FIELD TESTING IN CANADA XXVI: POSTS AND POLES

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Summary

The present paper summarizes results from several experiments evaluating the impact of natural durability, preservative treatment, and barrier systems on the durability of fenceposts and pole stubs. Key results include long-term service life data on industrial preservatives including creosote, penta, copper naphthenate, CCA-C and ACA. Old-growth and second-growth western redcedar were found to have similar durability and were not as durable as posts treated with ACQ. Data from experiments with barrier wraps suggest that they can extend the service life or posts made from naturally durable or preservative-treated wood. The effect on service life of mounting fence posts on metal spikes, or boots on poured concrete footings, is also under investigation.

1. Introduction

Data from FPInnovations' field testing program is used to support preservative registration by Health Canada's Pest Management Regulatory Agency, gain market acceptable, predict service life, develop life cycle assessments for treated wood products, and facilitate changes to codes and standards. The present paper summarizes results from several experiments on posts and poles. Earlier inspections from several of these studies have been previously reported (Morris and Ingram 2010, Morris et al. 2012).

Wood posts and poles are critical components of Canada's energy, agriculture and horticultural sectors. To meet customer needs they must have a long and predictable service life, minimal environmental impact, and be easy to maintain and replace. FPInnovations' field testing program supports the development of technologies to protect and grow the use of wood posts and poles. FPInnovations has evaluated naturally durable species, a wide range of wood preservatives, as well as barrier wraps and metal spikes and boots for their ability to improve the service life of wood posts and poles.

Barrier wraps applied to below ground parts of posts/poles have been suggested to improve service life by blocking strand-forming wood-rotting basidiomycetes, blocking soft-rot fungi growing from soil, reducing uptake of nutrients and iron, and reducing depletion of preservatives or extractives (Morris et al. 2015). They have also been hypothesized to limit access to oxygen and moderate moisture content. Several authors have demonstrated the benefits of wraps (Baecker 1993, Baecker and Behr 1995, Behr et al. 1996, 1997, Scheffer and Morrell 1997, Cooper and Phillips 1997, Freeman et al. 2006, Barnes et al. 2009, Morris et al. 2015). The aim of the barrier wrap experiments described here was to develop specific performance data on Canadian species under Canadian conditions.

Mounting treated posts on metal spikes or in metal shoes on concrete footings has been assumed to substantially extend their service life, particularly against termites but, as far as the authors are aware, there are no data to support this assumption.

2. Methods

2.1 Materials

2.1.1 Industrial oilborne preservatives

Posts for the test, most commonly jack pine, aspen poplar, and white spruce, have generally been obtained from the Petawawa Research Forest, although at times supplied by local retail outlets. Other common eastern Canadian species have also been used. Felled trees of approximately 10 to 15 cm in diameter were cut to 2 m in length, bevelled at the top to permit shedding of rain and snow, then hand-peeled. Posts were generally stacked and allowed to air-season to a suitable moisture content for treatment (<15%).

Posts of several species were butt treated with creosote in a hot bath followed by full-length immersion in a cold bath. Penta formulations were applied to red pine (*Pinus resinosa*) posts using a full cell process with an initial vacuum of 23 kPa followed by a pressure cycle of 1034 to 1207 kPa for up to 6 hours. Copper naphthenate was applied to jack pine (*Pinus banksiana*) posts using an empty cell process with an initial pressure phase at 207 to 310 kPa. Oilborne systems were frequently heated to 71 to 82 ^{o}C during the pressure cycle.

2.1.2 Industrial waterborne preservatives

Posts of several species were pressure treated with chromated copper arsenate type C (CCA-C) or ammoniacal copper arsenate (ACA) using a full cell process with an initial vacuum of 23 kPa followed by a pressure cycle of 1034 – 1207 kPa for up to 6 hours.

2.1.3 Western redcedar fence

Old-growth western redcedar (*Thuja plicata*) nominal 4 x 4 inch sawn fence posts were obtained from Haida Forest Products Ltd. in Burnaby, BC. Second-growth WRC posts were obtained from Twin Rivers Cedar Products Ltd. in Maple Ridge, BC. Seventy-five old-growth and 72 second-growth posts were selected. Samples about 0.3 m long were cut from the top of each post for analysis of extractive content. One end of approximately half of the posts was covered to a length of 0.5 m with Denso Fiber Wrap, forming a boot.

2.1.4 ACQ-treated fence

A total of 150 untreated lodgepole pine (*Pinus contorta*) round fence posts, 2.4 m long and 100 mm in diameter, were obtained from a treating plant in the Vancouver, BC area, and selected for maximum sapwood and minimal bark inclusions. These were separated into two groups and pressure-treated at FPInnovations' Vancouver laboratory. Using alkaline copper quat formulations supplied by Viance LLC, the lodgepole pine posts were treated at an elevated temperature of 60^{o}C. One group of 50 posts was treated with a 2% actives solution of amine copper quat (ACQ-Type D), and the second group of 100 posts was treated with 0.7 to 1.6% actives solutions of amine/ammonia copper quat (ACQ-Type D+). A variety of solution strengths were used for the amine/ammonia copper quat-treated posts to yield a range of retentions, while the amine copper quat treated posts were treated using only one solution strength, because the solution was needed at a high concentration for further experiments.

