in.] nominal diameter, and with an overall length of 1.5 - 3.7 m [5 - 12 ft.]. The shrouds were fitted with openings near the base to accommodate modified propane torches. Fuel was routed via electric solenoid valves to critical flow orifices, which controlled the amount of fuel introduced through the burners. The shrouds were elevated above grade level to control the air available for combustion. The mixing element in each torch was removed to cause pure propane to be expelled from the orifices, making the fuel/air mixture within the
test shroud very fuel rich. This ensured that combustion product temperatures achieved a minimum target temperature of 800°C [1,472°F]. The combustion products flowed through the annular space between the pole and the shroud and exited the top of the shroud. Figure 4 details the placement of the propane torches in the base of the shroud and critical flow orifices in the test configuration. Figure 5 shows the shroud and heat flux sensors placement during a fire exposure test. Figure 6 shows an RS Pole fire exposure test and Figure 7 shows a 35 ft. [10.7 m] CL5 Red Pine Pole protected with an RS Fire Shield™ fire exposure test. Figure 8 displays a 45 ft. [13.7m] RS Composite Pole with Fire Shield™ fire exposure test including permanent pole steps and temporary step holes with stainless steel (SS) hole plugs installed. Figure 9 shows the same pole being full scale bend tested to failure. Lastly, Table 3 summarizes the fire exposure tests conducted on RS composite poles and wood poles, with and without RS Fire Shields™.

![Image of fire exposure test setup with labels for various components such as sheet metal shroud, propane torch, electric fuel solenoid valve, critical flow orifice inside fitting, plywood ground plane, spark ignition system, ceramic blanket, and space between shroud bottom and ceramic blanket for combustion air - all around base.]

Figure 4: Placement of the Propane Torches in the Base of the Fire Exposure Test Shroud [1]
Figure 5: Placement of Fire Exposure Test Shroud Around Pole, Typical Heat Flux Sensor Locations \textsuperscript{[2,5]}
Figure 6: RS Composite Pole Fire Test, 2-Minute (Severe) Exposure [1]
Figure 7: 35 ft. [10.7m] Red Pine Wood Pole with RS Fire Shield™ Fire Test, 2-Minute (Severe) Exposure [1]
Figure 8: 45 ft. [13.7m] RS Composite Pole with Fire Shield™ Fire Test, 3-Minute (Extreme) Exposure [1]
Figure 9: 45 ft. [13.7m] RS Composite Pole with Fire Shield™ After 3-Minute Fire Exposure Full Scale Test
<table>
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<tr>
<th>Description of Test</th>
<th>Test Date and Location</th>
<th>Test No</th>
<th>Exposure Time (sec)</th>
<th>Max Gas Temp (°F)</th>
<th>Height Shroud (feet)</th>
<th>Holes Present</th>
<th>Pole to Shield Air Gap</th>
<th>Exposure Dose (kW·s/m²)</th>
<th>FST Breaking Strength</th>
<th>Breaking Strength Spec</th>
<th>Observations</th>
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<td>N/A</td>
<td>6,000 - 10,000</td>
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<td>1,000 lbs</td>
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<td>None</td>
<td>4 lbs Silicon</td>
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<td>30,000 lbs</td>
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</table>

**Notes:**
1. per Figure 19, Heat Flux vs Time [A]
2. per Figure 17, Heat Flux vs Time [A]
3. per Figure 17, Heat Flux vs Time [B]
4. per Figure 19, Heat Flux vs Time [C]
5. per Figure 19, Heat Flux vs Time [D]
6. per Figure 19, Heat Flux vs Time [E]
7. per Figure 19, Heat Flux vs Time [F]
8. per Figure 19, Heat Flux vs Time [G]
9. per Figure 19, Heat Flux vs Time [H]
10. per Figure 19, Heat Flux vs Time [I]
11. per Figure 19, Heat Flux vs Time [J]
12. per Figure 19, Heat Flux vs Time [K]
13. per Figure 19, Heat Flux vs Time [L]
14. per Figure 19, Heat Flux vs Time [M]
15. per Figure 19, Heat Flux vs Time [N]
16. per Figure 19, Heat Flux vs Time [O]
17. per Figure 19, Heat Flux vs Time [P]
18. per Figure 19, Heat Flux vs Time [Q]
19. per Figure 19, Heat Flux vs Time [R]
20. per Figure 19, Heat Flux vs Time [S]
21. per Figure 19, Heat Flux vs Time [T]
22. per Figure 19, Heat Flux vs Time [U]
23. per Figure 19, Heat Flux vs Time [V]
24. per Figure 19, Heat Flux vs Time [W]
25. per Figure 19, Heat Flux vs Time [X]
26. per Figure 19, Heat Flux vs Time [Y]
27. per Figure 19, Heat Flux vs Time [Z]

