FIELD TESTING OF WOOD PRESERVATIVES IN CANADA. IX:PERFORMANCE OF POSTS AND LUMBER IN GROUND CONTACT

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Summary

Forintek Canada Corp is the principle source of long-term field test data on preservative-treated wood products in Canada. A field test of untreated and preservative-treated round-wood fence posts has been running at Petawawa, Ont., since 1937. Treatments by a variety of pressure and non-pressure processes with waterborne and oilborne preservatives are under test. Thermal immersion in creosote was an effective non-pressure method, while brush treatments proved ineffective for long-term protection. Pressure treatment using standard waterborne and oil-borne preservatives provided excellent protection with mean service lives over 30 years.

Samples of end-matched preservative-treated dimensional lumber have been exposed in ground contact for 10 years at Forintek's two test plots in Ontario. Decay was somewhat more pronounced at Kincardine than at Petawawa. Material with thin shell treatments performed surprisingly well against decay.

CCA-treated hem-fir 4x4 posts in service for ten years were analysed for preservative content and inspected for decay. The posts were in excellent condition, despite in some cases not meeting CSA O80.2 penetration and retention requirements. In contrast, comparable untreated material had essentially failed within four years of exposure.

1 Introduction

Forintek Canada Corp. is the principal source of long-term field testing data on preservative-treated wood products in Canada. The objective of the work reported here was to generate long-term performance data on untreated and preservative-treated wood products to support codes, standards and marketing of such products. A service trial of round fence posts was established by Forintek (then the Eastern Forest Products Laboratory) at the Petawawa Experimental Forest Station near Chalk River, Ontario in 1937. Posts prepared from 9 different softwood species, untreated and creosote-treated, were initially installed to evaluate both the natural durability of the wood and the effectiveness of the preservative treatment. The test plot was relocated within the

Petawawa National Forestry Institute in 1958, and has been greatly expanded over the years by the addition of test material treated with a variety of preservative formulations. As a result of the changing commercial and regulatory climate, many of these preservatives are no longer in use. Nevertheless, service life data generated from some of this material are of interest to the Canadian commercial treating industry, and to codes and standards organisations. The test results are directly applicable to fence posts as a commodity, and they provide an accelerated method of predicting the service life of full-sized poles.

The Canadian wood preservation standard for lumber (CSA 080.2) requires 16 of 20 pieces sampled from a charge to be penetrated to a depth of 10 mm for ground contact exposure. Due to the low permeability of the heartwood of Canadian wood species, this requirement is very difficult to achieve. Questions have been raised as to whether 10mm penetration is actually necessary to achieve protection from decay. To support any changes in existing standards, performance data on treated commodities are required.

Forintek Canada Corp. established a test site at Kincardine, Ont., in 1988 to determine whether wood treated to the CSA O80.2 standard can provide effective protection in the termite-infested areas of southern Ontario. At the time this test was installed, end-matched samples (where available), were also placed in test at Forintek's Petawawa site in an effort to compare rates of decay at the two sites. Petawawa is located about 400 km east and slightly north of Kincardine, and has a similar climate. The purpose of this study was to provide an indication of the relative severity of decay and termite damage in Ontario. Previous reports have described the set-up of the test at Kincardine and performance against termites (Doyle 1992; Morris and Motani 1997).

While round-wood fence-post tests have been running for decades in Ontario, the western test site has been mainly devoted to stake tests of alternate preservatives. The only posts installed at Forintek's field test site at Westham Island, B.C. were commercially treated sawn stock used to support racks for above-ground durability and weathering tests. The opportunity was therefore taken to evaluate those posts when they were removed after ten years in service. As a basis for comparison, untreated hem-fir posts were installed in the same area, and rated for four years.

This report summarizes selected performance data on preservative-treated softwood fence-posts in Ontario, commercially treated dimensional lumber at two locations in Ontario (with respect to decay only) and commercially CCA-treated sawn posts in British Columbia.