The posts were air-dried in FPInnovations' courtyard, after which penetration and retention core borings were removed at approximately 0.75 m from the bottom of the post. From the centre of each post, a core was removed and analyzed for preservative penetration (AWPA 2014), and retention, using x-ray fluorescence spectroscopy (AWPA 2016). The penetration and retention data were used to select posts for installation. One end of approximately half of the posts was covered to a length of 0.5 m with Denso Fiber Wrap, forming a boot.

2.1.5 Carbon-based preservatives with a barrier wrap

One hundred and twenty pieces of Pacific silver fir (*Abies amabilis*) lumber, nominal 4x4 inches in dimension, 8 ft. in length were forced-air dried at FPInnovations' Vancouver laboratory. Twenty of these posts were pressure-treated at FPInnovations with ACQ-D carbonate as reference material, and 50 were pressure-treated with a carbon-based preservative containing triazole and quatermary ammonium compound active ingredients. The treating schedule followed was an initial 30 minutes of vacuum at 75 kPa, followed by 90 minutes at a pressure of 1034 kPa, and a final 15 minutes of vacuum at 75 kPa. Treatment was carried out at 20°C. After treatment, the posts were forced-air dried. The remaining 50 posts were left untreated.

The 20 posts treated with ACQ-D, 20 posts treated with the carbon-based preservative, and 20 untreated pieces were left unwrapped. Thirty posts treated with the carbon-based preservative and 30 untreated pieces were shipped to Conrad Wood Preserving in Coos Bay, OR for wrapping with PostSaver®. After wrapping was complete, on ten treated and ten untreated wrapped pieces the wrap was pierced with a nail on one side 150 mm from the base and on the other side at the intended ground line. Pierced, wrapped samples were included to determine the effect of small holes in the wrap, as might be expected to occur in service, on the efficacy of the system.

2.1.6 Large dimension posts

Red pine round fence posts 6" in diameter and 2.2 m in length (Maurice Miller Lumber Ltd., Barrie, ON), red pine sawn 6x8" posts 2.2 m in length (Robert Richie Forest Products, Elmvale, ON), and Eastern spruce sawn 4x4" posts 2.2 m in length (***Lavern Heideman & Sons Ltd.,*** Eganville, ON) were treated by Ram Forest Products, Vandorf, ON, with a 1.4% ACQ-D solution. The treating schedule was an initial 20 minute vacuum at a minimum of 75 kPa, followed by 2 hours at a pressure of 1034 kPa, then a final 1 hour vacuum at a minimum of 75 kPa. A boring was taken from each post for measurement of penetration, and a pooled retention was determined for each treatment group. Untreated coastal western redcedar sawn 4x4" posts (Terminal Forest Products, Richmond, BC) were also included in the study. Half of each group of posts (both treated and untreated) were shipped to Lebanon, PA for wrapping to a length of 0.5 m with spray-applied bitumen and a helically wound plastic strip, forming a boot.

2.1.7 Copper only posts

Jack pine round fence posts, six inches (150 mm) in diameter and 2.2 m in length, with tapered ends, were obtained from L & M Wood Products (Glaslyn, SK). The posts were treated at FPInnovations' Vancouver laboratory with a solution of 1.4% micronized copper carbonate (35.05% copper oxide) supplied by Timber Specialties Co, with no co-biocide. The treating schedule followed was an initial 30 minute vacuum at a minimum of 85 kPa, followed by 2 hours at a pressure of 1034 kPa, then a final 15 minutes of vacuum at a minimum of 85 kPa. Treatment was carried out at about 20°C.

After treatment the posts were stickered to air dry and held in the FPInnovations compound prior to installation at the test sites. From each post a core was removed and analyzed for preservative penetration (AWPA 2014), and retention (AWPA 2016). The penetration and retention data were used to select posts for installation. Half of these posts were shipped to Lebanon, PA for wrapping to a length of 0.5 m with spray-applied bitumen and a helically wound plastic strip, forming a boot. These boots are intended for application to blunt posts, therefore the tapered ends were not wrapped.

2.1.8 Untreated posts in spikes and boots

Twenty untreated red pine 2.4 m long nominal 4x4 inch posts were obtained from Moggie Valley Timber (Holland Centre, ON). Forty-five red pine posts commercially treated with micronized copper azole-treated (MCA) were obtained from Hanover Home Hardware Building Centre (Hanover, ON). Ten untreated nominal 4x4 inch western redcedar posts (sapwood free) were purchased from Kincardine Timber Mart Building Centre. Ten untreated dowelled eastern white cedar (*Thuja occidentalis*) round posts (sapwood removed) were obtained from Mobilier Rustique (Saint-Martin, QC). All posts were unincised. The treated and untreated red pine posts were either embedded directly in soil, mounted on metal spikes (Simpson Strong-tie E-Z Spike™) using two screws or mounted in similar metal boots (Simpson Strong-tie E-Z Base™) supported on concrete footings. The treated red pine posts were installed at 2.4m (8ft) spacing to hold up a chain link fence. The untreated red pine posts and the two types of cedar post were placed half way in between these, and adjacent to the fence.

