Oregon State University Utility Pole Research Cooperative

26th Annual Report
November 9, 2006

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Executive Summary

The Coop continues to make progress on six objectives.

Objective I: Our efforts have largely concentrated on field and laboratory tests of the water diffusible treatments, although we will have an extensive report on our field trials with dazomet next year. We have continued to evaluate the release of methylisothiocyanate (MITC) from MITC-FUME vials. Vials at low temperatures still contain chemical 18 years after application to Douglas-fir poles.

An assessment of residual boron levels in CCA-treated Douglas-fir poles 12 years after above-ground application of fused boron rods showed that most poles contained very low levels of boron. This was not surprising given the time since treatment; however, we also found that some poles were colonized by a decay fungus that would appear to have been present at the time of installation (it is not native to the area). The results suggest that above ground application of boron rods was not completely effective. Further tests on additional poles are suggested. At present, some care should be exercised when using boron rods for above ground treatment because the moisture levels may be inadequate for subsequent boron movement.

Studies on the effect of moisture content on movement of boron from borate rods were undertaken to determine why increasing boron rod dosages do not translate to higher loadings in the wood. We suspected that the rods sorbed moisture from the surrounding wood, slowing subsequent boron movement. Laboratory trials indicated that moisture levels around holes containing boron rods did not markedly decrease following treatment in comparison with holes without rods. As a result, the cause for the seemingly lower release rates with higher rod dosages remains unknown.

Objective II: We continue to seek methods for protecting untreated wood exposed when holes are drilled in poles for attachments. Preservative paste coated bolts have been evaluated as a possible solution to this problem. In principle, utilities could require use of these bolts for any attachment on a pole. The bolt threads are coated with a water soluble preservative paste which is, in turn, protected by a thin layer of plastic. Driving the bolt into the hole ruptures the plastic coating, allowing moisture to interact with and aid in diffusion of the chemical into the surrounding wood. Field trials indicate that chemicals in the systems move for short distances into the surrounding wood where they can protect against invading fungi. Further tests are planned on this approach.

Objective III: Large-scale tests on the effects of through-boring on strength of Douglas-fir poles have been completed and a summary of all prior through-boring work has been prepared. The intent is to bring this packet before both the American Wood Preservers' Association and the American National Standards Institute so that through-boring can be standardized in both standards. This effort will begin in the spring of 2007.

As a follow up to this project, we have also examined the strength properties of the upper portions of the poles. The upper zones of smaller diameter poles contain higher proportions of juvenile wood, a material with very different properties from mature wood produced in the older portions of a tree. Some utilities have questioned the strength values for the upper portions of a pole. In order to address this issue, we examined longitudinal compression strength of the upper sections of the poles tested in the through-boring study and found no significant differences between the butts and upper portions of these poles. The results suggest that the presence of juvenile wood does not impact the strength of Douglas-fir poles.

Assessment of moisture resistant external barriers below groundline continues. Moisture levels in all barrier treatments rose markedly this past year, indicating that the barriers were not capable of complete moisture exclusion. Further tests are planned once the poles are installed in the field.

An assessment of crossarms removed after 30 years in service in upstate New York revealed that most had strength values below those specified in ANSI and a number contained evidence of decay in the heartwood/sapwood interface. These results differed substantially from those found with Douglas-fir arms in a wishbone configuration; however, we suspect that the results differ because of the exposure conditions. The Douglas-fir arms were angled and thus tended to shed water, while the southern pine arms were horizontal and water could pool in checks. Further studies will be undertaken when we obtain additional arms. Despite the low values for the arms, the results do indicate that crossarms easily performed for 30 years.

Field trials of fire resistant coatings continue. Fire trials this past year showed that when compared to untreated poles, Osmose Fire-Guard provided good protection three years after application, and an elastomeric coating provided a slightly lower degree of protection. Attempts to take advantage of boron diffusion upward from CuRap 20 groundline paste failed.

Studies of the ability of end-plates to control checking on Douglas-fir crossarms have been installed. Moisture cycling has been used to accelerate checking, but no substantial differences have emerged in checking on plated and non-plated arms. These tests will continue.

Objective IV: Tests of external groundline pastes continue in New York and Georgia. The New York tests indicate chemical levels are declining in all treatments five years after application. This finding agrees with previous studies. The Georgia study is only its first year, but the results show that copper levels in the outer 6 mm are above the threshold in all but the Cobra wrap treatment, while boron and fluoride levels are both above threshold in their respective systems. The tests will continue to be monitored to determine end points for chemical protection.

Objective V: Fungus cellar tests of copper naphthenate continue to show that this chemical provides excellent protection to western redcedar. Efforts also continue to identify suitable poles in the field for monitoring.

Objective VI: Studies of chemical migration from poles in storage continue. The results from this past season's monitoring show that penta concentrations in rainwater runoff remain remarkably stable regardless of temperature, time between rainfall events, and amount of rainfall. The results indicate that packing poles as tightly as possible to limit the amount of rainfall that can strike treated wood has may be the best approach to limiting penta runoff. Tests are now underway on ammoniacal copper zinc arsenate treated poles in the same system.

Objective I

DEVELOP SAFER CHEMICALS FOR CONTROLLING INTERNAL DECAY OF WOOD POLES

Remedial treatments continue to play a major role in extending the service life of wood poles. While the first remedial treatments were broadly toxic, volatile chemicals, the treatments have gradually shifted to more controllable treatments. This shift has resulted in the availability of a variety of internal treatments for arresting fungal attack (Table I-1). Some of these treatments are fungitoxic based upon movement of gases through the wood, while others are fungitoxic based upon movement of boron or fluoride in free water. Each system has advantages and disadvantages in terms of safety and efficacy. In this section, we discuss the active field tests of the newer formulations as well as additional work to more completely characterize the performance of several older treatments.

Table I-1. Characteristics of internal remedial treatments for wood poles.

Trade Name	Active Ingredient	Conc. (%)	EPA Registration Number	Supplier
TimberFume	trichloronitromethane	96	3008-39	Osmose Utilities Services, Inc.
WoodFume ISK Fume	sodium n-methyldithiocarbamate	32.1	3008-33 1022-562-50534	Osmose Utilities Services, Inc. ISK Biocides
MITC-FUME	methylisothiocyanate	96	69850-1-3008	Osmose Utilities Services, Inc.
Super-Fume UltraFume DuraFume	Tetrahydro-3,5-dimethyl-2H-1,3,5-thiodiazine-2-thione (dazomet)	98-99	1448-104-54471 7969-162-10465 01448-00104-75341	Copper Care Wood Preservatives, Inc. Intec, Inc. Osmose Utilities Services, Inc.
Impel Rods	anhydrous disodium octaborate	100	10465-30	Intec, Inc.
Polesaver Rods	disodium octaborate tetrahydrate/sodium fluoride	58/24	not registered in U.S.	Preschem Pty Ltd.
Flurods	sodium fluoride	98	3008-63	Osmose Utilities Services, Inc.
Cobra-Rods	disodium octaborate tetrahydrate and boric acid/copper hydroxide	97/3	71653-2	Genics Inc.

A. Develop Improved Fumigants for Control of Internal Decay

While there are a variety of methods for internal decay control used around the world, fumigants remain the most widely used systems for arresting internal decay in North America. Initially, two fumigants were registered for wood, metam sodium (32.1 % sodium n-methyldithiocarbamate) and chloropicrin (96 % trichloronitromethane) (Table I-1). Of these, chloropicrin was the most effective, but both systems were prone to spills and carried the risk of worker contact. UPRC research identified two alternatives, solid methylisothiocyanate (MITC) and dazomet. Both chemicals were solid at room temperature, reducing the risk of spills and simplifying cleanup of any spills that occur. MITC was commercialized as MITC-FUME, while dazomet has been labeled as Super-Fume, UltraFume and Dura-Fume. An important part of the development process for these systems have been continued performance evaluation to determine when retreatment is necessary and to identify any characteristics that might affect performance.

1. Effect of Temperature on Release Rates of MITC From MITC-FUME Ampules

MITC-FUME has been commercially available for over 14 years, first as a glass encapsulated material and later in aluminum ampules. In both cases, the cap was removed and the tube was inserted, open end down, into the treatment hole. As with any encapsulated material, the time required for the chemical to move from the tubes and into the surrounding wood has important implications on efficacy. As a part of our initial evaluations of MITC-FUME, we established small scale trials to assess the rates of MITC release under varying temperature conditions.

Eighteen untreated Douglas-fir pole sections (250 mm in diameter by 750 mm long) were obtained either freshly cut or air-seasoned. The objective of using green material was to determine if excess moisture would affect release rate. A single hole (205 mm long by 19 mm in diameter) was drilled at a 45 degree angle near the center of each pole section and a single MITC-FUME ampule containing 30 g of MITC was added to the hole. The holes were plugged with wooden plugs, and then sets of three poles each were stored at 5 C, outdoors at ambient temperature or at 32 C and 90 % relative humidity. The ampules were periodically removed and weighed to determine the rate of MITC release.

As noted previously, ampules stored at 32 C lost most of their chemical within 1 year (Figure I-1). Ampules stored outdoors lost chemical more slowly and there was a slight, but noticeably more rapid release rate for ampules in pole sections that were initially seasoned. Ampules stored at ambient conditions required 4 to 8 years to lose all of the initial chemical, although the vast majority of chemical was lost within the first 4 years after treatment.

Ampules stored at 5 C continue to lose chemical very slowly at rates that will require 25 to 30 years for the chemical to completely leave the ampule (Figure I-2). MITC is an interesting chemical in that it sublimes directly from a solid to a gas at room temperature. Clearly, cooler temperatures retard this process. Conversely, decay fungi are only marginally active at 5C, making it unlikely that any significant decay would occur under these conditions. Thus, the slow release of MITC may be attractive from a practical aspect for poles exposed in cooler climates. The only concern about this

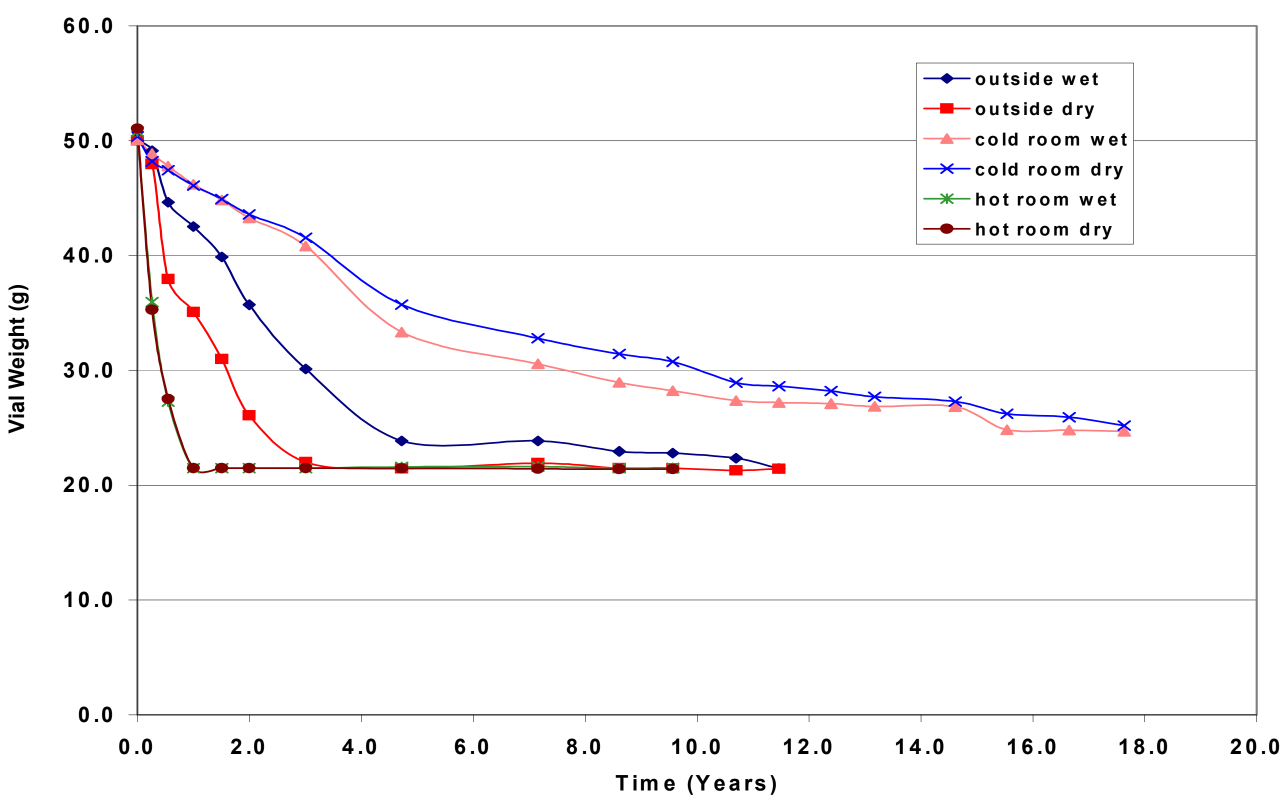

Figure I-1. MITC remaining in glass ampules installed in Douglas-fir pole sections exposed at 5 C, 32 C or ambient outdoor conditions.

prolonged release would be that the ampules continue to retain active ingredient for many years. This might become a concern were the pole to be involved in a vehicle accident, since the ampule could be ejected from the hole, or the chemical could be released if the pole were cut through with a chainsaw. However, prior tests by the manufacturers have shown that even cutting through an ampule in the wood results in little or no airborne exposure of workers to the chemical. In addition, there is only 2 to 4 g of chemical in the tubes stored under the cooler condition at this time. Thus, there are minimal risks posed by long term residual chemical in the tubes.

Figure I-2. MITC –FUME tubes 18 years after application to wet (3 tubes on left) or dry (3 tubes on right) Douglas-fir poles sections. The tubes contained 3.3, 2.1, 4.4, 4.9, 3.5, and 3.1 g of MITC, respectively, from the original approximately 30 g of MITC. Some of the material on the glass is elemental sulfur.