2 Materials and Methods

2.1 Test Sites

2.1.1 Petawawa

The Petawawa site is located on the grounds of the Former Petawawa National Forestry Institute (now closed) near Chalk River, Ontario. The test site is located in a cleared area surrounded by a mixed coniferous/deciduous forest. The soil is 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 ground cover is grass, wild strawberries and sweet fern. Results collected over the years have indicated that the level of soft rot activity at this site is low compared to other test sites. The Sheffer index for the Petawawa site is 43. The Sheffer index (Scheffer 1971, Setliff 1986) is a measure of the severity of the climate in terms of decay above ground. In Canada, the index ranges from 0.6 at Alert in the Northwest Territories to 79.6 at Cape Scott on Vancouver Island. Miami, Florida has an index of 130.3. In ground contact, the severity of decay will be modified by the consistency of moisture supply from the soil and other soil characteristics.

2.1.2 Kincardine

The test site at Kincardine, Ontario is owned by the City of Kincardine and maintained with their co-operation. It is a fenced area of grass attached to a storm-water pumping station. The soil is a sandy loam, but the pH has not been characterised. Soil drainage is very good, due to the location on a raised beach of lake Huron. The Scheffer index of the site is 41 (Owen Sound).

2.1.3 Westham Island

The site at Westham Island in the Fraser River Delta, British Columbia is owned by the Canadian Wildlife Service. The groundcover is grass and the soil at the site is a silty clay loam with a high organic matter content and a pH of 5.7 to 6.0. Below this lies river sand. Soil drainage is poor due to a high water table and fine soil texture. Surface water is common in the winter months. The site has a Scheffer index of 45 (Vancouver Airport).

2.2 Round-Wood Fence-Posts at Petawawa

2.2.1 Preparation of Posts

Posts for the test have generally been obtained on site, although at times supplied by local retail outlets. These were most commonly jack pine, and white spruce, however, common eastern Canadian species have also been used (Table 2). Felled trees of approximately 10 - 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 suitable moisture contents for treatment (< 15%).

2.2.2 Treatments

Pressure treatments

Posts requiring pressure treatment were commercially treated with both oil-borne and waterborne preservatives. In the "full-cell" (Bethell) process, an initial vacuum of 23 kPa was followed by a pressure cycle of 1034 - 1207 kPa for up to 6 hours. In the "empty-cell" process, the vacuum stage was replaced by an initial pressure phase at 207 - 310 kPa.. Higher preservative loadings were achieved using the full-cell method. Oil-borne preservatives were frequently heated to 71 - 82 °C during the pressure cycle.

Non-pressure treatments

Non-pressure treatments have the advantage of not requiring elaborate equipment or training to be performed. However, much lower preservative retentions result from treatments without the use of pressure. The application of preservatives by brushing or swabbing the wood surface is the most simple, but least effective of the methods. It was used only for oil-borne preservatives. A second coat was applied after several hours, particularly at the ground-line of the post. This treatment results in a very shallow preservative penetration, and care must be taken in handling the post to avoid damage to the treated surfaces.

The thermal or hot-and-cold-bath process is the most effective non-pressure treatment, but it is labour-intensive and requires some equipment. Debarked, air-seasoned posts are immersed in creosote or other oil-borne preservatives, and the temperature is raised to 71°C (93°C for creosote) and maintained for 4 hours, after which the temperature is allowed to return to ambient temperature. During heating, air and moisture within the wood expand and evaporate, and the subsequent cooling creates a partial vacuum that draws preservative into the wood.

2.2.3 Post Installation and Testing

The posts were planted about 1 m deep in a random pattern. They were rated on a pass/fail basis annually in the autumn until 1985, then every 2 – 3 years. For rating, the posts were manually pushed at breast height (about 1.2 m above the ground-line), 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. A computerised database of post treatment information and service life is maintained.

2.3 Lumber at Petawawa and Kincardine

Material for this study was provided by the Canadian wood treating industry specifically for use in these test plots, and was intended to meet the CSA 080.2 ground contact standard (CSA 1997). This standard requires preservative retention of 6.4 kg/m^3 and penetration of 10 mm. Included in lots of five or 10 replicates each were 2 x 4, 2 x 6, 4 x 4, and 6 x 6 inch jack pine, red pine and lodgepole pine boards and posts treated with either chromated copper arsenate (CCA-C) or ammoniacal copper arsenate (ACA). One lot of 2 x 6 inch hemlock treated with ammoniacal copper/ quaternary ammonium compound type B (ACQ-B) was also included. The white spruce and SPF installed at Kincardine were not replicated at Petawawa, and results from the Kincardine material are therefore not reported here.