2.2 Test sites

The Petawawa test site is located on the grounds of the Petawawa Research Forest near Chalk River, ON. The test site is located in a cleared natural forest area surrounded by a mixed coniferous/deciduous forest. Mean daily maximum and minimum temperatures are -7°C and -18°C in January, and 25°C and 13°C in July. The site receives mean annual precipitation of 822 mm. It falls within the moderate decay hazard zone for outdoor above-ground exposure using Scheffer's climate index (Scheffer 1971; Setliff 1986). The Scheffer climate index was 40.6 for the years 1950–1980 (Setliff 1986), and 48 for the years 1970–2000 (Morris and Wang 2008). Frequently, tree seedlings become established in the plot and must be manually removed every few years. The soil is classified as a dark brown loam to a depth of 9 cm, changing to a light brown loam that extends to 18 cm. Below this lies coarse sand. The pH is 6.0 at the surface and 5.4 at a depth of 9 cm. The average moisture-holding capacity of the soil is 25%, with a grassy ground cover. Results in the early years indicated that the level of soft rot activity at this site was low compared to other test sites; however this may have been due to removal of topsoil when levelling the site. A new layer of topsoil has built up in the last 50 years and there are areas where soil inhabiting, strand-forming, wood-rotting basidiomycetes, including *Leucogyrophana pinastri*, *Tapinella atrotomentosa*, *Hypholoma fasciculare*, *Serpula himantiodes,* and *Oligoporus balsameus* are very active.

The test site at Maple Ridge, BC is located within the University of BC Malcolm Knapp Research Forest. The area is a clearing in second growth coastal western hemlock forest but was a grass field for decades. It was previously used as a deer pen. The soil is a sandy silt loam to a depth of 0.3 m. It has a pH around 5.1 and is relatively high in organic matter (15 - 21%). Below this is a layer of fine- to coarse-grained sand with some gravel and silt.

In summer, groundwater is between 0.5 and 2.4 m below grade and flows in a predominantly southwest direction. During the winter months, the groundwater reaches the surface at the southwest end of the site. This site has a rainfall of over 2150 mm per year and an average yearly temperature of 9.6°C with mean daily maximum and minimum temperatures of 6°C and 1°C in January, and 23°C and 12°C in July. It falls within the moderate decay hazard zone for outdoor above-ground exposure using the Scheffer Index (Scheffer 1971; Setliff 1986), with an updated value of 63 (Morris and Wang 2008). This zone includes most of the major population centres of North America. Soil-inhabiting strand-forming wood-rotting basidiomycetes including *Leucogyrophana pinas*tri , *Fibroporia vaillantii*, *Tapinella* sp., and *Antrodia serialis* have been found on test material sporadically across the entire site. *Ptychogaster rubescens* has also been found on test samples.

FPInnovations' Paul Morris Termite Research Site is a residential lot in the centre of the Lorne Beach Termite Management Area near Tiverton in the Municipality of Kincardine, Ontario. It is a triangular area with an evergreen/deciduous tree-screen on all three sides. It has a thin layer of leaf litter and sandy loam over at least 1.5 m of sand. The somewhat uneven soil surface is elevated about 1 m above the roads on two sides, providing very good drainage. However there is marshland at a lower elevation nearby, indicating a high water table and plentiful supply of soil moisture at depth. The area receives mean annual precipitation of 998 mm, with a low of 70 mm in July and a high of 130 mm in January. It has an average yearly temperature of 6.2°C, with mean daily maximum and minimum temperatures of -2°C and -10°C in January, and 24°C and 13°C in July (Owen Sound Data). The climate places it within the zone of medium out-of-ground decay hazard with an updated climate index (Owen Sound) of 49 (Morris and Wang 2008). The temperatures are moderated by proximity to Lake Huron and the area is prone to lake-effect snow which provides additional insulation to the soil in winter. Ground cover is mixed grasses and forbs which are left to grow, frequently above the level of the stakes, plus wild grapevine, tree seedlings and suckers that are controlled manually. Observation of untreated controls shows a relatively uniform infestation of Eastern subterranean termites, *Reticulitermes flavipes*. The live and dead trees on the site provide a reservoir of termites. This site (44.25° N) is near the current northerly known limit of *R. flavipes* in Eastern North America. A soil-inhabiting wood-rotting basidiomycetes, *Coniophora olivacea*, has been found on feeder stakes of the above-ground field tests. Due to the humidity provided by the groundcover, decay is commonly observed in the above-ground portion of test stakes.

2.3 Inspection Methods

For rating, the posts were manually pushed at breast height (about 1.2 m above the groundline), with approximately 150 Newtons of force applied consecutively in two directions. If decay had progressed to a critical point, the post would break and a failure would be recorded. The soil was tamped back around the post following rating.