2. Performance of Copper Amended Dazomet in Douglas-fir Transmission Poles

The poles treated with dazomet plus copper were not inspected this year, but will be sampled in 2008.

3. Performance of Dazomet in Granular and Rod Forms in Douglas-fir Pole Sections

Dazomet was originally supplied in a powdered formulation which was intended for application to agricultural fields where it could be tilled into the soil. Once in contact with the soil, the dazomet would rapidly react to release MITC, killing potential pathogens prior to planting. The drawbacks to the use of granular formulations for treatment of internal decay in wood poles include the risk of spillage during application, as well as the potential for the presence of chemical dusts that can be inhaled. Spills and exposure can be avoided by using a dosing device that avoids overtreatment. In our early trials, we produced dazomet pellets by wetting the powder and compressing the mixture into pellets, but these were not commercially available. The desire for improved handling characteristics, however, encouraged the development of a rod form. These rods simplified application, but we wondered whether the decreased wood/chemical contact associated with the rods, might reduce dazomet decomposition, thereby slowing fungal control.

These poles were sampled in 2005 and are not scheduled to be sampled until next year.

4. Use of Copper Naphthenate to Enhance Release of MITC from Dazomet

Our preliminary field data clearly showed that copper sulfate accelerated the decomposition of dazomet to produce MITC, but this chemical is not generally used by utility personnel. One alternative to copper sulfate is copper naphthenate, which is commonly recommended for treatment of field damage to utility poles. There were, however, questions concerning the ability of copper naphthenate, a copper soap, to enhance decomposition in comparison with the copper salt.

This test was last sampled in 2005 and is scheduled to be sampled next year.

5. Performance of Dazomet in Granular and Tube Formulations

Date Established:	August 2006
Location:	Peavy Arboretum, Corvallis, OR
Pole Species, Treatment, Size	Douglas-fir, penta
Circumference @ GL (avg., max., min.)	35.1, 38, 32 in

Dazomet has been successfully applied for almost 5 years; however, one concern with this system is the risk of spilling the granules during application. In previous tests, we explored the use of dazomet in pellet form, but this does not appear to be a commercially viable product. As an alternative, dazomet could be placed in degradable tubes that contained the chemical prior to application. The tubes would protect the material prior to application, but may also affect subsequent dazomet decomposition and release of methylisothiocyanate. In order to investigate this possibility, the following trial was established.

Pentachlorophenol treated Douglas-fir pole sections (2.1 m long by 250-300 mm in diameter) were set to a depth of 0.6 m at the Peavy Arboretum test site. Three 22 mm diameter by 375 to 400 mm long steeply angled holes were drilled into the poles beginning at groundline and moving upward 150 mm and 120 degrees around the pole.

Seventy grams of dazomet was pre-weighed into 125 ml glass bottles. The contents of one bottle was then applied to each of the three holes in each of 10 poles. The holes in 10 additional poles received a 400 to 450 mm long by 19 mm diameter paper tube containing 60 g of dazomet. The tubes were gently rotated as they were inserted to avoid damage to the paper. The holes in one half of the poles treated with either granular or tubular dazomet were then treated with 7 g of 2 % copper naphthenate in mineral spirits (Tenino Copper Naphthenate). The holes were plugged with tight fitting plastic plugs (Scotty Plugs).

MITC distribution will be assessed beginning next year by removing increment cores from locations within and above the treatment zone. The outer and inner 25 mm of each core (Figure I-3) will be extracted in ethyl acetate and these extracts will be analyzed by gas chromatography for MITC.

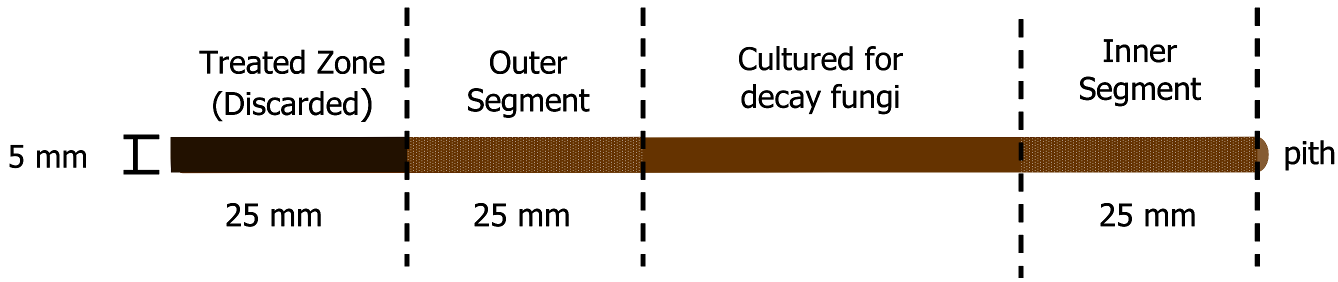

Figure I-3. Representation of increment core showing inner and outer 25 mm segments analyzed for fumigant content.

B. Performance of Water Diffusible Preservatives as Internal Treatments

While fumigants have long been an important tool for utilities seeking to prolong the service lives of wood poles and limit the extent of internal decay, some users have expressed concern about the risk of these chemicals. Water diffusible preservatives such as boron and fluoride have been developed as potentially less toxic alternatives to fumigants.

Boron has a long history of use as an initial treatment of freshly sawn lumber to prevent infestations by various species of powder post beetles in both Europe and New Zealand. This chemical has also been used more recently for treatment of lumber in Hawaii to limit attack by the Formosan subterranean termite. Boron is attractive as a preservative because it has exceptionally low toxicity to non-target organisms, especially humans, and because it has the ability to diffuse through wet wood. In principle, a decaying utility pole should be wet, particularly near the groundline and this moisture can provide the vehicle for boron to move from the point of application to wherever decay is occurring. Boron is available for remedial treatments in a number of forms, but the most popular are fused borate rods which come as pure boron or boron plus copper. These rods are produced by heating boron to its molten state, then pouring the molten boron into a mold. The cooled boron rods are easily handled and applied. In theory, the boron is released as the rods come in contact with water.

Fluoride has also been used in a variety of preservative formulations going back to the 1930's when fluor-chrome-arsenic-phenol was employed as an initial treatment. Fluoride, in rod form, has long been used to treat the area under tie plates in railroad tracks and has been used as a dip-diffusion treatment in Europe. Fluoride can be corrosive to metals. Sodium fluoride is also formed into rods for application, although the rods are less dense than the boron rods.

Both of these chemicals have been available for remedial treatments for several decades, but widespread use of these systems has only occurred in the last decade and most of this application has occurred in Europe. As a result, there is considerable performance data on boron and fluoride as remedial treatments on European species, but little data on performance on U.S. species used for utility poles.

1. Performance of Copper Amended Fused Boron Rods

Date Established:	November 2001
Location:	Peavy Arboretum, Corvallis, OR
Pole Species, Treatment, Size	Douglas-fir, penta and Douglas-fir creosote
Circumference @ GL (avg., max., min.)	78, 101, 66 cm

The ability of boron and copper to move from fused rods was assessed by drilling holes perpendicular to the grain in pentachlorophenol treated Douglas-fir poles beginning at the groundline and then moving upward 150 mm and either 90 or 120 degrees around the pole. The poles were treated with either 4 or 8 copper/boron rods or 4 boron rods. The holes were then plugged with tight fitting plastic plugs. Chemical movement was assessed 1, 2, and 3 years after treat ment by removing increment cores from locations 150 mm below groundline as well as at groundline, and 300 or 900 mm above this zone. The outer, 2.5 cm of treated shell was discarded, and the core was divided into inner and outer halves. The cores from a given height and treatment were combined and then ground to pass a 20 mesh screen. The resulting sawdust was first analyzed for copper by x-ray fluorescence spectroscopy, and then extracted in hot water. The extract was analyzed for boron content using the azomethine-H method.

This test was last inspected in 2005 and is not scheduled to be inspected until November 2006.

2. Performance of Fused Borate Rods in Internal Groundline Treatments of Douglas-fir Poles

Date Established:	May 1993
Location:	Peavy Arboretum, Corvallis, OR
Pole Species, Treatment, Size	Douglas-fir, penta
Circumference @ GL (avg., max., min.)	100, 114, 89 cm

Thirty pentachlorophenol treated Douglas-fir poles (283-364 mm in diameter by 2 m long) were set to a depth of 0.6 m at the Peavy Arboretum test site. Three 19 mm diameter by 200 mm long holes were drilled perpendicular to the grain beginning at groundline and moving around the pole 120 degrees and upward 15 cm. Each hole received either 1 or 2 boron rods (180 or 360 g of rod, respectively). The holes were then plugged with tight fitting wooden dowels. Each treatment was replicated on 10 poles.

The poles were sampled 1, 3, 4, 5, 7, 10, and 12 years after treatment by removing increment cores from sites located 15 cm below groundline as well as 7.5, 22.5, 45, and 60 cm above the groundline.

These poles will next be inspected in 2008.

3. Effect of Glycol on Movement of Boron from Fused Borate Rods

Date Established:	March 1995
Location:	Peavy Arboretum, Corvallis, OR
Pole Species, Treatment, Size	Douglas-fir, penta
Circumference @ GL (avg., max., min.)	87, 99, 81 cm

While boron has been found to move with moisture through most pole species (Dickinson et al., 1988; Dietz and Schmidt, 1988; Dirol, 1988; Edlund et al., 1983; Ruddick and Kundzewicz, 1992), our initial field tests showed slower movement in the first year after application. One remedy to the slow movement that has been used in Europe has been the addition of glycol. Glycol is believed to stimulate movement through dry wood that would normally not support diffusion (Bech-Anderson, 1987; Edlund et al., 1983).

Pentachlorophenol treated Douglas-fir pole sections (259 to 315 mm in diameter by 2.1 m long) were set to a depth of 0.6 m in the ground at the Peavy Arboretum test site. The poles were treated with varying levels of boron and glycol mixtures. Boron levels have been assessed over a 10 year period, but were not sampled this year.

The poles will be sampled in 2007.

4. Performance of Fluoride/Boron Rods in Douglas-fir Poles

Date Established:	August 1993
Location:	Peavy Arboretum, Corvallis, OR
Pole Species, Treatment, Size	Douglas-fir, penta
Circumference @ GL (avg., max., min.)	80, 86, 74 cm

Fluoride/boron rods are used in Australia for remedial treatment of internal decay in Eucalytpus poles. Although not labeled in the U.S, these rods have potential for use in this country. The rods contain 24.3 % sodium fluoride and 58.2 % sodium octaborate tetrahydrate (Preschem, Ltd). The rods have a chalk-like appearance. In theory, the fluoride/ boron mixture should take advantage of the properties of both chemicals which have relatively low toxicity and can move with moisture through the wood.

Pentachlorophenol treated Douglas-fir poles (235-275 mm in diameter by 3.6 m long) were set to a depth of 0.6 m and a series of three steeply sloping holes were drilled into each pole, beginning at groundline and moving upwards 150 mm and around the pole 90 or 120 degrees. A total of 70.5 or 141 g of boron/fluoride rod (3 or 6 rods per pole) was equally distributed among the three holes which were plugged with tight fitting wooden dowels. Each treatment was replicated on five poles. Chemical movement was assessed 1, 2, 3, 5, 7, 10 and 12 years after treatment.

The poles were not sampled this year but will be inspected in 2008.

5. Performance of Sodium Fluoride Rods as Internal Treatments in Douglas-fir Poles

Date Established:	May 1995
Location:	Peavy Arboretum, Corvallis, OR
Pole Species, Treatment, Size	Douglas-fir, penta
Circumference @ GL (avg., max., min.)	87, 97, 81 cm

Fluoride has a long history of use as a water diffusible wood preservative and was long an important component in Fluor-Chrome-Arsenic-Phenol as well as in many external preservative pastes. Like boron, fluoride has the ability to move with moisture, but a number of studies have suggested that it tends to remain at low levels in wood even under elevated leaching conditions. Fluoride has also long been used in rod form for protecting the areas under tie plates on railway sleepers (ties) from decay. These rods may also have some application for internal decay control in poles.

Fifteen pentachlorophenol treated Douglas-fir pole sections (259-307 mm in diameter by 2.4 m long) were set in the ground to a depth of 0.6 m at the Peavy Arboretum test site. Three 19 mm diameter by 200 mm long holes were drilled beginning at groundline and moving around the pole 120 degrees and upward 150 mm. Each hole received either one or two sodium fluoride rods. The holes were then plugged with tight fitting wooden dowels. Eight poles were treated with one rod per hole and seven poles were treated with two rods per hole. After 3 years five of the poles were destructively sampled. The remaining five poles from each treatment were sampled in subsequent years.

The poles were sampled 1, 2, 3, 5, 7, and 10 years after treatment but were not sampled this past year.

They are scheduled to be sampled in 2008.

6. Residual Boron Levels in CCA Treated Douglas-fir Poles 12 Years After Application of Fused Borate Rods Above Ground

Fused borate rods have been available for over three decades and have found widespread use in many European countries because of their ease of handling and low toxicity to non-target organisms. The rods require some moisture in order for the boron to be released from the rods and subsequently diffuse into the surrounding wood. While moisture levels at groundline are most suitable for boron release, our trials studying moisture content of Douglas-fir poles in Western Oregon suggest that moisture levels above the ground are also suitable for at least portions of the year. The presence of internal decay above the ground in poles in the same region confirms that free water is present in these structures. As a result, boron rods might be suitable for arresting internal decay above the ground, although there are few data supporting this premise

The potential for using boron rods to control internal decay above ground was assessed in Douglas-fir poles installed in upstate New York between 1972 and 1974. These poles had a unique history. The poles were air-seasoned for 3 to 5 years prior to being treated with chromated copper arsenate. The long air–seasoning period ensured that decay fungi had thoroughly colonized the poles and lack of sterilization resulted in these poles being installed with pre-existing fungal attack. The concern over this problem was part of the impetus for an extensive study of air-seasoning practices; however, the utility still had to deal with an extensive inventory of very large (H-1 and bigger) poles with decay above the groundline. At the time, solid fumigants had just entered the market and there were concerns about the use of MITC-FUME. Instead, the utility elected to use a sufficient number of boron rods to produce a boron concentration at or above the threshold for fungal attack. At the time, this threshold was believed to be 0.5 % boric acid equivalent (BAE) based upon work on *Virola* spp. (Williams and Amburgey, 1987). Subsequent work under the Coop has shown that the threshold for protecting against internal decay is much lower, in the range of 0.1 % BAE (0.5 kg/m^3).