Each piece of treated lumber was cut into three sections: 0.91 m (3-foot) lengths were installed at Kincardine, 1.22m (4-foot) lengths were installed at Petawawa, and 0.30m (1-foot) lengths were retained for analysis of preservative retention and penetration. The cut ends of pieces intended for installation were double brush-coated with a commercial copper naphthenate field-cut preservative, and the boards were planted, half with pressure-treated ends down and half with cut ends down, upright to half their length in randomised positions throughout each test plot. Installation took place in late 1988 and early 1989.

Beginning in 1995 at Kincardine and 1996 at Petawawa, the samples were visually graded for decay caused by fungi, according to the 0 to 4 scale (Table 1) recommended by the International Union of Forestry Research Organisations (IUFRO) based on Becker's (1972) proposed standard method. The ratings entered into a computerised database.

Table 1: Decay rating system

Stake condition	IUFRO rating
No attack	0
Suspicion of, or superficial decay (< 1 mm deep)	1
Evident, but moderate decay (1-3 mm deep)	2
Severe decay, but stake still sound (> 3 mm deep)	3
Failure when flexed	4

4x4 Hem-fir Sawn Posts at Westham Island

In 1980, 60 nominal 4x4 inch hem-fir posts, commercially treated with chromated copper arsenate (CCA), were used in the construction of test racks for weathering of composite wood products. The sample support racks were bolted to the top of the posts. A 20 cm wide strip of flashing was nailed to each post at the expected ground-line, 90 cm from the base, to protect from damage during vegetation control. Treated crosspieces, 50-60 cm in length, were then bolted on just below the expected ground-line to prevent the posts from sinking into the soft soil. The test racks were installed at Forintek's field test site at Westham Island, B.C.

When the racks were dismantled after 10 years in service the crosspieces and the flashing were removed and the posts were inspected for signs of decay. Core samples were removed with an increment borer from two positions on each post, 10 cm below the bolt hole at the top of the post and 10 cm below ground-line. Each sample was inspected for signs of decay then analysed for preservative penetration and retention. Two distinct incising patterns, both being blunt-tooth, wide-spaced type incisors, were recognised on these posts, suggesting two separate suppliers. Two groups of 20 posts (groups 1 and 2) from one supplier and one group of 20 posts (group 3) from the second supplier were examined. Penetration was measured on one-half of the split core using chrome azurol S reagent. Retention was analysed for each of the three groups of 20 cores on the combined ground halves of the core samples, using x-ray spectroscopy.

20 untreated hem-fir posts were installed at the same location in 1993. These posts were removed from the ground annually and rated for decay using the IUFRO scale (Table 1).

3 Results and Discussion

3.1 Round-Wood Fence-Posts at Petawawa

Service lives of untreated eastern Canadian softwood species, installed in 1937, ranged from 3.7 years for balsam fir to 17.9 years for eastern white cedar (Table 2). Untreated jack pine and white spruce posts have regularly been replaced over the years to ensure that fungal activity at the site has remained reasonably constant.

Table 2 **Service life of untreated softwood posts**

Species	Mean Service Life (years)
Eastern white cedar	17.9
Balsam fir	3.7
White spruce	3.5
Black spruce	4.5
Eastern hemlock	4.4
Red pine	3.8
White pine	5.7
Jack pine	5.5
Tamarack	8.3

Mean service lives of CCA type A treated jack pine posts, installed in 1951, were >45 years for retentions of 7.7 kg/m^3 and above (Table 3). There were no major differences in service life between jack pine and white spruce (with the exception of one lot of spruce posts). CCA type C treated jack pine posts installed in 1960 had mean service lives >38 years at retentions of 3.7 kg/m^3 and above (Table 3). ACA treated spruce posts were all in good condition after 16 years at retentions as low as 5.2 kg/m^3 (Table 3). The addition of polyethylene glycol to modified ACA appears not to have affected durability. It should be noted that where few failures have occurred the numbers given for mean service life greater than X are mainly determined by the time in test.