All unwrapped posts, excluding posts installed prior to 2000, were also evaluated for decay as described by the rating system in AWPA E8-15 (AWPA 2015):

Decay Rating	Condition	Description
10	Sound	No sign or evidence of decay, wood softening, or discoloration caused by microorganism attack.
9.5	Trace-suspect	Some areas of discolouration and/or softening associated with superficial microorganism attack.
9	Slight attack	Decay and wood softening is present. Up to 3% of the cross sectional area affected.
8	Moderate attack	Similar to "9" but more extensive attack with 3-10% of cross sectional area affected.
7	Moderate/severe attack	Sample has between 10-30% of cross sectional area decayed.
6	Severe attack	Sample has between 30-50% of cross sectional area decayed.
4	Very severe attack	Sample has between 50-75% of cross sectional area decayed.
0	Failure	Sample has functionally failed. It can either be broken by hand due to decay, or the evaluation probe can penetrate through the sample.

3. Results and Discussion

3.1 Industrial oilborne preservatives

The natural durability of typical eastern Canadian wood species included in this test is presented in Table 1. Service lives represent 28 fully debarked, seasoned posts installed in 1937. Softwoods ranged from 3.7 years for balsam fir to 17.9 years for eastern white cedar. The less durable hardwoods lasted from 3.0 years for basswood to 8.3 years for elm. Untreated jack pine, white spruce, aspen poplar, and white birch posts have regularly been replaced over the years to ensure that fungal activity at the site has remained reasonably constant.

Table 1: Service life of untreated posts

	Species		Mean Service Life (years)
Hardwoods	Basswood	*Tilia americana*	3.0
	Aspen poplar	*Populus tremuloides*	3.3
	Soft maple	*Acer spp.*	3.7
	Yellow birch	*Betula alleghaniensis*	4.1
	Red oak	*Quercus rubra*	4.4
	Hard maple	*Acer spp.*	4.5
	Beech	*Fagus grandifolia*	4.6
	Ironwood	*Ostrya virginiana*	4.9
	White birch	*Betula papyrifera*	6.0
	Ash	*Fraxinus nigra*	6.5
	Elm	*Ulnus spp.*	8.3
Softwoods	White spruce	*Picea glauca*	3.5
	Balsam fir	*Abies balsamea*	3.7
	Red pine	*Pinus resinosa*	3.8
	Eastern hemlock	*Tsuga canadensis*	4.4
	Black spruce	*Picea mariana*	4.5
	Jack pine	*Pinus banksiana*	5.5
	White pine	*Pinus strobus*	5.7
	Tamarack	*Larix laricina*	8.3
	Eastern white cedar	*Thuja occidentalis*	17.9

Results of posts treated with creosote using the thermal process are in Table 2. Butts of the posts in Table 2 were treated in a hot bath followed by full-length immersion in a cold bath. This treatment has been very effective; many species have not had a recorded failure in over 75 years of service, and their mean service lives are approximately 45 to 75 years.

Table 2: Thermal creosote immersion (butts/full-length)

Wood species	Mean absorption (kg)	Year installed	Ratio of posts still in service in 2016	Mean service life
Jack pine	3.0	1937	19/20	> 76.8
White pine	1.8	1937	19/20	> 79.0
Red pine	4.0	1937	20/20	> 79.0
Black spruce	0.5	1937	1/20	> 44.0
White spruce	0.5	1937	3/19	> 49.0
Eastern hemlock	1.0	1937	10/20	> 66.5
Balsam fir	0.9	1937	1/20	> 47.0
E. white cedar	2.2	1937	15/20	> 65.0
E. white cedar	2.7	1937	8/10	> 70.0
Tamarack	1.5	1937	19/21	> 73.0

Oilborne preservatives applied by pressure treatments are performing very well. Posts treated with pentachlorophenol to above the retention specified by the AWPA standard (6.4 kg/m^3) have been in test for 45 to 49 years with virtually no failures (Table 3). Similarly, copper naphthenate at above the recommended retention of 0.88 kg/m^3 has been effective for 66 years (Table 4).

Table 3: Pressure treatments of red pine with penta formulations

Preservative	Retention (kg/m^3)	Year installed	Ratio of posts still in service in 2016	Mean service life
Penta in pole oil (boultonized)	8.0	1967	10/10	> 49.0
Penta in pole oil (steamed)	7.2	1967	13/13	> 49.0
Penta/Celon (set in foamed plastic)	7.5	1967	4/4	> 49.0

Table 4: Pressure treatments of jack pine with copper naphthenate

Preservative	Retention (kg/m^3)	Year installed	Ratio of posts still in service in 2016	Mean service life
Copper naphthenate (1% Cu) in pole oil	1.3	1950	13/14	> 65.0

3.2 Industrial waterborne preservatives

Table 5 shows results of posts pressure-treated with CCA-C and ACA. The bulk of these posts remain in service after 34 to 65 years, even those treated to less than the 6.4 kg/m^3 specified by CSA O80 (CSA 2015) for ground contact.