**Table 3: RS Composite and Wood poles with and without Fire Shields Fire Exposure Summary**

-Severity is fire type dependent; max exposures ≤ 90 sec, max gas temp 1,000 - 1,200° C, dosage 6,000 - 10,000 kW·s/m² for boreal type fuels (spruce, pine) which is more severe than charred.
-Outer layer of resin burned off (1mm deep) exposing glass, 75% of pole assembled and full scale tested (FST) and strength reduced but still above specified strength.
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Fire Exposure and Full-Scale Test Observations

Data collected during the ICFME experiments and from literature on wildfire events were used to gauge the severity of the simulated wildfire exposures. Observations from these studies showed gas temperatures ranging from 800 - 1,200°C [1,472 - 2,192°F], and total heat energy of 6,000 - 10,000 kW-s/m². Under the controlled test conditions, a flame exposure time of 120 seconds was considered severe and one of 180 seconds was considered extreme. Various RS and wood poles with and without RS Fire Shields™ were exposed to wildfire conditions and afterward full-scale bend tested to failure to observe the impact on pole strength and stiffness.

RS Composite Module and Pole Fire Performance

Severe Test Protocol

- 3 x RSM-07 modules (Tests 1, 2 and 5) were fire exposed for 120 seconds, with an average maximum gas temperature of 1,047°C [1,916°F] and an average energy exposure of 8,267 kWs/m².
  - Fire Test Result - In each, the outer layer of resin was burned off, exposing glass. The surface damage sustained was approximately 1 mm [0.04 in.] deep.
  - Full Scale Bend Test Result - Two modules were assembled into 75 ft. [22.9 m] 0307 poles and full scale tested. Failure strength was reduced by an average of 30% but remained above the published RS maximum load strength specification due to the safety factors (performance margin) incorporated in the product design. Pole stiffness was not impacted.
• 1 x RSM-07 module (Test 6) with a split RSS-09 RS Fire Shield™ was fire exposed for 120 seconds, with a maximum gas temperature of 1,180°C [2,156°F] and a total energy exposure of 9,600 kWs/m².
  o Fire Test Result - The fire shield outer resin layer burned off with the most extensive damage occurring near the uncovered shield edge. The RSM-07 module sustained localized charring only in the areas directly under the fire shield edge.

Extreme Test Protocol

• 1 x 45 ft. [13.7 m] 0204 pole (Test 8) 20 ft. [6.1 m] section only with a split RSS-05 RS Fire Shield™ covered on the edge with an aluminum J-Channel was fire exposed for 180 seconds, with a maximum gas temperature of 850°C [1,562°F] and a total energy exposure of 16,540 kWs/m².
  o Fire Test Result - The lower Fire Shield™ was largely destroyed, the upper Fire Shield™ was less affected, and the pole surface below was discolored in some areas but overall undamaged.
  o The aluminum guard melted but protected the shield edge and the pole surface below.
• 1 x 45 ft. [13.7 m] 0204 pole (**Test 12**) covered with a split RSS-05 RS Fire Shield™ edge protected with an aluminum J-Channel was fire exposed for 180 seconds, with a maximum gas temperature of 1,100°C [2,012°F] and a total energy exposure of 15,840 kWs/m².

  o Fire Test Result - The lower Fire Shield™ was largely destroyed, the upper Fire Shield™ was less affected, the pole surface below was discolored in some areas but overall undamaged.

  o Full Scale Bend Test Result - *The pole was tested to failure, with no reduction in ultimate failure strength or stiffness observed.*

• 1 x 45 ft. [13.7 m] 0204 pole (**Test 11**) without an RS Fire Shield™ was fire exposed for 180 seconds, with a maximum gas temperature of 1,100°C [2,012°F] and a total energy exposure of 11,988 kWs/m².

  o Fire Test Result - The test was normal until after the burners were shut off, when black smoke started to exit from the pole top and continued for 6 minutes until the pole collapsed. The test duration, open holes within the fire zone and no top cap present contributed to cause the failure.
• 1 x 45 ft. [13.7 m] 0204 RS pole (Test 14) covered with a split RS Fire Shield™ and aluminum J-Channel with an intentional 12.7 mm [0.5 in.] uncaulked gap below the slip joint was fire exposed for 180 seconds, with a maximum gas temperature of 1,018°C [1,864°F] and a total energy exposure of 13,428 kWs/m².
  o Fire Test Result – The lower Fire Shield™ was largely destroyed, the upper shield was less affected and the uncaulked 12.7 mm [0.5 in.] gap showed no excess damage.
  o Full Scale Bend Test Result - The pole was tested to failure, with the observed failure strength above the published RS specification and no change in stiffness. The pole failed just above the groundline, with no issues observed at the slip joint.