The service lives recorded here would probably be representative of highway or farm fence posts. They would not, however, indicate the likely service life of posts in horticultural applications, such as vineyards and soft fruit orchards. In these applications, posts have to resist considerable loads from foliage on the wires and they are typically exposed to more aggressive decay promoted by organic and mineral amendments, and irrigation. Under these conditions, premature failure of posts treated to ground contact standards have been noted world-wide (Hedley and Drysdale 1986, Baecker 1993, Stephan and Peek 1992, Morris 1994). This may be partly due to detoxification of the arsenic component of CCA by iron, mobilised under reducing conditions promoted by irrigation and organic amendment (Morris 1993). For horticultural applications, we recommend considering the posts as structural elements and treating them to the pole standard, CSA O80.4, rather than the post standard CSA O80.5. CSA O80.4 requires 9.6 kg/m^3, which appears to be adequate to provide performance under aggressive decay conditions (Morris and Ingram 1991). This approach was successfully adopted in New Zealand (Hedley 1990).

Table 3: Full-cell pressure treatment with water-borne preservatives

Preservative	Wood species	Retention (kg/m^3)	Year installed	Ratio of posts still in service in 1998	Mean service life
CCA type A (Greensalt)	Jack pine	7.7	1951	20/20	> 47.0
	Jack pine	14.9	1951	13/14	> 45.3
	Jack pine	18.6	1951	9/9	> 47.0
	White spruce	7.5	1951	11/15	> 42.7
	White spruce	8.0	1951	3/7	> 35.7
	White spruce	8.3	1951	7/8	> 46.4
	White spruce	10.7	1951	4/6	> 40.3
	White spruce	12.8	1951	15/16	> 45.3
	Douglas fir	6.6	1951	7/8	> 42.9
CCA type C (Boliden K33)	Jack pine	3.7	1960	29/29	> 38.0
	Jack pine	7.8	1960	30/30	> 38.0
CCA-C	Jack pine	2.7	1982	10/10	> 16.0
	Jack pine	5.8	1982	9/10	> 15.1
CCA type C (Tanalith C)	Jack pine	4.5	1963	24/30	> 31.8
	Jack pine	9.8	1963	30/30	> 35.0
ACA	White spruce	5.2	1982	8/8	> 16.0
	White spruce	12.4	1982	8/8	> 16.0
	White spruce	21.3	1982	8/8	> 16.0
	White spruce	25.4	1982	8/8	> 16.0
Modified ACA	White spruce	6.4	1974	60/60	> 24.0
Modified ACA + 4% PEG	White spruce	4.8	1975	10/10	> 23.0

Posts treated with pentachlorophenol to above the retention specified by the AWPA standard (6.4 kg/m^3) have been in test for 27 - 31 years with virtually no failures (Table 4). Similarly, copper naphthenate at above the recommended retention of 0.88 kg/m^3 has been effective for 48 years. Two preservatives not specified in preservation standards for the treatment of posts, oxine copper (copper-8-quinolinolate) and copper abietate, have provided full protection from decay for 24 years and 41 years, respectively (Table 4).

Table 4: Pressure treatments with oil-borne preservatives

Preservative	Wood species	Retention (kg/m^3)	Year installed	Ratio of posts still in service in 1998	Mean service life
Full-cell					
PCP in pole oil (boultonized)	Red pine	8.0	1967	10/10	> 31.0
PCP in pole oil (steamed)	Red pine	7.2	1967	13/13	> 31.0
PCP/Celon (set in foamed plastic)	Red pine	7.5	1967	4/4	> 31.0
PCP in methylene chloride	Jack pine	8.3	1971	13/16	> 25.3
PCP in methylene chloride	Red pine	8.3	1971	4/4	> 27.0
Empty-cell					
Oxine copper in pole oil	Jack pine	6.3	1974	5/5	> 24.0
Oxine copper in pole oil	Jack pine	11.7	1974	6/6	> 24.0
Copper naphthenate (1% Cu) in pole oil	Jack pine	1.3	1950	14/14	> 48.0
Copper abietate (1% Cu) in pole oil	Jack pine	1.4	1957	9/9	> 41.0
Copper abietate (1% Cu) in pole oil	Jack pine	2.2	1957	32/32	> 41.0

Approximately 3 – 8 years (depending on the species) of additional service, was added by brush treatment with pentachlorophenol, copper naphthenate, and creosote compared to untreated posts (Table 5).