However, 20% of jack pine and aspen poplar posts treated with CCA-C to about 4.5 kg/m^3 failed in about 25 years. There were no major differences in service life between jack pine and white spruce (with the exception of one lot of spruce posts). Surprisingly, aspen poplar gave similar performance. This finding contradicts predictions from laboratory tests (Morris and Parker 1988) of poor performance against soft rot by aspen CCA-treated to standard retentions. This may be explained by the low soft rot activity at the Petawawa site.

Table 5: Full-cell pressure treatment with waterborne preservatives

Preservative	Wood species	Retention (kg/m^3)	Year installed	Ratio of posts still in service in 2016	Mean service life
CCA type C (Boliden K33)	Jack pine	3.7	1960	28/29	> 55.7
	Jack pine	7.8	1960	30/30	> 56.0
	Aspen poplar	4.2	1960	24/26	> 56.0
	Aspen poplar	8.4	1960	30/30	> 56.0
	Aspen poplar	6.7	1967	1/2	> 40.0
	E. hemlock	6.7	1967	1/2	>45.0
	E. white pine	6.7	1967	2/2	> 49.0
	Jack pine	6.7	1967	2/2	> 49.0
	White birch	6.7	1967	2/2	> 49.0
CCA-C	Jack pine	2.7	1982	8/10	> 34.0
	Jack pine	5.8	1982	9/10	> 31.3
	Sugar maple	14.4	1981	8/8	> 35.0
CCA type C (Tanalith C)	Jack pine	4.5	1963	21/30	> 45.8
	Jack pine	9.8	1963	30/30	> 53.0
	Aspen poplar	4.3	1963	19/30	> 46.8
	Aspen poplar	8.5	1963	29/30	> 53.0
ACA	Aspen poplar	16.2	1982	6/6	> 34.0
	White spruce	5.2	1982	8/8	> 34.0
	White spruce	12.4	1982	8/8	> 34.0
	White spruce	21.3	1982	8/8	> 34.0
	White spruce	25.4	1982	8/8	> 34.0

3.3 Western redcedar fence

The posts supporting the fence are inspected at 5-year intervals, after uncoupling the fence to allow the posts to be lifted out of the ground after the push-test. All WRC posts passed the push test after five years in service. Two non-wrapped old-growth posts and one non-wrapped second-growth post failed the pass/fail test at the ten-year inspection, while the remainder of the non-wrapped and all of the wrapped, posts remained sound. At fifteen years, four additional old growth and three second growth non-wrapped WRC posts failed, while the wrapped posts all passed the push test. While the non-wrapped posts had mean decay ratings below 7, posts wrapped below ground remained sound as far as could be ascertained without removing the wraps, suggesting there will be an extension of service life as a result of wrapping.

There was no difference in performance, using a *t*-test at the 95% confidence interval, between old- growth, with a mean decay rating of 5.0, and second-growth non-wrapped posts, with a mean decay rating of 5.6 after fifteen years in test. Figure 1 illustrates the incidence of each decay rating after 15 years.

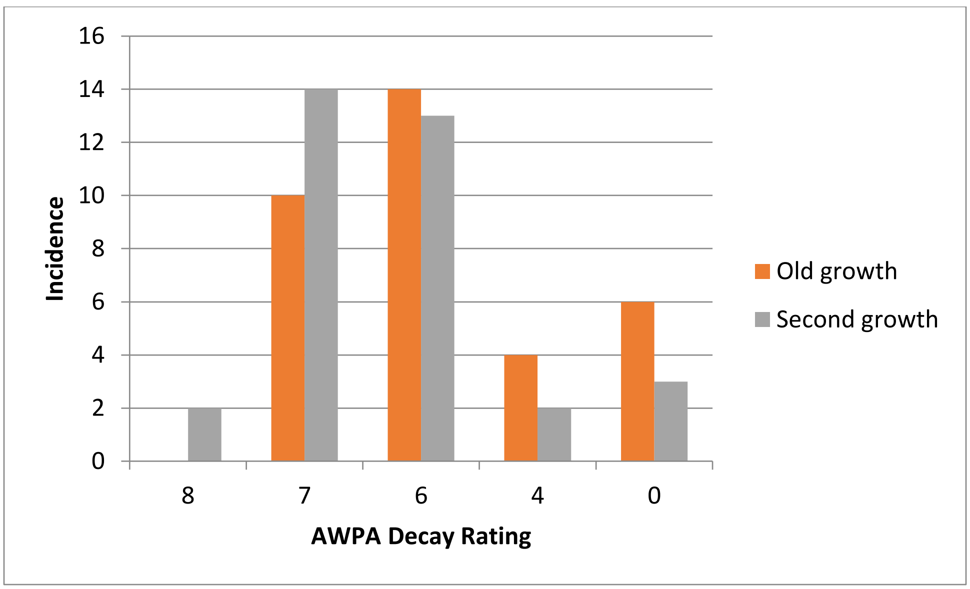

Figure 1: Distribution of decay ratings after 15 years for non-wrapped WRC posts

3.4 ACQ-treated fence

Thirty-four posts treated with ACQ-Type D and 67 posts treated with ACQ-Type D+ were selected for installation. Despite the use of different solution strengths, the mean retentions for the two formulations were very similar (Table 6). These were then subdivided into groups to yield mean retentions close to those specified in CSA standards for use classes UC3.2, UC4.1 and UC4.2 (CSA O80 Series-15).