• 1 x 45 ft. [13.7 m] 0204 RS pole (Test 15) had the base module covered with a slip-fit RS Fire Shield™ and the second module wound with an integrated 3 mm [0.12 in.] Fire Shield™ was fire exposed for 180 seconds, with a maximum gas temp of 1,278°C [2,332°F] and a total energy exposure of 12,582 kWs/m². Fire Test Result - Both the lower and upper pole shields were burnt but remained intact. A pole step was also fire exposed, one of the stainless steel hole plugs fell out during exposure.
  Full Scale Bend Test Result - The pole was tested to failure, with a failure strength above the published RS specification and no change in stiffness.
1 x 45 ft. [13.7 m] 0204 RS pole (Test 16) covered with a split RS Fire Shield™ and aluminum edge had 1 unplugged temporary step hole in the fire exposure shroud was fire exposed for 180 seconds, with a maximum gas temperature of 1,018°C [1,864°F] and a total energy exposure of 11,867 kWs/m².

- Fire Test Result - The lower Fire Shield™ was largely destroyed, the upper shield was less affected, the laminate burnt through at the open step hole.
- Full Scale Bend Test Result - The pole was tested to failure, with a failure strength above the published RS specification and no change in stiffness.

1 x 45 ft. [13.7 m] 0204 RS pole (Test 18) without an RS Fire Shield™ was fire exposed for 180 seconds, with a maximum gas temperature of 1,109°C [2,028°F] and a total energy exposure of 11,808 kWs/m².

- Fire Test Result – The test was normal however the pole collapsed 5 minutes after the flames were turned off. A gas release sound similar to what was observed on the RSM-02 unshielded module tested per the ASTM wood pole test standard was heard 1 minute before the collapse.
- 1 x 45 ft. [13.7 m] 0204 RS pole (Test 17) covered with a split RS Fire Shield™ and aluminum edge fitted with a 318 kg [700 lb] simulated transformer mounted 310 mm [12 in.] away from the pole surface plus a 1.2 m [48 in.] composite cross-arm was fire exposed for 180 seconds, with a maximum gas temperature of 1,059°C [1,938°F] and a total energy exposure of 12,060 kWs/m².

  - Fire Test Result - The lower Fire Shield™ was largely destroyed, the upper shield was much less affected.
  - There was no pole deflection or deformation observed during or after the fire exposure.
  - Full Scale Bend Test Result - The pole was tested to failure, with an observed failure strength above the published RS specification and no change in stiffness.

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<td>Displacement (in)</td>
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</tr>
<tr>
<td>Displacement %</td>
<td>23.6</td>
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Wood Pole Fire Performance:

Severe Protocol

- 1 x 35 ft. [10.7 m] CL5 red pine pole (Test 3) was fire exposed for 120 seconds, with a maximum gas temperature of 1,040°C [1,904°F] and a total energy exposure of 12,200 kWs/m².

  - Fire Test Result - The pole ignited and continued to burn following the removal of the ignition source. The pole mass was 50% consumed after 3.5 hours and the flames were put out by rain after 5 hours. The pole broke while being removed.
• 1 x 35 ft. [10.7 m] CL5 red pine pole (Test 4) with an RSS-03 RS Fire Shield™ was fire exposed for 120 seconds, with a maximum gas temp of 1,080°C [1,976°F] and a total energy exposure of 14,400 kWs/m².
  o Fire Test Result - the Fire Shield™ burned through in isolated spots while in others, only the outer layer was affected, with the wood pole only suffering surface charring in limited areas.
  o Full Scale Bend Test Result - The pole was tested to failure with no reduction in ultimate failure strength or stiffness observed.
• 1 x 35 ft. [10.7 m] CL5 red pine pole (Test 13) with a split-fit RSS-03 RS Fire Shield™ was fire exposed for 120 seconds, with a maximum gas temperature of 1,100°C [2,102°F] and a total energy exposure of 12,280 kWs/m².
  
  o Fire Test Result - the Fire Shield™ burned through in isolated spots while in others, only the outer layer was affected, with the wood pole only suffering surface charring in limited areas.
  
  o Full Scale Bend Test Result - *The pole was tested to failure with no reduction in ultimate failure strength or stiffness observed.*
Extreme Protocol

- 1 x 35 ft. [10.7 m] CL5 red pine pole (Test 9) was fire exposed for 180 seconds, gas temperatures and heat flux values were not recorded.
  - Fire Test Result - The flame height reached well above the test shroud, the pole caught fire and continued to smolder after removing the ignition source for 2 hours, then it collapsed.
• 1 x 35 ft. [10.7 m] CL5 red pine pole (**Test 10**) with a split-fit RSS-03 RS Fire Shield™ (15 ft. [4.6 m] high) was fire exposed for 180 seconds, with a maximum gas temperature of 1,200°C [2,192°F] and a total energy exposure of 17,500 kW/m².
  