Table 5: Brush treatments

Preservative	Wood species	Treating solution uptake (kg/m^3)	Year installed	Ratio of posts still in service in 1998	Mean service life
5% Pentachlorophenol/pole oil	Jack pine	12.5	1953	0/20	16.5
	White spruce	7.5	1953	0/20	12.6
	White spruce	13.0	1953	0/20	8.8
2% Copper naphthenate/pole oil	Jack pine	15.9	1953	0/20	16.4
	White spruce	8.5	1953	0/20	9.7
	White spruce	10.6	1953	0/20	5.6
Creosote	Jack pine	14.9	1953	0/20	13.6
	White spruce	9.0	1953	0/20	11.3
	White spruce	21.5	1953	0/20	11.4

Butt/full-length treatment has been very effective; many species have not had a recorded failure in over 60 years of service, and their mean service lives are approximately 45 - 60 years (Table 6A). Unexpectedly, the naturally less durable hardwoods have performed better than the softwoods, probably because of better preservative solution uptake. Service lives for butt-only treatments averaged about 35 years for all species tested

(Table 6B). These results illustrate that butt-only treatment, though simpler and more economical, is less effective than full-length treatment. The untreated tops decay within 15 - 25 years.

Table 6A: Thermal creosote immersion (butts/full-length)

Wood species	Mean absorption (kg)	Year installed	Ratio of posts still in service in 1998	Mean service life
Jack pine	3.0	1937	19/20	> 59.7
White pine	1.8	1937	20/20	> 61.0
Red pine	4.0	1937	20/20	> 61.0
Black spruce	0.5	1937	3/20	> 43.5
White spruce	0.5	1937	3/16	> 45.8
Eastern hemlock	1.0	1937	19/28	> 55.8
Balsam fir	0.9	1937	2/20	> 44.3
E. white cedar	2.2	1937	15/20	> 57.8
E. white cedar	2.7	1937	8/10	> 60.1
Tamarack	1.5	1937	20/21	> 60.0

Table 6B: Thermal creosote immersion (butts only)

Wood species	Depth of decay (cm) in untreated tops	Year installed	Ratio of posts still in service in 1998	Mean service life
Jack pine	25.0	1937	0/28	37.0
White pine	1.3	1937	0/26	37.0
Red pine	25.0	1937	0/26	35.0
Black spruce	25.0	1937	0/27	35.0
White spruce	5.0	1937	0/26	35.0
Eastern hemlock	7.5	1937	0/25	35.7
Balsam fir	12.5	1937	0/28	32.3
E. white cedar*	15.0	1937	16/26	> 31.9
Tamarack	12.5	1937	0/25	35.7

* *data current to 1978 only.*

Mechanical barriers applied to the ground-line of untreated posts had variable effects on service life (Table 7). While the polyethylene bag did not substantially increase service life, there did appear to be some positive effect from the polyurethane foam.

Table 7: Ground-line barriers

Treatment	Wood species	Year installed	Ratio of posts still in service in 1998	Mean service life
None	Jack pine	1938	0/10	5.5
Polyethylene bag	Jack pine	1960	0/5	7.4
Polyurethane foam	Jack pine	1967	5/17	> 12.5

3.2 Lumber at Petawawa and Kincardine

After 10 years, all batches of lumber at both sites were performing well with respect to decay. Mean ratings of 1.0 or less indicate superficial attack (Table 8).

Of the 16 CCA-C treatments, only two showed decay at Petawawa. One fine-tooth incised red pine 4 x 4 was rated 1, and two red pine non-incised 2 x 4's were rated 3. At Kincardine, samples from seven of the 16 lots showed a trace to moderate attack.

None of the ACA-treated replicates at Petawawa showed decay. In contrast, four of these six lots at Kincardine showed superficial damage, with one or two replicates per lot of five rated 1. Similarly, for ACQ-treated hemlock, no boards were decayed at Petawawa, while two of five at Kincardine were rated 1 and one piece was moderately decayed, rated 2.

These preliminary results indicate that CCA-C- and ACA-treated dimensional lumber may be decaying more rapidly at Kincardine than at Petawawa. Any differences in soil type or climate between the two locations have not been quantified. However, the lake effect at Kincardine does moderate low winter temperatures and increase precipitation.