Table 6: ACQ-treated lodgepole pine post groups mean penetration and retention data

ACQ Formulation	Mean Penetration (mm)	Mean Retention (kg/m³)	Retention Range (kg/m³)
Amine Copper Quat (ACQ-Type D)	12	6.0	3.7 to 9.3
Amine/Ammonia Copper Quat (ACQ-Type D+)	14	6.4	2.3 to 11.7

At the fifteen-year evaluation there were no post failures in the push (pass/fail) test, whether the posts were wrapped or not (Tables 7 and 8). However, decay had significantly progressed since the previous inspection at ten years when the majority of non-wrapped posts inspected below the groundline had been rated 10 for no fungal attack. One post treated with ACQ-Type D+ was severely attacked, rated 6. While this post had a retention of 10.1 kg/m³, it had a penetration of only 7 mm. Overall, there was no statistically significant difference ($p < 0.05$) between the average ratings for ACQ-Type D and ACQ-Type D+, nor was there a clear dose response.

Table 7: Decay ratings after ten and fifteen years for non-wrapped ACQ-treated lodgepole pine fence posts

	No. of posts	Mean ret'n (kg/m³)	Mean pen. (mm)	Years in test	Mean decay rating	No. rated 10	No. rated 9.5	No. rated 9	No. rated 8	No. rated 7	No. rated 6
ACQ D	6	4.1 (0.5)	8 (2)	10	9.7 (0.5)	4	0	2	0	0	0
	6	4.1 (0.5)	8 (2)	15	9.0 (0.6)	1	0	4	1	0	0
	13	6.4 (0.6)	13 (3)	10	9.6 (0.8)	9	1	1	2	0	0
	13	6.4 (0.6)	13 (3)	15	8.6 (0.5)	0	0	8	5	0	0
ACQ D+	9	4.0 (0.8)	13 (2)	10	9.7 (0.4)	6	1	2	0	0	0
	9	4.0 (0.8)	13 (2)	15	8.5 (1.2)	2	0	3	2	2	0
	11	6.4 (0.9)	15 (2)	10	9.9 (0.3)	10	0	1	0	0	0
	11	6.4 (0.9)	15 (2)	15	9.6 (0.5)	6	5	0	0	0	0

8	9.2 (1.2)	15 (3)	10	9.6 (1.1)	7	0	0	0	1	0
8	9.2 (1.2)	15 (3)	15	9.1 (1.4)	4	3	0	0	0	1

Standard deviations are given in parentheses

In contrast to the ACQ-treated posts, after 11 years in test, the non-wrapped untreated lodgepole pine posts had a mean decay rating of 3.1, with four out of eleven posts having failed, and the remainder severely decayed, rated 4 or 6.

Table 8: Push test results after fifteen years for wrapped ACQ-treated lodgepole pine fence posts

	No. of posts	Mean retention (kg/m³)	Mean penetration (mm)	% pass
ACQ D	4	4.2 (0.4)	8 (2)	100
	8	6.5 (0.6)	13 (2)	100
	1	9.3 N/A	16 (0)	100
ACQ D+	9	4.2 (0.5)	13 (3)	100
	17	6.3 (0.9)	15 (2)	100
	6	9.6 (0.6)	16 (0)	100

Standard deviations are given in parentheses

3.5 Carbon-based preservatives with a barrier wrap

Mean decay ratings for the unwrapped posts during ten years of exposure are given in Tables 9 and 10. Early decay was found in the untreated controls after one year at both test sites, which progressed significantly during the second year, particularly at Petawawa. By the third year, all unwrapped untreated control posts had failed at Petawawa. The extremely rapid failure of unwrapped, untreated posts in this test may be due to the high level of activity of strand-forming, soil-inhabiting, wood-rotting basidiomycetes at this site. This type of fungus has an extremely high inoculum potential, facilitating rapid and extensive colonization of wood placed in ground contact. At Maple Ridge, two unwrapped control posts failed at the third inspection. All unwrapped controls had failed by year nine.

In contrast unwrapped preservative-treated posts remained in excellent condition over ten years of testing. Only one post treated with either preservative at Petawawa was rated 9. It was determined that the mycelium indicating a suspicion of attack (a rating of 9.5) noted on six of the ACQ-D samples at Maple Ridge at the one-year inspection was most likely mould rather than decay, and these posts were rated 10 at the subsequent inspections. After ten years at Maple Ridge, early decay was present on all carbon-based preservative-treated posts, while ACQ-D treated posts remained sound. These data suggest that the carbon-based preservatives are more vulnerable to the soft-rot fungi that predominate at Maple Ridge than the basidiomycetes that predominate at Petawawa.