The poles in question were treated with boron rods by drilling holes every 0.6 m in a spiral pattern around the pole. The rods were added and then the holes were plugged with tight fitting wooden dowels. The treatments were performed by utility personnel and no monitoring was performed following treatment. We recently had an opportunity to examine the condition of portions of several of these poles which were removed as part of a maintenance and upgrade program. The poles were sampled by cutting cross-sections (at least 125 mm thick) from the groundline, the mid-point, the location of one attachment, and the top. These cross sections were labeled and shipped to OSU for analysis.

A total of 22 poles were sampled, although not all locations were sampled on every pole. The poles were assessed for fungal colonization and residual boron level. Fungal colonization was assessed by cutting a series of thin slices (20 mm wide) along four radial axes of the pole. The first radial slice was taken adjacent to the largest visible check, then the other three were taken at 90 degree increments away from that check or from near other large checks or apparent treatments holes.

Small wood blocks were then cut from the zone immediately inside the original treatment zone (outer zone), from the pith (pith), and from points 1/3 and 2/3 of the distance between the outer and pith samples (mid 1 & mid 2). These blocks were then flamed to remove any contaminating surface fungi prior to being placed on the surface of malt extract agar in a plastic Petri dish. The blocks were observed over a 30 day period for evidence of fungal growth and any growth was examined for characteristics typical of basidiomycetes, a class of fungi containing many important wood decayers.

In this test, the fungi were also examined to determine if any isolates were *Antrodia carbonica*. In the original sampling of these poles in 1977, this fungus was among the most frequently isolated species. This was particularly important because this fungus is native to the western US and had not reported to be present in New York. These results suggested that the fungus had not invaded the poles after installation, but was present in the poles at the time of treatment.

The presence of this fungus in the poles at the present time would indicate that the boron had failed to diffuse through the poles at levels capable of eliminating the fungus.

Residual boron in the poles was assessed by cutting blocks immediately adjacent to the cultural samples. These blocks were ground to pass a 20 mesh screen and hot water extracted. The hot water extracts were then analyzed according to American Wood Preservers' Association Standard A2 Method 16, the Azomethine H method. Boron levels in the samples were determined by comparison with standards containing known amounts of boron. For comparison purposes, boron was considered to be at an effective level when present at 0.5 kg/m^3 BAE (boric acid equivalent) or greater.

The cores were heavily colonized by a variety of non-decay fungi. As noted in previous reports, the roles of these fungi are unknown. Some of these fungi can produce potent antibiotics that might inhibit the activity of other fungi, including decay fungi, while others have been shown to condition the wood, making it easier for decay fungi to colonize the materials. With traditional fumigants, we would expect to see a sharp drop in the isolation levels of non-decay fungi, followed by a graduate re-colonization. Some of these re-colonizing fungi are potential antagonists to decay fungi.

Table I-2. Frequency of decay and non-decay fungi in cross sections of CCA treated Douglas-fir poles 12 years after treatment with fused boron rods.

Pole #	Percentage of cores containing fungi[a]							
	Groundline		Mid-point		Attachments		Top	
	Decay	Non-decay	Decay	Non-decay	Decay	Non-decay	Decay	Non-decay
44	0.0	100.0					0.0	88.9
212			68.8	100.0	25.0	100.0	0.0	100.0
213.5	0.0	100.0	0.0	100.0	0.0	100.0	0.0	88.9
214	0.0	37.5	11.1	100.0	0.0	100.0	0.0	100.0
215	0.0	93.8	6.3	100.0	0.0	77.8	0.0	100.0
216			62.5	100.0	12.5	100.0	0.0	100.0
217			0.0	93.8	0.0	100.0	0.0	100.0
214A	0.0	81.3	0.0	100.0	0.0	88.9	0.0	100.0
215A			0.0	100.0	11.1	100.0	0.0	100.0
216A			11.1	100.0	11.1	100.0	22.2	100.0
217 A			0.0	100.0	0.0	100.0	0.0	100.0
217B			0.0	100.0	0.0	88.9	0.0	100.0
217C			0.0	100.0	0.0	100.0	0.0	100.0
U1	12.5	100.0	0.0	100.0			6.3	75.0
U2	0.0	93.7	6.3	100.0			0.0	88.9
U3	0.0	100.0	0.0	100.0			0.0	75.0
U4	0.0	100.0	0.0	66.7			0.0	88.9
U5			18.8	100.0	0.0	100.0	22.2	100.0
U6	0.0	66.7						
U7	18.8	62.5	0.0	93.8			22.2	88.9
U8	0.0	81.3					22.2	100.0
U9	0.0	37.5						

aValues represent isolations from 9, 12 or 16 samples per location per pole, depending on size.

Decay fungi were present at the groundline in 2 of 13 poles from which samples were obtained; however, only 2 and 3 isolates, respectively, were obtained from the 16 samples plated from these two poles (Table I-2). These results suggest that the groundline zones were relatively clean.

Seven of 18 poles sampled at the mid-point contained decay fungi. Four of these poles contained only 1 to 3 isolates from the 16 attempts; however, isolation frequencies in two poles were 62.5 and 68.8 %, suggesting that the midpoint of these poles was heavily colonized by decay fungi.

Four of 13 poles sampled near attachments also contained viable decay fungi. As with the groundline, however, the isolation frequencies were relatively low with the exception of one pole where 25 % of the cores contained decay fungi. Even this level is at the edge of the point where we might become concerned, but it does indicate that the poles remain colonized by an array of decay fungi.

Five of 20 poles sampled at the top contained viable decay fungi and four of these poles had isolation levels above 20%. As noted earlier, these levels are not cause for immediate concern, but they do indicate that the treatment has lost its effectiveness. Perhaps of greatest importance in these results was the presence of *A. carbonica* in the poles. Of the 49 decay fungi isolated from the poles, 10 were *A. carbonica*. These results suggest that the boron was unable to completely control this fungus. Three of the 10 isolates of this fungus were obtained from top sections; four were obtained at the mid-point sample, and three from the groundline, which had been subjected to conventional fumigant treatment.

Boron levels in the adjacent samples varied widely, ranging from 0.006 kg/m^3 to 42.214 kg/m^3 (Table I-3). Boron levels of 0.50 kg/m^3 or greater would be considered to be protective against internal decay, based upon our previous tests. Boron levels were protective at groundline at only two locations, both on the same pole (U6). Boron levels at groundline in the remainder of poles were generally well below the protective level. Boron levels at the mid-point of the poles tended to be higher than at groundline, particularly in the samples from the middle and pith zones. Thirteen of 29 samples in the middle zone were at or above the threshold, while 7 of 19 samples from the pith of the cross sections from the middle of the poles were above the threshold.

Boron levels in the outer zones of cross sections from the attachment zone also tended to be low and only two were above the threshold (Table I-4). Boron levels in the middle of these same sections were above the threshold in 8 of 15 samples and in 8 of 13 samples from the pith. Finally, boron levels near the tops of the poles were again low in the outer zone (3 of 21samples above threshold), slightly higher in the middle zones (7 of 23 samples above threshold) and pith (8 of 21 above threshold).

The relatively small numbers of samples at or above the threshold suggest that, at best, these poles were in need of retreatment, but could also mean that the treatment never achieved the threshold level. The absence of initial samples as well as the lack of sampling data over time makes it difficult to assess the relative performance of this treatment. A number of cross sections did contain visible decay; however, this decay may well have been present prior to treatment. Decay fungi were isolated from locations where boron levels in or immediately adjacent to the samples were well above the threshold for preventing fungal attack. It is unclear whether these isolations represent active fungal attack or merely survival of chlamydospores under harsh conditions.

The limited availability of moisture in the above ground zones of a pole would pose a major challenge to movement of water diffusibles. The presence of internal decay above ground makes it clear that moisture levels do exceed 30 % for at least some periods in a given year. Any moisture entering the wood likely does so as it runs along checks or through holes made in the original treatment shell. The limited distribution of checks and the relatively small number of holes drilled into a pole for cross arms and other attachments sharply limit the potential for moisture ingress. Furthermore,

Table I-3. Residual boron at the groundline and near the mid-points of CCA treated Douglas-fir poles 12 years after treatment with fused boron rods.

Pole #	Residual Boron Levels (kg/m^3)[a]							
	Groundline				Pole midpoint			
	Outer	Mid 1	Mid 2	Pith	Outer	Mid 1	Mid 2	Pith
44	0.09(0.06)	0.05 (0.03)	0.06(0.03)	0.06(0.01)	-	-	-	-
212	-	-	-	-	0.11(0.08)	**1.04(2.00)***	0.17(0.25)*	0.09(0.02)*
213.5	0.05(0.02)	0.06 (0.02)	0.06(0.04)	0.10(0.02)	0.08(0.04)	0.02(0.01)	0.02(0.01)	0.02(0.01)
214	0.10(0.03)	0.04 (0.01)	0.10(0.10)	0.04(0.01)	0.03(0.01)*	0.05(0.02)	-	0.14(0.11)
215	0.14(0.19)	0.09 (0.11)	0.14(0.15)	0.05(0.04)	0.0	0.0	0.0	0*
216	-	-	-	-	0.21(0.20)*	**3.92(5.05)***	**3.43(4.17)***	**1.77(2.63)***
217	-	-	-	-	0.02(0.03)	0.59(1.18)	0.37(0.73)	0.11(0.16)
214A	0.07(0.03)	0.02(0.02)	0.03(0.01)	0.02(0.02)	0.06(0.05)	0.46(0.89)	0.06(0.07)	0.09(0.12)
215A	-	-	-	-	0.10(0.09)	0.02(0.03)	-	0.01(0.01)
216A	-	-	-	-	0.02(0.01)*	0.01(0.01)	-	0.03(0.01)
217A	-	-	-	-	0.02(0.01)	0.02(0.01)	-	0.03(0.01)
217B	-	-	-	-	0.07(0.07)	0.08(0.12)	-	0.03(0.02)
217C	-	-	-	-	0.12(0.15)	0.15(0.23)	-	0.08(0.07)
U1	0.06(0.08)*	0.15(0.18)*	0.22(0.30)	0.08(0.05)	0.04(0.04)	**0.92(1.12)**	0.25(0.25)	**1.10(0.89)**
U2	0.0	0.01(0.01)	0.0	0.01(0.02)	0.05(0.04)	**1.49(0.56)**	0.36(0.30)*	**2.19(0.75)**
U3	0.03(0.02)	0.06 (0.04)	0.04(0.02)	0.05(0.02)	0.15(0.11)	**1.45(1.37)**	**0.82(1.07)**	**3.54(2.96)**
U4	0.01(0.01)	0.02 (0.01)	0.01(0.01)	0.04(0.04)	0.30(0.34)	**6.43(6.37)**	-	**42.21(29.63)**
U5	-	-	-	-	0.02(0.03)*	0.02(0.01)*	0*	0.01(0.01)
U6	0.03(0.06)	**0.67 (0.27)**	0.20(0.17)	**1.14(0.66)**	0.17(0.15)	**2.01(0.97)**	**0.88(0.59)**	**5.00(2.35)**
U7	0.01(0.01)	0.10(0.16)*	0.01(0.1)*	0.05(0.05)	**0.63(0.47)**	**4.20(4.07)**	**1.68(1.54)**	**14.60(12.90)**
U8	0.01(0.02)	0.03(0.03)	0.01(0.01)	0.0	-	-	-	-
U9	0.01(0.01)	0.01(0.01)*	0.02(0.02)	0.02(0.02)	-	-	-	-

[a]Values represent the mean of three or four samples per location and figures in parentheses represent one standard deviation. Numbers in bold represent boron levels above the threshold for fungal growth while values with an asterisk indicate locations where decay fungi were isolated.

they ensure that any moisture will be very unevenly distributed. This uneven distribution is especially important for water diffusible treatments because failure to locate the treatment in a zone prone to periodic wetting will sharply diminish the prospect for successful decay control. As a result, regular spacing of rods along the length of a pole without regard to check locations or the presence of drilled holes may result in a high percentage of the rods being placed where moisture conditions are largely unsuited for release.

While it is difficult to confirm that this occurred in the poles in this test because we lack data over time, this may be one explanation for the wide range in boron levels and the presence of fungal species that have appeared to survive throughout the life of the pole. Previous tests have shown that adding water or glycol at the time of treatment can enhance release and this may be one approach for producing slight improvements in performance of the rods above ground.

7. Effect of Wood Moisture Content on Boron Movement Through Douglas-fir Heartwood

Over the years, we have run a number of laboratory and field trials with fused boron and fluoride rods that suggest that increasing the rod dosage per hole results in lower boron or fluoride levels in the wood. We have suspected that sorption of moisture from the wood surrounding the rod essentially reduces the wood moisture content to the point that the free water needed for diffusion is limiting; however, we have not been able to produce data demonstrating this effect. In order to assess this potential phenomenon, the following trial was undertaken.

Table I-4. Residual boron at the attachment point and near the tops of CCA treated Douglas-fir poles 12 years after treatment with fused boron rods.