  o Fire Test Result - The flame height reached well above the Fire Shield™ (over 18 ft. [5.5 m]). The lower Fire Shield™ section was destroyed, the upper Fire Shield™ remained intact and the pole smoldered at the top of lower shield area and above upper shield area and collapsed overnight.
Other Fire Exposure Tests:

Hole Plug Performance

- 2 x 19 ft. [5.8 m] RSM-04 modules (Test 19) were each fitted with 40 hole plugs of a variety of materials, with half of the plugs mounted within the fire exposure shroud and half above it. One module was fire exposed for 120 seconds, with a maximum gas temperature of 1,019°C [1,866°F] and a total energy exposure of 6,276 kWs/m². The other module was fire exposed for 180 seconds, with a maximum gas temp of 1,160°C [2,120°F] and a total energy exposure of 13,230 kWs/m².

  o Hole Plug Materials Fire Tested: 1) Current RS LDPE, 2) Flame Retardant PE-LD11 LDPE, 3) 304 stainless steel, 4) High Temp Silicone Rubber
  o Fire Test Results - All LDPE plugs destroyed by 120 seconds fire exposure. The stainless steel and the silicone hole plugs both survived 180 seconds fire exposure. Silicone hole plugs should be replaced after a fire.
ASTM Wood Pole Fire Exposure Test

- 3 x 7 ft. [2.1 m] RSM-02 module sections (Test 20) with 4 step holes fitted with silicone rubber plugs were exposed to radiant energy and fire per the proposed ASTM “Standard Test Method for Determining Charring Depth of Wood Utility Poles Exposed to Simulated Wild Fires”. Total exposure time was 600 seconds for each test. The first 300 seconds applies 50 kW radiant energy only followed by 300 seconds of 50 kW radiant energy plus fire exposure from a 40 kW ring burner positioned at the pole base. Total energy exposure is in excess of 30,000 kWs/m². Pole surface and gas temperatures were not measured.
  - A standard RSM-02 module experienced substantial laminate damaged on the radiant heat side. Just before the end of the test a burst of gas being released was heard.
  - An RSM-02 module with an integrated 3 mm [0.12 in.] RS Fire Shield™ also experienced laminate damage on the radiant heat side, but to a much lesser extent. No gas discharge was heard.
  - A standard RSM-02 module covered with a slip-fit RSS-03 RS Fire Shield™ experienced no laminate damage other than some localized discoloration.
Conclusions

RS Composite Poles With and Without RS Fire Shields™

Unprotected RS composite poles were exposed to conditions simulating crown fires in boreal forests for severe duration times of 120 seconds, which far exceeds typical actual wildfire durations, and then full-scale bend tested to failure. The tested poles were observed to retain enough strength to continue to exceed their published maximum strength specifications, with no effect on pole stiffness. Unprotected RS poles exposed to conditions simulating crown fires for extreme duration times of 180 seconds, did not survive.

RS poles protected with an RS Fire Shield™ were fire exposed for extreme durations of 180 seconds and all survived intact. Subsequent full-scale bend testing of these RS poles resulted in no reduction in ultimate failure strength or stiffness. Statistical analysis of the breaking strength of these fire exposed poles vs unexposed poles revealed no difference in the mean failure strength as shown below in Figure 10.

![Probability Plot of Equiv. Breaking Load (lbf) Normal - 95% CI](image)

Figure 10: 45 ft. [13.7m] RS Composite Pole with RS Fire Shield™ 3-Minute (Extreme) Fire Exposure vs Unexposed Pole Breaking Strength Distribution
Numerous fire exposure and full-scale testing has demonstrated that RS composite poles can survive wildfire conditions for severe durations and continue to support design loads. An RS Fire Shield™ increases the fire resistance of an RS pole, allowing it to survive wildfire conditions for extreme durations.

**Wood Poles With and Without RS Fire Shields™**

All unprotected wood poles exposed to simulated wildfire conditions for severe durations of 120 seconds and extreme durations of 180 seconds, were consumed by flames to the point of failure. An RS Fire Shield™ may be installed on wood poles to protect them from wildfire conditions for severe durations. Wood poles, protected by an RS Fire Shield™ when tested under severe conditions of 120 second durations, sustained only minor surface charring. Post fire exposure full scale bend testing of wood poles protected with an RS Fire Shield™ did not exhibit any loss of strength. Wood poles protected with an RS Fire Shield™ and exposed to extreme wildfire durations of 180 seconds did not survive. For wood poles to have the best opportunity to survive wildfires of severe durations, it is critical that the RS Fire Shield™ be of greater height than the height of the expected flame front.

Completed By: Mark Forget // April 18th, 2019 (Rev 1)

Name // Date

Title: Technical Director

**References**