Unfortunately, duplicate untreated dimensional lumber from the Kincardine test was not placed at Petawawa, precluding a direct comparison of decay in untreated controls. However, at Petawawa, untreated red pine stakes (1 x 2 inch) fail from decay in about 4 years and untreated red pine and jack pine round posts of 4 x 6 inches in diameter last 4 – 6 years. These results confirm that high fungal activity is present at Petawawa.

The performance of thin (less than 5mm) shell treatments against termites at the Kincardine site (Morris and Motani 1997) was much less impressive than the performance against decay described here. Treatments which came close to meeting CSA O80.2 standards performed well against termites as well as decay.

Table 8: Performance of dimensional lumber in service at Petawawa and Kincardine test plots (with respect to decay only)

Preservative	Wood species	Size	Ret^n (kg/m^3)	% Cores with pen^n (mm)		Average IUFRO rating	
				≥5	≥10	Petawawa	Kincardine
ACA non-incised	RP	2 x 4	10.2	100	100	0.0	0.2
ACA non-incised	JP	2 x 4	3.4	60	20	0.0	0.4
ACA non-incised	RP	2 x 6	4.2	60	40	0.0	0.4
ACA non-incised	JP	2 x 6	3.2	60	0	0.0	0.0
ACA non-incised	RP	4 x 4	6.2	80	40	0.0	0.0
ACA non-incised	JP	4 x 4	3.1	60	20	0.0	0.4
ACQ non-incised	Hem	2 x 6	1.5	80	20	0.0	0.8
CCA-C non-incised	LPP**	2 x 6	0.9	20	0	0.0	1.0
CCA-C non-incised	LPP	2 x 4	1.7	20	0	0.0	0.0
CCA-C non-incised	LPP	2 x 6	5.4	40	40	0.0	0.0
CCA-C non-incised	LPP	4 x 4	1.8	20	20	0.0	0.2
CCA-C incised 6mm	LPP	4 x 4	5.9	100	40	0.0	0.2
CCA-C incised 13 mm	LPP	4 x 4	4.7	100	80	0.0	0.2
CCA-C incised	JP	6 x 6	6.8	90	30	0.0	0.1
CCA-C incised (FT)*	JP	2 x 6	3.6	60	40	0.0	0.0
CCA-C non-incised	JP	2 x 6	4.2	20	20	0.0	0.0
CCA-C non-incised	JP	2 x 4	4.8	60	20	0.0	0.0
CCA-C incised	RP	6 x 6	9.7	100	100	0.0	0.0
CCA-C incised (FT)	RP	2 x 4	3.5	20	10	0.0	0.1
CCA-C incised (FT)	RP	4 x 4	10.0	100	80	0.1	0.0
CCA-C incised	RP	4 x 4	10.8	100	80	0.0	0.1
CCA-C non-incised	RP	4 x 4	10.1	90	90	0.0	0.0
CCA-C non-incised	RP	2 x 4	2.9	80	0	0.6	0.0
Untreated	JP	2 x 4	0.0	0	0	N/A	3.6
Untreated	RP	2 x 4	0.0	0	0	N/A	3.9

Ret^n = Retention;
pen^n = Penetration;
* *(FT) = fine-tooth incisor;*
** *LPP lots were composed of five replicates; all other lots treated with CCA-C contained 10 replicates.*

3.3 4x4 Hem-Fir Posts at Westham Island

After 10 years' exposure, 58 of the 60 CCA-treated posts were virtually sound, with ratings of 0 or 1 (Table 9). Two of the 40 posts with incising pattern 1 contained internal brown rot, one with a rating of 4 and the other with a rating of 0. In both cases longitudinal sawing of the post revealed that the fungus had entered through the bolt-hole drilled for attaching the cross-piece just below ground-line.

Breaching the treated zone at the ground-line with a bolt hole is obviously not a good design feature, but this did not seem to cause a problem with most of these posts. Furthermore, even where decay fungi had entered the bolt holes, one of the two posts with internal decay was still fulfilling its function due to the residual strength of the undecayed treated shell.

In contrast to the excellent performance of the treated posts, after just four years in test, 11 of the 20 untreated posts had failed due to decay, with a mean decay rating of 3.2.