	Residual Boron Levels (kg/m^3)[a]							
	Attachment				Pole Top			
Pole #	Outer	Mid 1	Mid 2	Pith	Outer	Mid 1	Mid 2	Pith
44	-	-	-	-	**0.77(1.15)**	**2.10(3.40)**	-	**33.53(51.60)**
212	0.49(0.68)*	0.89(0.56)*	-	**1.15(0.47)**	**0.90(0.42)**	**2.96(1.17)**	-	**4.05(2.18)**
213.5	0.05(0.04)	0.05(0.04)	-	0.06(0.01)	0.37(0.55)	0.03(0.01)	-	0.03(0.01)
214	0.16(0.05)	0.07(0.03)	-	**0.79(0.54)**	0.02(0.00)	0.04(0.01)	-	0.10(0.03)
215	0.29(0.47)	**0.66(0.99)**	-	**5.41(6.35)**	0	0	-	0
216	**0.59(1.00)**	**0.74(0.86)**	0.44(0.66)*	**1.86(1.19)**	0.05(0.01)	**0.65(0.16)**	-	**11.51(4.83)**
217	0.41(0.40)	**2.37(2.26)**	-	**4.22(0.94)**	0.02(0.02)	0.02(0.02)	-	0.02(0.02)
214A	0.37(0.62)	**0.53(0.89)**	-	0.14(0.20)	0.03(0.01)	0.03(0.02)	-	0.04(0.01)
215A	**2.42(1.57)***	**3.02(1.79)**	-	**4.93(3.26)**	0.14(0.23)	0.05(0.08)	-	0.01(0.01)
216A	0.07(0.07)*	**0.55(0.74)**	-	**1.34(0.76)**	0.02(0.01)*	0.02(0.01)	-	0.04(0.02)
217A	0.04(0.04)	0.03(0.02)	-	0.02(0.02)	0.01(0.01)	0.01(0.01)	-	0.01(0.02)
217B	0.48(0.72)	**2.22(3.31)**	-	**1.50(0.75)**	0.02(0.01)	0.02(0.02)	-	0.02(0.01)
217C	0.07(0.04)	0.09(0.10)	-	0.05(0.02)	0.25(0.22)	0	-	0
U1	-	-	-	-	0.03(0.02)	0.13(0.021)*	0.02(0.01)	0.10(0.11)
U2	-	-	-	-	**0.63(0.81)**	**5.13(7.27)**	-	**6.87(4.72)**
U3	-	-	-	-	0.08(0.02)	0.10(0.05)	0.06(0.02)	0.09(0.04)
U4	-	-	-	-	0.12(0.06)	**0.96(0.86)**	-	**7.63(4.29)**
U5	0.01(0.01)	0.01(0.01)	0	0	0.01(0.01)*	0.35(0.56)*	-	**1.19(1.28)**
U6	-	-	-	-	0.36(0.32)	**3.39(2.28)**	-	**2.82(1.43)**
U7	-	-	-	-	0.32(0.44)*	**4.39(1.58)**	-	**14.28(3.41)**
U8	-	-	-	-	0.02(0.01)	0.01(0.01)	-	0.02(0.02)*
U9	-	-	-	-	-	-	-	-

[a]Values represent the mean of three or four samples per location and figures in parentheses represent one standard deviation. Numbers in bold represent boron levels above the threshold for fungal growth while values with an asterisk indicate locations where decay fungi were isolated.

Douglas-fir heartwood blocks (50 by 100 by 150 mm long) were oven-dried, weighed and then pressure soaked with water. The blocks were then weighed prior to being air-dried to 30, 60, or 90 % moisture content. Once the block achieved its target moisture content, it was dipped in molten paraffin to retard further moisture loss, and then stored at 5 C to allow for further equilibration.

A single 9 mm diameter hole was drilled on the narrow face of each block and a single fused borate rod was added. The treatment hole was sealed with duct tape and the blocks were incubated at room temperature for 7, 30 or 90 days. At each time point, 6 blocks at each moisture content were removed and sections were sawn immediately adjacent (0-5 mm) to the original treatment hole as well as at 5-10 mm and 10-20 mm away from the treatment hole. These sections were immediately weighed, oven dried, and weighed again to determine wood moisture content. The wood was then ground to pass a 20 mesh screen prior to hot water extraction. The extract was analyzed for boron using the azomethine H method.

Moisture contents of the blocks were generally lower than the target levels for all three moisture contents although the differences were slight at 30 % MC and became increasingly larger with target moisture level (Table I-5). Moisture contents for the 30, 60 and 90 % blocks ranged from 27.1 to 28.9 %, 50.3 to 51.5 %, and 79.6 to 83.9 % in the 0-5, 5-10 and 10-20 mm depths, respectively. The moisture gradients from the surface to the interior were also relatively small, indicating that the moisture distribution in the blocks was relatively uniform.

Analysis of boron at the same points assessed for moisture level showed that boron contents tended to increase with increasing moisture content as well as with incubation time. Boron within the wood tended to be well above the threshold for protection against internal attack even at 30 % moisture content. Since free water is necessary for boron diffusion, this would suggest that sufficient moisture remained in the blocks, even at the lowest moisture level tested. It is also clear that the rods do not sorb excessive moisture to the point where further movement of boron from the rods is inhibited. This finding still leaves us at a loss to explain the lack of a dose response when increasing amounts of boron are used.

Table I-5. Moisture and boron contents at selected locations away from the treatment zone in Douglas-fir heartwood blocks conditioned to 30, 60, or 90 % moisture content and incubated for 0, 7, 30 or 90 days at room temperature.

Incubation Time (days)	Distance from Treatment Hole (mm)	Wood Moisture Content			Boron Content (% BAE)		
		30 %	60 %	90 %	30 %	60 %	90 %
0	0-5	21.7(2.9)	50.3(2.9)	79.6(5.4)	-	-	-
	5-10	28.1(1.0)	50.9(4.4)	83.2(3.1)	-	-	-
	10-20	28.9(1.0)	51.5(5.3)	83.9(4.6)	-	-	-
7	0-5	25.3(5.50	45.2(2.7)	68.9(9.7)	0.94(0.90)	8.10(3.70)	12.28(2.80)
	5-10	23.7(1.6)	38.3(6.1)	60.8(9.1)	0.37(0.50)	2.49(2.60)	5.25(3.80)
	10-20	24.2(2.3)	42.2(4.1)	62.0(6.5)	0.15(0.50)	0.78(0.20)	2.45(1.30)
30	0-5	20.7(1.0)	32.2(4.3)	69.1(7.2)	0.45(0.30)	4.70(2.80)	6.22(4.50)
	5-10	20.9(1.4)	28.9(3.3)	68.4(9.0)	0.13(0.10)	2.38(1.60)	5.42(3.20)
	10-20	21.8(1.3)	31.1(4.2)	70.3(7.2)	0.04(0.01)	0.91(0.90)	3.47(2.30)
90	0-5	18.2(2.3)	17.0(3.2)	46.8(4.7)	2.68(4.40)	9.19(6.00)	10.97(3.10)
	5-10	18.4(10.4)	16.0(2.3)	44.3(4.0)	1.92(4.10)	4.33(1.80)	9.19(2.60)
	10-20	21.1(11.3)	18.9(4.3)	50.9(5.5)	1.15(2.60)	1.46(0.50)	5.07(1.70)

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OBJECTIVE II

IDENTIFY CHEMICALS FOR PROTECTING EXPOSED WOOD SURFACES IN POLES

Preservative treatment prior to installation provides an excellent barrier against fungal, insect, and marine borer attack, but this barrier only remains effective as long as it is intact. Deep checks that form after treatment, drilling holes after treatment for attachments such as guy wires, cutting poles to height after setting and heavy handling of poles that result in fractures or shelling between the treated and untreated zone can all exposed untreated wood to possible biological attack. The Standards of the American Wood Preservers' Association currently recommend that all field damage to treated wood be supplementally protected with solutions of copper naphthenate. While this treatment will never be as good as the initial pressure treatment, it provides a thin barrier that can be effective above the ground. Despite their merits, these recommendations are often ignored by field crews who dislike the oily nature of the treatment and know that it is highly unlikely that anyone will later check to confirm that the treatment has been properly applied.

In 1980, The Coop initiated a series of trials to assess the efficacy of various field treatments for protecting field drilled bolt holes, for protecting untreated western redcedar sapwood and for protecting untreated Douglas-fir timbers above the groundline. Many of these trials have been completed and have led to further tests to assess the levels of decay present in above ground zones of poles in this region and to develop more accelerated test methods for assessing chemical efficacy. Despite the length of time that this Objective has been underway, above ground decay and its prevention continues to be a problem facing many utilities as they find increasing restrictions on chemical usage. The problem of above ground decay facilitated by field drilling promises to grow in importance as utilities find a diverse array of entities operating under the energized phases of their poles with cable, telecommunications and other services that require field drilling for attachments. Developing effective, easily applied treatments for the damage done as these systems are attached can lead to substantial long term cost savings and is the primary focus of this objective.

A. Evaluate Treatments for Protecting Field Drilled Bolt Holes

The test to evaluate field drilled bolt holes was inspected in 2002 after 20 years of exposure. This test is largely completed, although some follow-up inspection to assess residual chemical levels around bolts in specific poles is planned.

B. Develop Methods for Ensuring Compliance With Requirements for Protecting Field-Damage to Treated Wood.

Date Established:	March 2001
Location:	Peavy Arboretum, Corvallis, OR
Pole Species, Treatment, Size	Douglas-fir, penta
Circumference @ GL (range)	102 to 123 cm

While most utility specifications call for supplemental treatment whenever a hole or cut penetrates beyond the depth of the original preservative treatment, it is virtually impossible to verify that a treatment has been applied without physically removing the bolt and inspecting the exposed surface. Most line personnel realize that this is highly unlikely to happen, providing little or no motivation for following the specification.

Given the low probability of specification compliance, it might be more fruitful to identify systems that ensure protection of field damage with little or no effort by line personnel. One possibility for this approach is to produce bolts and fasteners that already contain the treatment on the threaded surface. Once the "treated" bolt is installed, natural moisture in the wood will help release the chemicals so that they can be present to inhibit the germination of spores or growth of hyphal fragments of any invading decay fungi.

The potential for these treatments was evaluated using both field and laboratory tests. In the initial laboratory tests, bolts were coated with either copper naphthenate (Cop-R-Nap) or copper naphthenate plus boron (CuRap 20) pastes and installed in Douglas-fir pole sections which were stored for one or two weeks at 32 C. The poles were then split through the bolt hole and the degree of chemical movement was assessed using specific chemical indicators. Penetration was measured as average distance up or down from the bolt.

Because we have a limited number of stubs with treated bolts remaining, we did not destructively sample any poles this year. Instead, one set will be inspected next year and the remaining sets will be sampled over the next few years.

The results, to date, show that the coated rods can deliver chemicals to a small area around the treatment hole. These results, coupled with previous trials of boron and fluoride sprays into field drilled bolt holes, suggest that treated bolts may represent one method for ensuring that field drilled wood is protected. This approach would allow utilities to specify specific treated bolts when other utilities occupy portions of the pole and must field drill for attachments, allowing utilities to minimize the risk of decay in field drilled holes above the ground.

As utilities continue to use internal and external treatments to protect the groundline zone, slow development of decay above the ground may threaten the long term gains provided by groundline treatments. This type of treatment could be used to limit the potential for above ground decay, allowing utilities to continue to gain the benefits afforded by aggressive groundline maintenance.

Objective III

EVALUATE PROPERTIES AND DEVELOP IMPROVED SPECIFICATIONS FOR WOOD POLES

A well treated pole will provide exceptional performance under most conditions, but even a properly treated structure can experience decay in service. While most of our efforts have concentrated on developing systems for arresting in-service decay, developing methods for preventing this damage would produce even greater investment savings for utilities. The goals of Objective III are to develop new treatment methods, explore the potential for new species, assess various inspection tools and explore methods for producing more durable wood poles.

A. Effects of Through-Boring on Preservative Treatment and Strength of Douglas-fir Poles

Many species used for utility poles are characterized by an outer band of treatable sapwood surrounding a core of largely untreatable heartwood. Since poles are often treated while their internal moisture content remains above the fiber saturation point, they will continue to dry in service. As they dry, differential stresses develop and relieving these stresses leads to check formation. These checks often penetrate beyond the depth of original treatment, exposing the untreated heartwood to moisture, fungi, and insects. Over time, the interior of the pole deteriorates to the point that the structure no longer supports the design load and must be replaced.

This scenario describes the state of affairs for many users of Douglas-fir in the late 1950s. While this species had excellent structural properties, treatment specifications that limited the heating required for sterilization and the checking characteristics of the species led to numerous early failures and a prediction that average pole service life might only be 12 years.

The potential for such a stunningly short service life led a consortium of Pacific Northwest utilities including Portland General Electric, Pacific Power and Bonneville Power Administration to cooperate with Oregon State University to develop solutions to these problems. Among the outcomes from this ground breaking work was the recognition that sterilization was a critical component of initial treatment and the development of fumigants (Graham, 1980).

These outcomes were important, but neither really addressed the inability to treat the interior of a Douglas-fir pole. Engineers at Portland General Electric explored a number of options including kerfing to the pith to control checking, radial drilling, and through-boring (Brown and Davidson, 1961; Graham et al., 1969; Merz 1959; Grassel, 1969). The latter two approaches involved drilling holes into the pole to increase the percentage of cross-section exposed to treatment. Since wood permeability is several orders of magnitude greater longitudinally, the result was reasonable treatment of the heartwood. Both radial drilling and through-bored poles were tested to assess the effects on mechanical properties, which were found to be slight (Brown and Davidson, 1961). While all three approaches worked to limit internal decay, these three utilities adopted the through-boring or the Merz method into their standards (Mankowski et al., 2002).