Table 9: Ratings for unwrapped posts during ten years of exposure at Maple Ridge

Treatment	Mean decay rating									
	1 year	2 years	3 years	4 years	5 years	6 years	7 years	8 years	9 years	10 years
Control	8.8 (0.4)	7.8 (0.9)	5.6 (3.0)	4.4 (3.2)	3.1 (3.4)	1.4 (3.0)	1.3 (2.8)	0.8 (1.7)	0.0 (0.0)	0.0 (0.0)
Carbon-based preservative	10.0 (0.0)	10.0 (0.0)	9.9 (0.3)	9.8 (0.4)	9.9 (0.3)	9.8 (0.4)	9.4 (0.5)	9.6 (0.5)	9.1 (0.3)	8.8 (0.4)
ACQ-D carbonate	9.7 (0.3)	10.0 (0.2)	10.0 (0.0)	10.0 (0.2)	10.0 (0.0)	10.0 (0.0)	10.0 (0.0)	10.0 (0.0)	9.9 (0.3)	10.0 (0.0)

Standard deviations are given in parentheses

Table 10: Ratings for unwrapped posts during ten years of exposure at Petawawa

Treatment	Mean decay rating									
	1 year	2 years	3 years	4 years	5 years	6 years	7 years	8 years	9 years	10 years
Control	9.1 (0.5)	3.7 (3.9)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Carbon-based preservative	10.0 (0.0)	10.0 (0.0)	10.0 (0.0)	10.0 (0.0)	10.0 (0.2)	10.0 (0.0)	9.9 (0.2)	10.0 (0.0)	9.9 (0.2)	9.9 (0.3)
ACQ-D carbonate	10.0 (0.0)	10.0 (0.0)	10.0 (0.0)	10.0 (0.0)	10.0 (0.2)	10.0 (0.0)	10.0 (0.0)	10.0 (0.0)	10.0 (0.2)	9.9 (0.3)

Standard deviations are given in parentheses

For the first three years of inspection, all of the wrapped untreated posts remained sound at both test sites. At the fourth annual inspection, two wrapped control posts failed the push test at Petawawa and one wrapped, and one wrapped and pierced control post failed at Maple Ridge. Wrapped untreated posts continued to fail rapidly at Petawawa with nine out of ten posts failed by the tenth year (Table 11). The slightly greater attack in wrapped posts at Petawawa may be attributable to the unusually wet summers at that site recently coupled with unusually dry summers at Maple Ridge. From October 2004 to September 2013, the Scheffer index for Petawawa was 60, and for Maple Ridge it was 56. All wrapped posts treated with the carbon-based preservative at both test sites remained sound (in terms of passing the push test) over the ten years of study (Table 11).

Table 11: Push test results for wrapped posts after ten years of exposure

Treatment	% pass Maple Ridge	% pass Petawawa
	10 years	10 years
Control – wrapped	90	10
Control – wrapped/pierced	90	NA
Carbon-based preservative – wrapped	100	100
Carbon-based preservative – wrapped/pierced	100	NA

3.6 Large dimension posts

Preservative retention and penetration for each group, and the condition in terms of decay after five years are summarized in Table 12. Note that for wrapped posts a pass/fail rather than AWPA decay rating is given.

Table 12: Ratings for industrial posts after five years of exposure

Species/Preservative	Maple Ridge			Petawawa		
	Retention[1] (kg/m^3)	Penetration (mm)	5 year decay	Retention (kg/m^3)	Penetration (mm)	5 year decay
Red pine 6" round, ACQ-D-treated, wrapped	12.5	25 (0)	All passed	12.0	25 (0)	All passed
Red pine 6" round, untreated, wrapped	NA	NA	All passed	NA	NA	All [2] passed
Red pine 6" round, ACQ-D-treated, non-wrapped	9.4	25 (0)	10.0 (0.0)	11.1	25 (0)	10.0 (0.0)
Red pine 6" round, untreated, non-wrapped	NA	NA	6.2 (0.9)	NA	NA	5.8 (3.2)
Red pine 6x8" sawn, ACQ-D-treated, wrapped	8.9	25 (0)	All passed	6.7	23 (5)	All passed
Red pine 6x8" sawn, untreated, wrapped	NA	NA	All passed	NA	NA	All passed
Red pine 6x8" sawn, ACQ-D-treated, non-wrapped	8.9	24 (2)	All passed	6.7	18 (8)	10.0 (0.0)
Red pine 6x8" sawn, untreated, non-wrapped	NA	NA	All passed	NA	NA	6.6 (2.5)