The posts had been tentatively separated into two groups (1 and 2) with one incising pattern and one group (3) with a different incising pattern. The CCA analysis (Table 10) provided further evidence that the 20 posts of group 3 probably came from a different supplier. Group 3 posts contained half the preservative retention and half the mean penetration of the 40 posts from groups 1 and 2. Only 45% of the group 3 posts had penetrations of 5 mm and 55% had penetrations of just 1 or 2 mm. Core samples were taken between incisions, and penetration adjacent to the incisions may well have been deeper than those measured. Despite the lower quality of treatment, group 3 posts had a similar mean decay rating to the other two groups which met the CSA 080 ground-contact retention requirement of 6.4 kg/m^3 and came much closer to meeting the penetration requirement of 80% of cores with 10 mm. The two posts with internal brown rot came from the two groups with the better overall treatment.

The apparently deeper preservative penetration below ground compared to above ground, despite almost identical retentions, was probably due to the movement of iron into the posts below ground. Analysis of these posts found an iron content of approximately 0.07 kg/m^3 below ground. Ruddick and Morris (1990) showed that iron could give a false positive indication for copper using Chrome Azurol S reagent on wood removed from service.

The performance of the treated posts is all the more impressive considering the evidence showing Westham Island to have 2.5 times the decay rate of other test sites in temperate zones (Morris and Ingram 1991, Ruddick and Morris 1990). Ruddick and Morris (1990) showed that iron moved into wood in ground contact at Westham Island. Morris and Ingram (1991) showed that iron uptake was associated with poor performance of CCA-treated wood against a brown-rot fungus, *Leucogyrophana pinastri*, endemic to Westham Island and Morris (1992, 1993) showed that iron detoxified the arsenic component of CCA.

An explanation for this unexpectedly good performance could lie in the high preservative loadings in the treated zone. The CCA in groups 1 and 2, analysed as 6.8 kg/m^3 in a 16mm assay zone, was concentrated in an average penetration zone of 10.5 mm. This would represent 10.4 kg/m^3 (6.8 x 16/10.5) in the treated zone. Similarly, group 3 would have 10.7 kg/m^3 (3.2 x 16/4.8) in the treated zone. This retention had been shown to perform well under the aggressive conditions of Westham Island. After 10 years in test at this site, ponderosa pine stakes through-treated to a retention of 10.3 kg/m^3 had a mean rating of approximately 9.0 (Morris and Ingram 1991).

Table 9: Decay Ratings for Treated and Untreated Posts

Treatment	Group	Incising	Mean IUFRO Decay Ratings				
			1 year	2 years	3 years	4 years	10 years
CCA	1	1	-	-	-	-	0.3 (0.4)
	2	1	-	-	-	-	0.6 (0.9)
	3	2	-	-	-	-	0.6 (0.5)
none	-	-	1.0 (0.6)	2.1 (1.1)	2.3 (1.2)	3.2 (0.9)	N/A

* *Standard deviations are given in parentheses*

Table 10: CCA Penetration and Retention

Group	Incising	Above ground				Below ground			
		Ret^n (kg/m^3)	Mean Pen^n (mm)	% with 10mm	% with 5mm	Ret^n (kg/m^3)	Mean Pen^n (mm)	% with 10mm	% with 5mm
1	1	6.8	10.7 (6.1)*	60	75	6.6	13.2 (2.8)	85	100
2	1	6.8	10.4 (5.6)	60	85	7.4	13.5 (4.2)	80	90
3	2	3.2	4.8 (4.9)	15	45	3.4	8.3 (4.0)	60	85

Ret^n = Retention
Pen^n = Penetration
* *Standard deviations are given in parentheses*

4 Conclusions

- The service life of treated round-wood fence posts is determined by the treatment quality, not the natural durability of the wood used.
- CCA-treated jack pine and white spruce at retentions around 8 kg/m^3 had mean service lives over 36 years.

- Full-length thermal immersion in creosote provides twice the service life of butt-only treatments, with many posts lasting over 60 years to date.
- Organo-copper complexes in pole oil applied using empty-cell pressure treatment showed good potential as treatments for posts.
- Mechanical barriers to decay showed variable results.
- Thin shell treatments provide a minimum 10-year life to lumber in ground contact in the absence of termites.

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