Through-boring was gradually adopted into the standards of many utilities across North America as a means for protecting the groundline of Douglas-fir poles against internal decay and a utility survey revealed that more than half of utilities using this species incorporated this method into their specifications. Despite this widespread use, through-boring is not addressed in the American National Standards Institute Standard ANSI-.05 (ANSI, 2002), nor is there any attempt in the American Wood Preservers' Association Standards to produce a standard through-boring pattern (aling to many engineers, who inherently fear a treatment process that places holes in a pole at the critical groundline region, regardless of the potential benefits.

Concerns about the possible strength effects of through-boring came to a head several years ago with several failures of through-bored poles at the groundline. These failures led to utility concerns that through-boring had inadvertently weakened the pole, although the failures occurred during severe storm events and both through-bored and non-bored poles failed in one of these events. The concerns led to a review of all through-boring data, which will be the subject of this report.

Through-Boring Process

Through-boring is a remarkably simple process in which holes are drilled at a slight angle (usually 5 degrees) from one side of the pole to the other (Figure III-1). Hole diameters range from 10.5 to 13.5 mm and every effort is made to keep holes away from the pole edge and to stagger holes to avoid removing too much cross-sectional area in any given pole plane. Through-boring is a manual process, although unsuccessful attempts have been made to automate through-boring and framing.

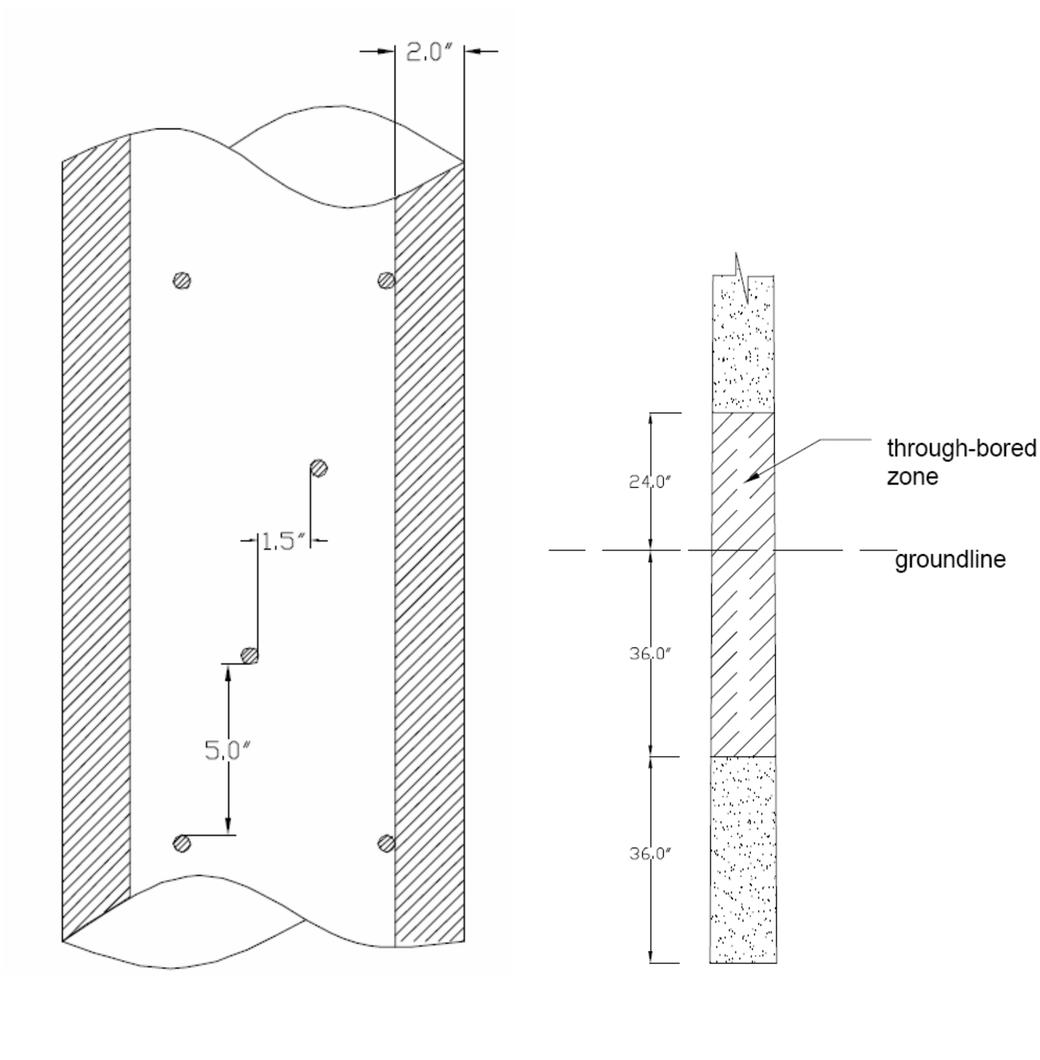

Figure III-1. Illustration of through-boring pattern showing a) hole spacing and b) through-boring zone on pole.

Treatment Results

Through-boring is generally presumed to produce complete preservative treatment within the bored zone and many utility specifications require 100% penetration of sample increment cores removed from poles. While initial studies indicated excellent penetration of the through-bored zones, there were no systematic studies of the degree of treatment.

In an effort to develop this data and to determine if through-boring hole spacings could be widened to reduce the amount of drilling, twenty 2.4 m long Douglas-fir pole sections (250-300 mm in diameter) were end-coated with an elastomeric paint to retard longitudinal penetration of preservative. Single holes (10.5 mm in diameter) were drilled through the pole every 0.6 m along the length of each section. The pole sections were then pressure-treated with pentachlorophenol in P9 Type A oil using an empty cell process in a commercial cylinder.

Preservative penetration was assessed by removing increment cores from sites around each through-bored hole (Figure III-2). Longitudinal penetration in the outer 50 mm of the poles generally ranged from 150-225 mm above and below

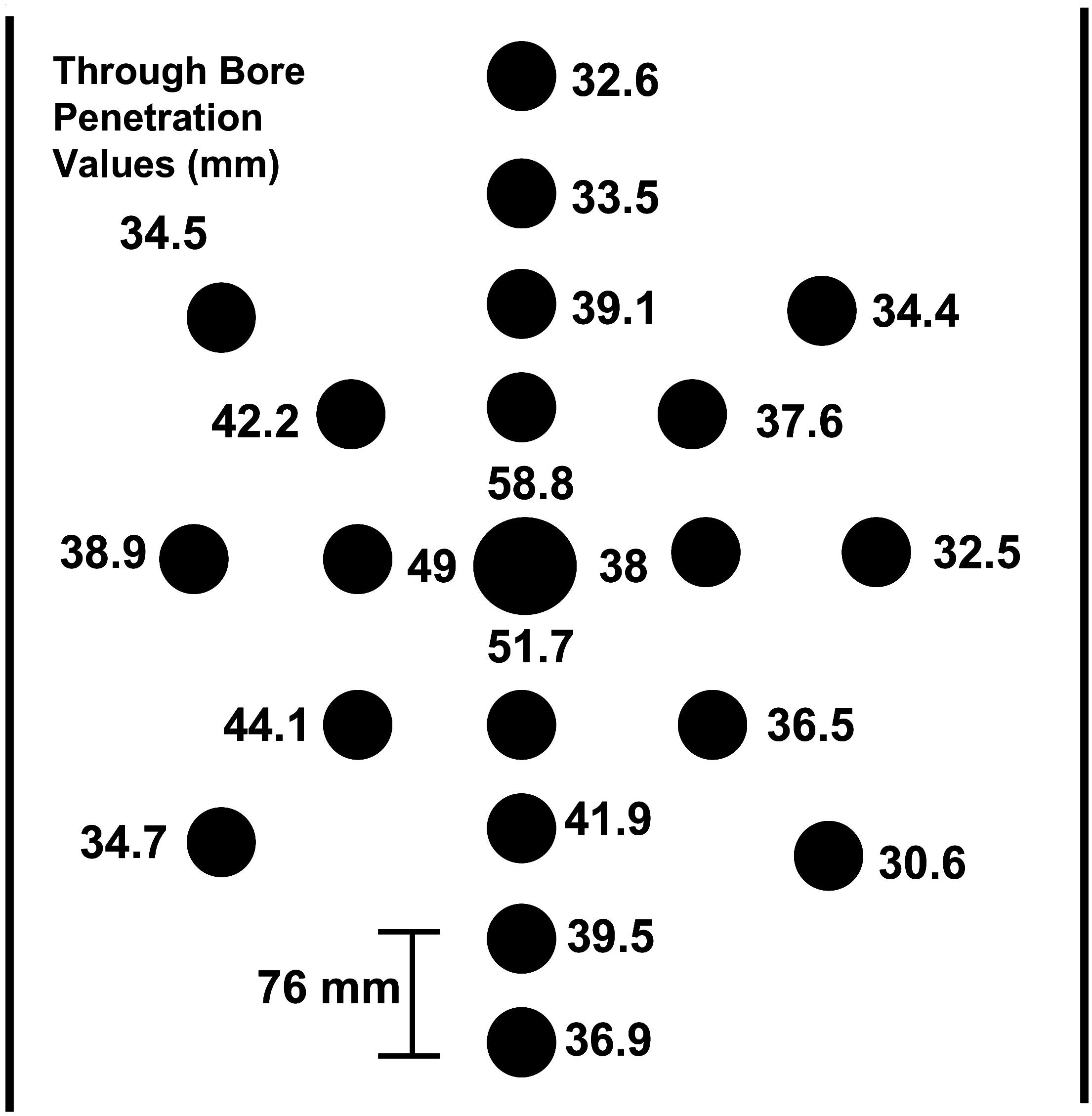

Figure III-2. Increment core sampling pattern employed to evaluate preservative penetration around the through-bored holes in Douglas-fir poles. Numbers represent the average penetration (mm) along cores removed from 3 holes in each of 5 pole sections.

the hole, illustrating the treatability of sapwood, while penetration tangentially often only extended 50 mm. Longitudinal penetration further inward was somewhat reduced but much more variable, while tangential penetration declined to 15 mm. These differences suggest that holes, rather than being uniformly distributed along a surface, might be more efficient if they were more widely scattered on the edges and closer together towards the center. This also has the added benefit of placing fewer holes in the critical outer zones of the pole.

As a follow-up, twenty 3 m long poles sections were coated with elastomeric paint then divided into 600 mm long zones which were randomly assigned to one of ten treatment groups of ten segments. Through-boring patterns were then applied to nine of the groups, while the tenth group served as the control (Table III-1, Figure III-3).

The pole sections were commercially treated to a target retention of 7.2 kg/m^3 of pentachlorophenol in P9 Type A oil. Preservative penetration was assessed by removing increment cores from the center of each diamond shaped through-boring pattern. Preservative penetration was then visually assessed and the location of any untreated wood was recorded. The cores were then divided into zones corresponding to 0 to 25 mm, 25 to 62.5 mm and 62.5 to 125 mm from the wood surface. Wood from a given zone from cores from the same pole section was combined, ground to pass a 20 mesh screen and analyzed for pentachlorophenol using an ASOMA 8620 x-ray fluorescence analyzer (Spectro Titan Instruments, Austin, Texas).

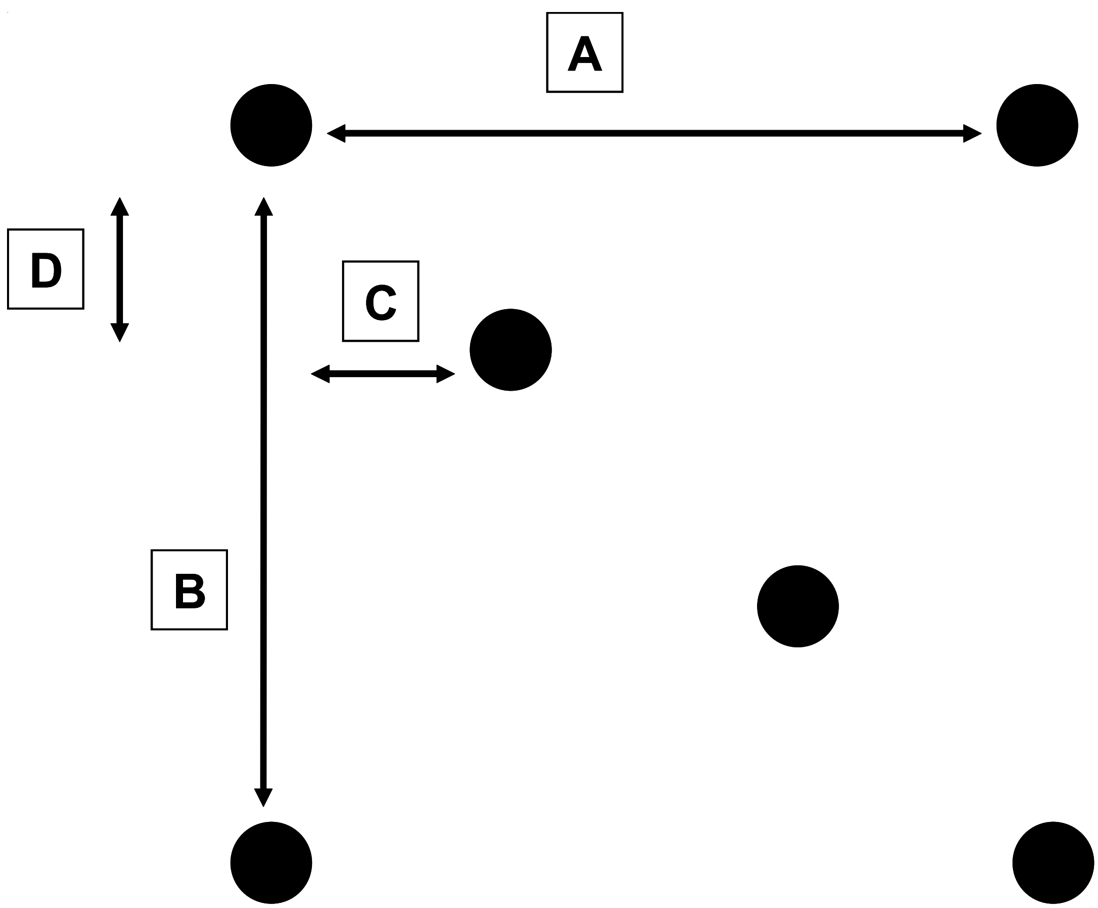

Figure III-3. Distances between holes drilled into Douglas-fir poles to assess the effect of through-boring pattern on treatment.