Spruce 4x4” sawn, ACQ-D-treated, wrapped	4.6	18 (7)	All passed	4.1	16 (6)	All passed
Spruce 4x4” sawn, untreated, wrapped	NA	NA	All passed	NA	NA	One failure
Spruce 4x4” sawn, ACQ-D-treated, non-wrapped	4.6	15 (8)	10.0 (0.2)	4.1	16 (6)	9.9 (0.2)
Spruce 4x4” sawn, untreated, non-wrapped	NA	NA	5.2 (3.6)	NA	NA	0.7 (2.2)
Western redcedar 4x4” sawn, untreated, wrapped	NA	NA	All passed	NA	NA	All passed
Western redcedar 4x4” sawn, untreated, non-wrapped	NA	NA	7.9 (0.7)	NA	NA	7.5 (1.0)

Standard deviations for penetration given in parentheses

[1] one pooled retention per group

[2] fruitbody of *Gloeophyllum sepiarium* on one post above the wrap

After five years in test, all treated posts remained in excellent condition, while decay was advanced in untreated posts of all three species. It is too early to draw conclusions on the effectiveness of wrapping. However, it was observed that in untreated spruce at Petawawa, nine out of ten of the unwrapped posts had failed while only one wrapped post failed the push test.

3.7 Copper-only posts

Preservative retention and penetration for each group, and the condition in terms of decay after five years are summarized in Table 13. Note that for wrapped posts a pass/fail rather than AWPA decay rating is given.

Table 13: Ratings for micronized copper-treated round jack pine posts after five years of exposure

Treatment	Maple Ridge			Petawawa		
	Retention (kg/m^3) as CuO	Penetration (mm)	5 year decay	Retention (kg/m^3)	Penetration (mm)	5 year decay
Untreated control	NA	NA	5.8 (1.1)	NA	NA	6.8 (0.8)
Treated, non-wrapped	3.1 (1.5)	11 (5)	9.9 (0.3)	2.0 (0.9)	9 (6)	9.9 (0.3)
Treated, wrapped	2.3 (1.1)	10 (6)	All passed	2.6 (0.7)	9 (4)	All passed

After five years in test, all posts treated to a low retention of micronized copper only remained in excellent condition with only one post at each test site rated 9 for early decay, while decay was advanced in the untreated posts. It is too early to draw conclusions on the effectiveness of wrapping which was designed to prevent attack by soil-inhabiting, strand-forming, wood-rotting, copper-tolerant fungi to provide a treated fence post that may be acceptable to organic farmers.

3.8 Untreated Posts in Spikes and Boots

After two years in test, untreated red pine posts showed moderate decay and advanced termite attack, including two failures. Untreated red pine posts installed in elevated spikes and boot showed similar levels of decay, but less termite attack. Based on these early indications, neither the elevated spike nor the boot are anticipated to substantially improve untreated post service life. The western redcedar and eastern white cedar references showed low levels of decay and termite attack.

The treated posts supporting the fence will be inspected after 3 years, then at 3-year intervals, after uncoupling the fence to allow the posts in ground to be lifted out. The fence will then be re-attached.

Table 14: Ratings for untreated red pine posts after 2 years of exposure in Kincardine, Ontario

Species	Post Installation	Average Decay Rating	Average Termite Rating
Red pine (4x4)	Soil contact	7.0 (1.3)	5.7 (3.3)
	Elevated Spike	8.2 (0.4)	8.0 (1.9)
	Boot on footing	7.8 (1.1)	10.0 (0)
Western redcedar (4x4)	Soil contact	9.3 (0.8)	8.8 (0.8)
Eastern white cedar (dowelled heartwood-only rounds)	Soil contact	9.5 (0.7)	9.5 (0.5)

Standard deviations are given in parentheses

4. Conclusions

- Creosote thermal treatments, and pressure treatment with penta, copper naphthenate, CCA-C and ACA provide very long service life when treated to standardized retentions
- Old-growth and 2nd-growth WRC were similarly resistant to decay
- Barrier wraps reduced the failure rate of WRC posts
- ACQ-treated posts were more resistant to decay than WRC
- Carbon-based preservative-treated posts were resistant to decay after 10 years
- No decay found in ACQ-treated industrial posts after 5 years
- Posts treated with micronized copper (without a cobiocide) were resistant to decay after 5 years
- Longer exposure times are needed to assess the impact of barrier wraps, though data to date suggest a substantial positive impact
- Longer exposure times are needed to assess the impact of mounting posts on metal spikes or boots on concrete footings, though preliminary data suggest these may not substantially extend post service life

5. Acknowledgements

The operation and maintenance of FPInnovations' field test sites are supported by The Canadian Forest Service of Natural Resources Canada under a contribution agreement. The FPInnovations field test site at Maple Ridge, BC is maintained within and with the assistance of the Malcolm Knapp Research Forest of the University of British Columbia, Faculty of Forestry. The FPInnovations field test site at Petawawa, ON is maintained within and with the assistance of the Petawawa Research Forest of the Canadian Wood Fibre Centre, Canadian Forest Service. The FPInnovations Paul Morris Termite Research Site in Kincardine is maintained with the assistance of the Municipality of Kincardine, ON. FPInnovations would also like to thank the preservative suppliers who contributed materials in support of this work.

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