Preservative penetration was sharply limited in the non-through-bored pole sections, with an average of only 47% of the core penetrated (Table III-1). Average penetration in cores removed from through-bored poles ranged from 92 to 100% of the core, clearly illustrating the benefits of this process for improving treatment. The pattern with the closest spacing, achieved 100% penetration. Increasing the spacing between holes only slightly produced the lowest degree of penetration, although the pattern was not markedly more widely spaced than the previous pattern. We believe that these results were anomalies caused by two poorly treated sections. Patterns employing the greatest longitudinal spacing (390 and 400 mm) and tangential spacing (135 mm) both still produced 94% penetration. These results illustrate the ability of through-boring to markedly increase preservative penetration in heartwood.

Table III-1. Average penetration and retention of pentachlorophenol in Douglas-fir pole sections with various distances between through-boring holes.

Distance Between Holes (mm)[a]				Preservative Penetration (%)		Preservative (kg/m^3) retentions by assay zone (mm)[b]		
A	B	C	D	Mean	Range	0-25	25-62.5	62.5-125
114	250	38	83	100	--	8.2(1.8)	5.2(2.4)	6.7(1.9)
135	250	45	83	92	79-100	15.2(2.5)	6.8(1.5)	5.1(2.3)
114	270	38	90	99	85-100	7.5(1.2)	5.6(0.9)	7.0(1.9)
135	270	45	90	99	79-100	8.9(2.2)	6.2(2.0)	6.1(1.8)
114	300	38	100	95	70-100	9.7(1.8)	6.7(1.1)	6.3(2.2)
135	300	45	100	99	96-100	9.9(1.7)	8.1(2.8)	6.5(1.8)
135	360	45	120	98	79-100	9.1(2.7)	5.9(2.4)	5.6(2.6)
135	390	45	130	94	31-100	7.7(1.7)	6.8(1.4)	7.1(2.2)
135	400	45	140	94	14-100	5.2(1.3)	4.1(1.5)	4.4(1.5)
--	--	--	--	47	--	5.7(1.0)	3.6(2.0)	2.8(1.3)

[a] See Figure III-3 for key to spacings.
[b] Values represent means of six poles per pattern. Figures in parentheses represent one standard deviation.

Preservative retentions also sharply increased with through-boring, resulting in relatively shallow preservative gradients from the surface inward (Table III-1). The current AWPA Standards specify an inner assay level of penta in through-bored poles of 3.7 or 4.8 kg/m^3 depending on the outer zone retention (6 to 25 mm of 7.2 or 9.6 kg/m^3). All of the inner assay zones (62.5 to 125 mm) of through-bored poles met these retention levels, indicating that the inner zone was protected regardless of boring pattern.

The effect of hole spacing on treatment was further assessed on twenty-four 3.0-m long kiln dried (initial average moisture content 21% at 50 mm) Douglas-fir pole sections (approximately 300 mm in diameter) that were drilled with one of four patterns. These patterns were the original BPA and PGE specifications as well as modifications of each pattern which increased the distance between holes (Figure III-4). The goal of the study was the development of acceptable patterns for full-length through-boring of poles prior to treatment. Each pattern was replicated on six pole sections.

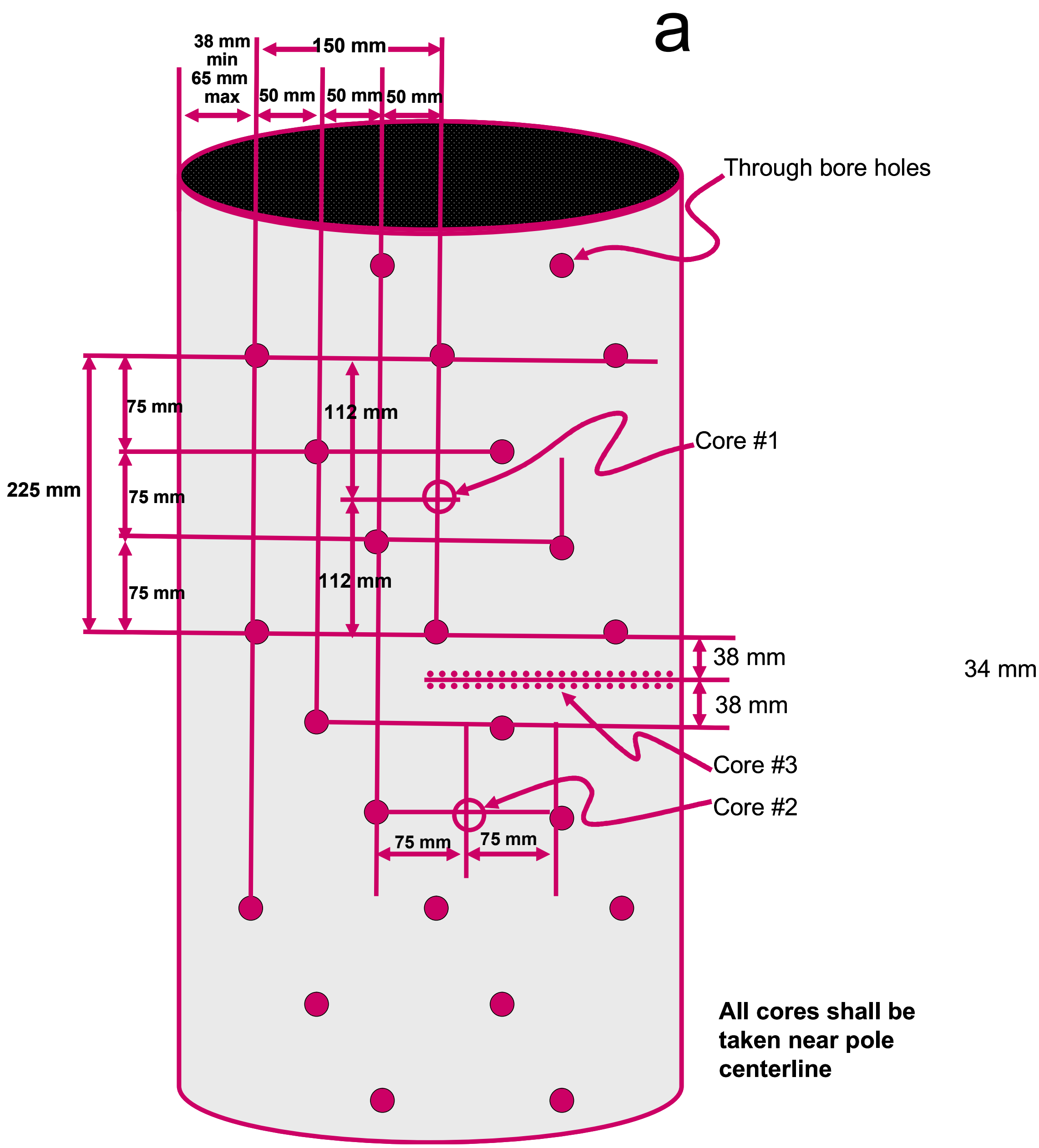

Figure III-4. Patterns used by (a) Bonneville Power Administration or (b) Portland General Electric for through-boring of Douglas-fir poles at the groundline prior to treatment along with modifications of each patter (c, d).

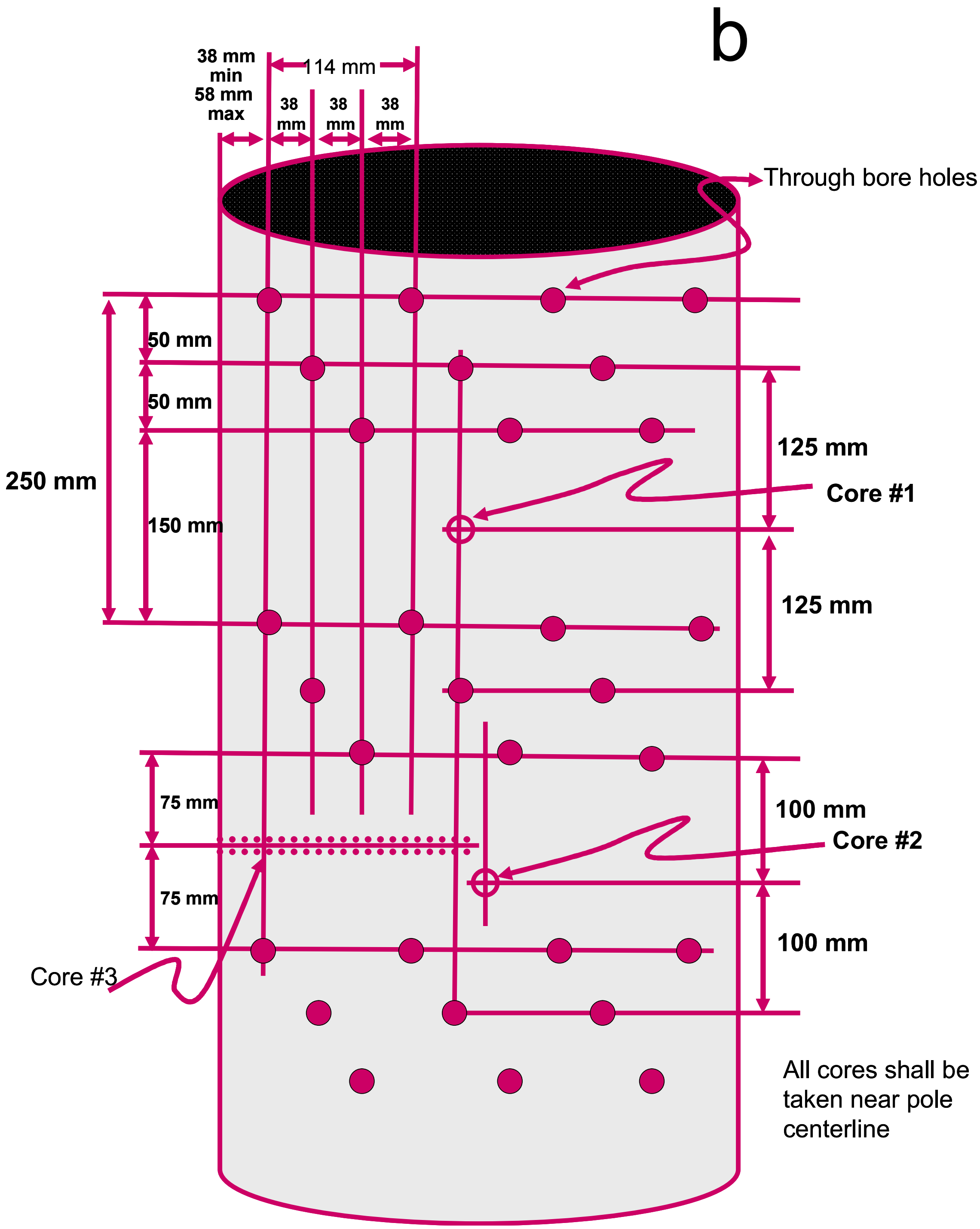

Figure III-4 (cont.). Patterns used by (a) Bonneville Power Administration or (b) Portland General Electric for through-boring of Douglas-fir poles at the groundline prior to treatment along with modifications of each patter (c, d).

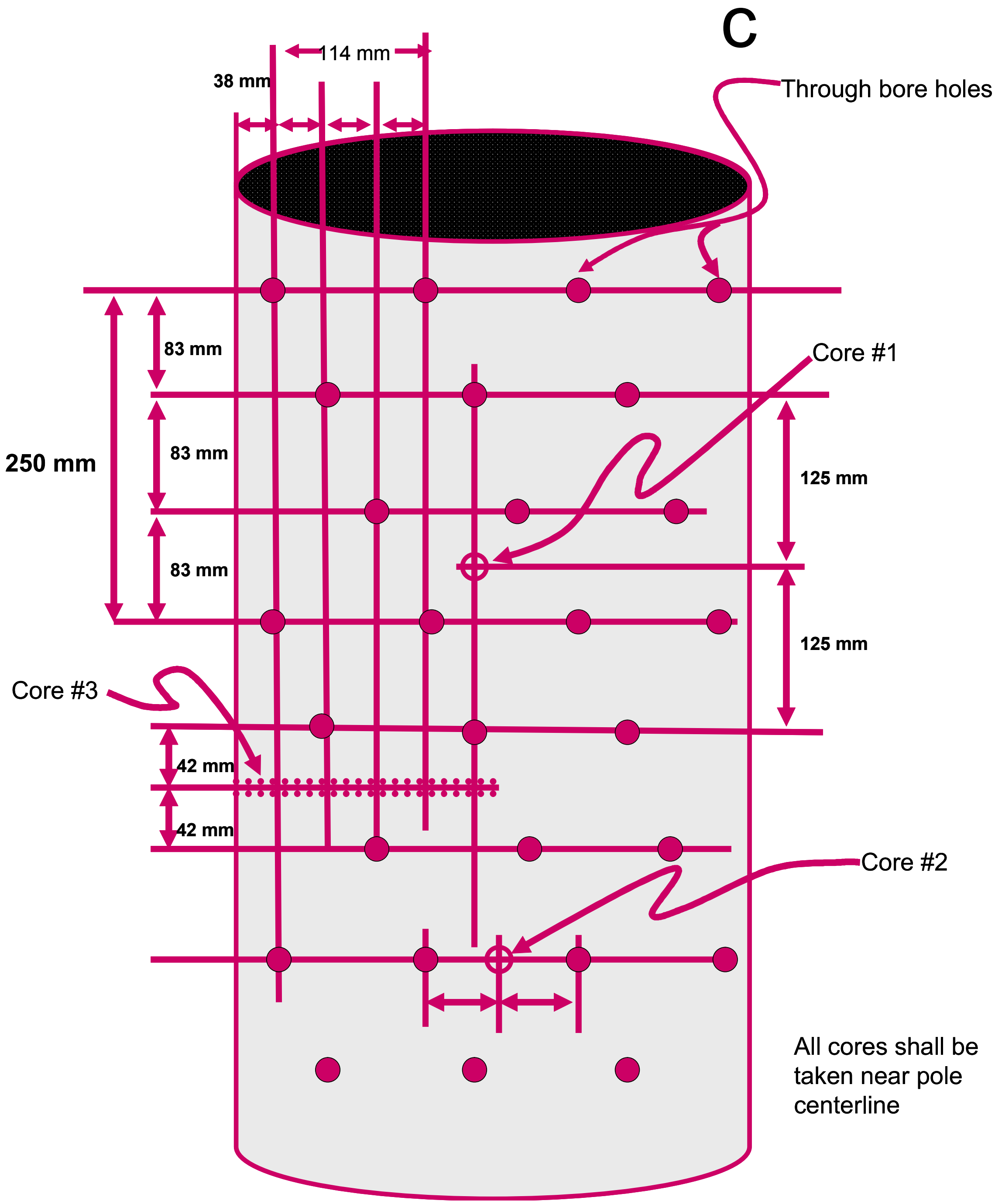

Figure III-4 (cont.). Patterns used by (a) Bonneville Power Administration or (b) Portland General Electric for through-boring of Douglas-fir poles at the groundline prior to treatment along with modifications of each patter (c, d).

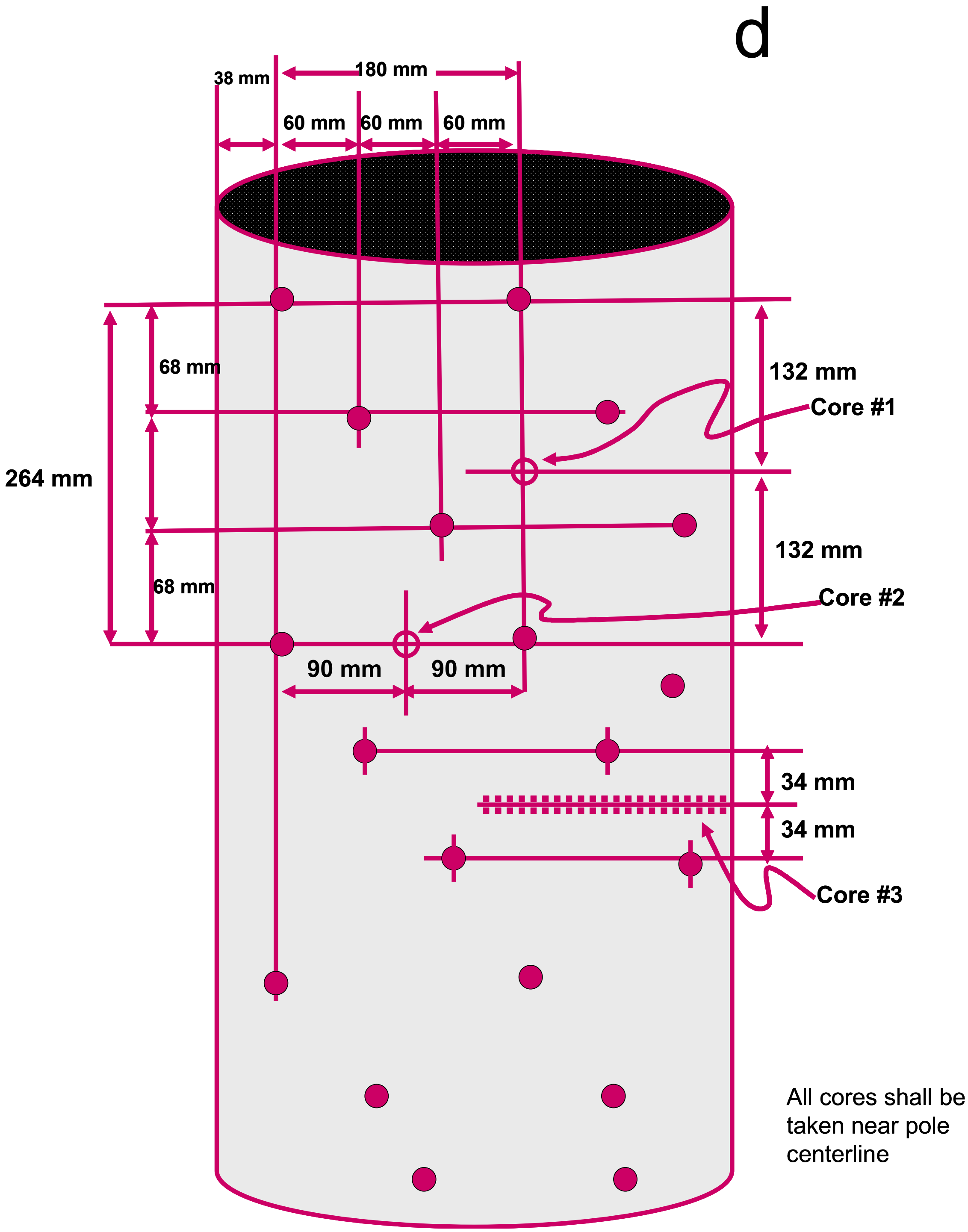

Figure III-4 (cont.). Patterns used by (a) Bonneville Power Administration or (b) Portland General Electric for through-boring of Douglas-fir poles at the groundline prior to treatment along with modifications of each patter (c, d).

The poles were treated with pentachlorophenol in P9 Type A oil to a retention of 9.6 kg/m^3 in the outer 25 mm assay zone using a modified empty cell process. The treatment consisted of an initial conditioning in oil for a period of 14 hours at 88° C, an initial pressure of 224 kPa, introduction of the preservative, and an application of 880 kPa for 2.5 hours. The poles were then subjected to a 4 hour expansion at 99° C and a 1 hour final 88 kPa vacuum.

Following treatment, preservative penetration and retentions were measured by removing increment cores from three regions; parallel to the boring and midway between two adjacent holes in a longitudinal plane (inline), offset radially from the original sample site by 25 mm (offset), and perpendicular to the original boring and midway between two adjacent holes in the longitudinal direction (perpendicular) (Table III-2). Four cores were removed from each region per pole section and each core was divided into six 25 mm long segments. Respective segments from the same region of a given pole stub were combined, ground to pass a 20 mesh screen, oven-dried for 1 hour at 100° C, weighed (nearest 0.1 g) and analyzed for residual penta content using an ASOMA 8620 x-ray fluorescence analyzer.

Table III-2. Effect of through boring pattern on pentachlorophenol retention at selected depths from the surface of Douglas-fir poles.

Sample Zone	Assay depth (mm)	Pentachlorophenol Retention (kg/m^3)[a]			
		BPA	Modified BPA	PGE	Modified PGE
In-line	0-25	18.49 (4.69)	16.83 (4.46)	16.40 (3.44)	16.37 (5.07)
	25-50	15.69 (4.59)	11.91 (3.87)	14.61 (3.74)	12.54 (3.78)
	50-75	12.08 (5.46)	10.53 (4.40)	13.82 (4.78)	9.90 (3.08)
	75-100	12.29 (4.96)	9.80 (4.14)	13.49 (4.27)	9.52 (2.46)
	100-125	11.20 (5.03)	8.72 (5.57)	13.50 (2.19)	10.84 (4.70)
	125-150	9.06 (4.37)	8.07 (5.15)	12.21 (2.64)	12.18 (4.51)
Off-set	0-25	17.15 (4.63)	15.50 (2.01)	16.14 (3.82)	15.45 (4.87)
	25-50	14.99 (4.40)	10.24 (4.17)	14.91 (3.33)	12.53 (4.48)
	50-75	12.78 (4.89)	7.36 (4.07)	13.30 (3.66)	9.76 (3.58)
	75-100	9.50 (4.49)	5.61 (4.75)	12.59 (3.55)	9.63 (2.94)
	100-125	8.90 (3.05)	4.98 (3.54)	11.46 (3.59)	8.78 (2.71)
	125-150	9.07 (2.61)	7.86 (1.33)	12.48 (3.39)	9.05 (3.98)
Perpendicular	0-25	16.81 (4.67)	16.03 (3.60)	15.97 (2.78)	15.00 (5.83)
	25-50	13.19 (4.23)	13.76 (2.76)	13.07 (3.58)	14.30 (3.96)
	50-75	13.14 (6.88)	10.94 (4.17)	13.97 (3.30)	11.17 (1.87)
	75-100	8.00 (2.00)	10.61 (3.68)	11.42 (3.94)	10.14 (2.47)
	100-125	10.46 (4.41)	7.69 (4.47)	14.11 (4.75)	12.11 (2.87)
	125-150	9.85 (1.99)	5.22 (1.53)	12.78 (2.98)	11.83 (4.19)
Combined	0-25	17.45 (4.71)	16.12 (3.55)	16.18 (3.38)	15.61 (5.30)
	25-50	14.59 (4.53)	11.97 (3.93)	14.19 (3.65)	13.12 (4.17)
	50-75	12.89 (5.80)	9.61 (4.51)	13.70 (3.98)	10.28 (3.00)
	75-100	9.93 (4.41)	8.67 (4.75)	12.50 (4.02)	9.76 (2.65)
	100-125	10.19 (4.35)	7.13 (4.87)	11.52 (5.36)	10.58 (3.80)
	125-150	8.32 (3.88)	6.18 (4.30)	11.14 (4.88)	10.34 (5.00)

While there were differences in retention among the various patterns, the data once again showed that penta retentions well above the threshold for fungal attack were achieved deep inside the poles (Table III-2). Furthermore, increasing spacings between holes had only a slight effect on retentions, suggesting the potential for even wider through-boring patterns.

Effect of Incomplete Treatment on Performance

While our controlled test indicated that through-boring markedly improved treatment, it was also clear that complete penetration in the through-bored zone was not always achievable. Given the presence of a heavily treated zone surrounding these skips in treatment, we wondered if the untreated wood in such gaps could decay in service. To answer this question, 147 through-bored poles in the PGE and BPA system that had been in service of 3-23 years in Western Oregon or Washington were sampled (Morrell and Schneider, 1994).

Each pole was sampled by removing one to three 150 mm long increment cores from sites located parallel to and equidistant between two through-bored holes near groundline. Preservative penetration was assessed as a percentage of core length, then classified as 100, 90-99, 70-89, and 60-69 percent. Penetration was considered acceptable if the latewood was treated. No cores had less than 60% penetration.

Most of the poles were located in the Long Beach area along the Washington coast where they were subject to a high hazard of internal decay development. Preservative penetration varied from 60 to 100% in the 272 cores examined (Table III-3). Nearly 95% of the cores examined were 90 to 100 percent penetrated, indicating that the through-boring

Table III-3. Relative degree of treatment in the through-bored zone of in-service Douglas-fir poles receiving either the Bonneville Power Administration or the Portland General Electric through-boring patterns.

Initial Treatment	Geographic Location	Pole Age	No. of Poles	No. of Cores	Percent of Cores with a Given Percent Preservative Penetration Range			
					60-69%	70-89%	90-99%	100 %
Creosote	Junction City, OR	4	15	45	0	0	0	100
Pentachlorophenol	Long Beach, WA	25	51	102	0	2	1	97
		18	25	50	0	6	4	84
	Salem, OR	21	6	12	6	8	8	84
		19	5	10	0	10	10	80
		18	3	6	0	0	0	100
		1	1	2	0	0	0	100
		10	3	6	0	0	0	100
		9	7	14	0	0	0	100
Copper Naphthenate	Cottage Grove, OR	3	21	25	8	8	0	84

process had produced a well-treated zone around the groundline. The remaining cores had penetration values ranging from 60 to 89%. The effects of gaps or skips in a through-bored pole on the development of internal decay in the groundline zone are difficult to predict. In principal, any untreated wood should be susceptible to decay; however, it is likely that most of the gaps present in through-bored poles are surrounded by preservative treated wood. If these poles were treated to the same degree as those in the first portion of this study, then any treatment gaps would be surrounded by wood containing high levels of preservative. Thus, the risk of decay in a gap is likely to be quite low given the small probability that a spore or hypha of a decay fungus will be able to penetrate the treated zone to reach the untreated wood. None of the poles examined in the current study had any visible evidence of decay in the untreated locations in the through-bored zone. The absence of visible decay fungi suggests that specifications which require 100% penetration of the through-bored zone may be excessive. The numbers of cores with penetration values below 90% in the current study was minimal, making it difficult to identify an appropriate penetration minimum for preventing internal decay in the through-bored zone. Further inspections would be required for this purpose.

Effects on Pole Properties

While improved treatment at groundline is an important attribute of through-boring, ultimately the pole must be capable of supporting wires. Holes in poles inherently raise concerns among engineers. Merz (1959) noted that engineers at Portland General Electric calculated that through-boring reduced strength 9.38 to 9.86% depending on whether holes were perpendicular or parallel to the line direction. He further noted that this would reduce the traditional safety factor from 4 to 3.33. Brown and Davidson (1961) then performed full scale tests on 42, Class 4, 13 m long poles (Table III-4). The poles were carefully selected to ensure a uniform population (based upon knot dimensions or other wood defects). These poles were tested untreated, treated without boring, bored with 10.5 mm diameter holes and treated, bored in this same pattern but only halfway through from each face, bored halfway through from one side then rotated 120 degrees, and bored again, radially drilled using 6 mm diameter holes halfway through the pole and radially drilled, but only to a 100 mm depth.

Table III-4. Breaking strength of Class 4, 12 m long Douglas-fir poles receiving various boring patterns above groundline prior to treatment (Brown and Davidson, 1961).

Treatment	Breaking Load (psi)	Percent of Treated Control
Treated, not bored	2611	100
Treated, Merz bored	2521	96.5
Untreated, not bored	2445	93.7
Treated, Merz parallel (1/2 through)	2383	91.4
Treated Merz rotated (1/2 through each side)	2380	91.2
Treated, radial to 4 inch	1973	75.5
Treated, radial to center	1903	73.0

[a]Values represent means of six replicates per treatment.

The poles were preservative treated using similar conditions, set in the ground to a depth of 1.8 m and then tested to failure by pulling them using a line attached 9.6 m above groundline. Nearly all failures occurred at or near groundline, which is the highest stress point for a pole of this size.

Pole breaking loads were recorded in pounds, and no attempt was made to quantify moisture contents.

The results showed that through-boring had only minimal effects on pole strength, while radially drilling produced a more substantive effect. PGE, BPA, and PacifiCorp used these data to support the incorporation of through-boring in their new pole specifications and thousands of poles have since been treated using this process.

Newbill et al. (1998) assessed the effect of full length through-boring on pentachlorophenol treatment and strength of ten, Class 2, 21 m long Douglas-fir poles. Retentions along the pole length were higher in the outer 25 mm, then uniform from 25 to 150 mm from the surface (Table III-5).

Table III-5. Pentachlorophenol retention at selected depths in Douglas-fir poles subjected to full length through-boring prior to treatment (Newbill et al., 1998).

Distance from surface (mm)	Retention (kg/m^3)
0-25	16.96
25-50	10.08
50-75	9.12
75-100	9.12
100-125	9.32
125-150	9.76

Full scale tests indicated that pole strength ranged from 70.5 to 106.9% of the ANSI value with a mean of 88.6% (Table III-6). These results supported the contention that through-boring had minimal effects on pole properties. In this case, the data were also used to support the use of full-length through-boring where above ground decay was a concern.

Despite the positive results from these tests, the total population of through-bored poles for which data was available remains frightfully small and the storm related failures only highlighted this fact. One approach to assessing the effects of through-boring on pole properties that early developers of this process could not use is finite element analysis. At its simplest, finite element analysis allows the structure to be broken down into an array of elements (or sections) each with a specific set of properties.

Forces can be applied to the structure and the model allows the user to assess changes while stress accumulates. Elkins (2005) developed a finite element model for holes of various diameters in a one foot stump or pole section to assess the effects of hole size or direction on stress concentration. The results showed that both small holes (6 mm) and large holes (25 mm) produced excessive stress around the hole. They also showed that holes perpendicular to line direction had a greater potential effect on pole strength.

Table III-6. Effect of full length through-boring on residual strength, failure zone, and deflection of pentachlorophenol-treated Douglas-fir poles.

Pole No.	Pole Circumference (mm)[a]			Deflection (mm)	Load at Max Deflection (KN)	Failure Location Above GL (m)	Breaking Point Stress (Mpa)	Percent ANSI
	Load Point	Groundline	Tip					
1	885	1134	875	2788	4000	--	57.8	104.7
2	748	1164	732	2702	3400	3.7	44.9	81.3
3	777	1161	762	2362	3500	1.3	47.3	85.7
4	792	1161	777	3077	4000	5.5	43.0	77.9
5	809	1219	792	2753	4200	3.0	47.9	86.8
6	760	1180	744	3483	3000	2.2	38.9	70.5
7	670	1186	649	3333	3400	5.5	44.9	81.3
8	800	1152	786	2657	4000	3.0	52.7	95.5
9	891	1155	881	2506	4300	--	59.0	106.9
10	861	1192	847	3268	4000	--	49.4	89.5
Mean	--	--	--	--	--	--	48.9 (6.3)	88.6

[a]Minimum ANSI Tip and GL circumferences for Class 2, 18 m long poles are 635 and 1124, respectively.

Elkins (2005) next moved to full scale testing using Class 4, 12 m long poles without treatment. A total of 140 poles were tested, 28 per test variable, using a modification of procedures described by Crews et al. (2004). A single boring pattern was assessed because finite element analysis indicated that adjacent holes did not interact. Poles received either no boring or the same pattern using 6, 13, 19, or 25 mm diameter holes between 0.6 m above groundline and three feet below. All poles were tested to failure in a test jig that applied a load to an area that approximated the through-bored zone. The apparatus allowed the pole to rotate during testing, thereby more closely approximating real pole stresses.

The results showed that hole sizes between 6 and 13 mm had no significant effect on strength and that the presence of holes in this range tended to reduce the variation in bending strength compared to non-through bored controls (Table III-7). This effect is believed to occur because the holes act as stress relievers, negating the effects of smaller knots. As a result, the population behaves more uniformly (Figure III-5). The results indicate that through-boring has no significant effect on pole strength.

Table III-7. MOR summary statistics by treatment (hole diameter).

Hole Diameter (inch)	MOR (psi)	MOR COV (%)	Difference from Control (%)	Difference Between Groups
0	7353	18	NA	NA
1/4	7207	13	2	2
1/2	6860	11	7	5
3/4	6554	12	11	4
1	6187	12	16	6

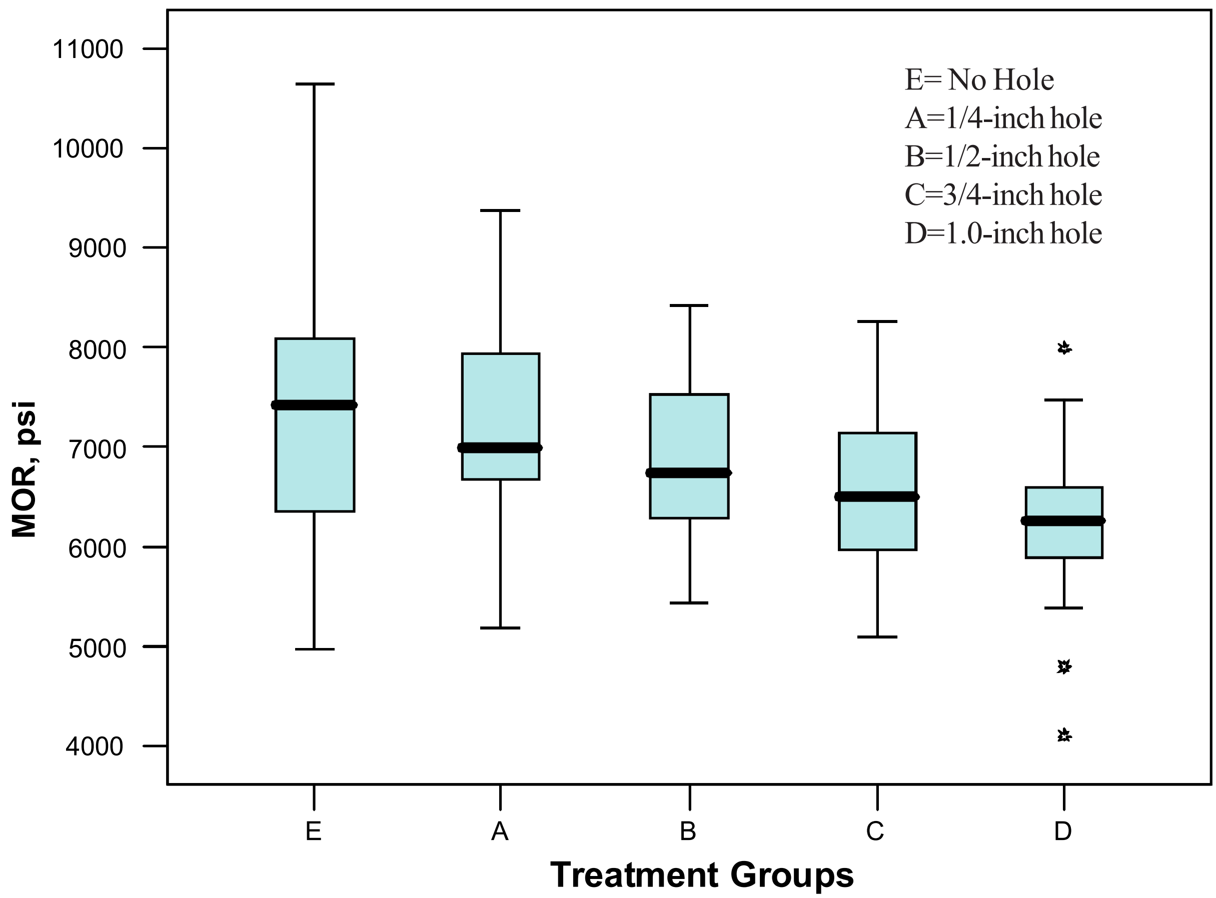

Figure III-5. MOR of Douglas-fir poles with through-boring holes of differing hole diameters. The boxed area represents 50 percent of each data set; the line through the shaded area is the median value. The bars represent the outer limits for the data except where there are outliers, which is only the case for the 1-inch treatment group. The outliers, represented by the stars, are determined as those points that lie outside 1.5 times the inner-quartile range of the plots.

Pole Disposal

One aspect of through-boring that is not often considered is the potential effect of this process on disposal. Through-boring will increase the amount of preservative in the pole and this additional preservative might affect disposal. Bonneville Power Administration examined the issue by grinding wood from the through-bored zone of a pentachlorophenol-treated pole and subjecting this material to the U.S. Environmental Protection Agency Toxicity Characterization of Leachate Procedures. The resulting preservative level was similar to that found with non-through bored material and easily met the limits for disposal. Thus, through-boring did not alter the ability to dispose of a pole at the end of its useful life.

Conclusions

Although it has been available for over 40 years for improving the performance of Douglas-fir poles, many engineers remain concerned about the potential effects of through-boring on pole strength. The results of our tests and those by others indicate that through-boring markedly improves preservative treatment in the critical groundline zone, reducing the risk of internal decay, thereby extending pole service life. Full scale tests indicate that through-boring has no significant negative effects on pole strength. These results suggested that through-boring should be incorporated into utility specifications and efforts are now underway to develop specifications for a single through-boring pattern in the ANSI Standards along with specific retention and penetration standards with the AWPA to further encourage use of this procedure.

B. Ability of External Pole Barriers to Limit Moisture Ingress into Copper Naphthenate and Pentachlorophenol Treated Western Redcedar Poles

Preservative treatment is a remarkably effective barrier against biological attack, but these same chemicals also remain susceptible to migration into the surrounding soil. A number of studies documenting the levels of chemical migration have shown that the migration occurs for only a short distance around a structure and that the levels present do not pose a hazard in terms of environmental impact or disposal. Despite these data, some utilities have explored the use of external barriers to contain any migrating preservative. These barriers, while not necessary in terms of environmental issues, may have a secondary benefit in terms of both retaining the original chemical and limiting the entry of both moisture and fungi. The potential for barriers to limit moisture uptake in poles was assessed in the following trial.

Western redcedar pole sections (200-250 mm in diameter by 2.4 m long) were treated with either pentachlorophenol or copper naphthenate in P9 Type A oil applied using a thermal process. Additional poles were left unwrapped and non-treated to serve as controls. The poles were then wrapped with either the Biotrans barrier originally developed in South Africa or the UPC coating. The Biotrans materials were all applied with a closed end on the butt. This seal was not complete, but it should presumably restrict moisture sorption from the surrounding soil. The UPC samples were applied with the ends open. The samples were either exposed in water from their butts to just below the tops of the barrier or they were buried in soil to a similar depth in large tanks maintained at 23-25 C in our testing laboratory. The soil was regularly watered to maintain moisture conditions, but every effort was made to limit the potential for wetting above the groundline so we could assess the potential influence of soil or water contact on the lined zones of the poles.

Prior to setting, the moisture content of each pole was sampled at the butt, 80 cm, and 140 cm above the butt by removing increment cores from side of each pole. These cores were divided into zones corresponding to 0-13, 13-25, 25-50, and 50-75 mm from the surface. These core segments were weighed, then oven dried and reweighed to determine wood moisture content. In addition, each pole was weighed. Moisture content was monitored 4 weeks after immersion or setting in soil by removing increment cores from locations adjacent to the original sampling sites. These cores were processed as described above. The poles were again weighed at this time to determine total moisture uptake.

The moisture contents of untreated poles in either water or soil both increased rapidly after immersion, reflecting the hygroscopic nature of wood (Figure III-6, 7). Moisture contents tended to be higher in poles in water than in soil. Moisture levels of poles in water tended to be elevated for a greater distance above the water line (600 mm) than in the soil immersed samples. Moisture contents above 100 % were detected up to 1.2 m from the butt in the interior of poles in water, but only exceeded 100% at 600 mm above the butt in soil immersed samples.

Moisture contents in soil immersed untreated poles were only above 30% for approximately 150 mm above the groundline, suggesting that decay hazard was minimal above this zone. These values differ substantially from previous field tests of seasonal pole moisture content, where moisture levels were suitable for decay far above this zone and it is unclear why our controlled values are so much lower. One possibility is the lack of overhead watering. In the field, moisture can enter poles as it runs down checks during rainfall events, while we limited this possibility in the tanks. In addition, the soil in the bins is relatively dry, unlike in the field, where the soil tends to become water-logged during the winter.

The untreated poles wrapped with the UPC initially wetted more slowly than non-wrapped untreated poles, but eventually, the moisture profile became similar to that found with the non-coated poles (Figure III-8). Every effort was made to limit soil contact near the groundline (i.e. the top of the barrier was above the soil), but the barrier was not continuous around the butt and this might have allowed moisture to migrate upward. This movement was fairly rapid and, eventually, produced a moisture profile that differed little from that found in non-coated poles.

The immersion of UPC coated copper naphthenate treated poles produced a very different moisture profile from the untreated materials (Figures III-9, 10). Moisture uptake was minimal in poles in both soil and water for the first 24 weeks, then rose in both media at 52 weeks and continued to slowly increase over the next year. Moisture contents at

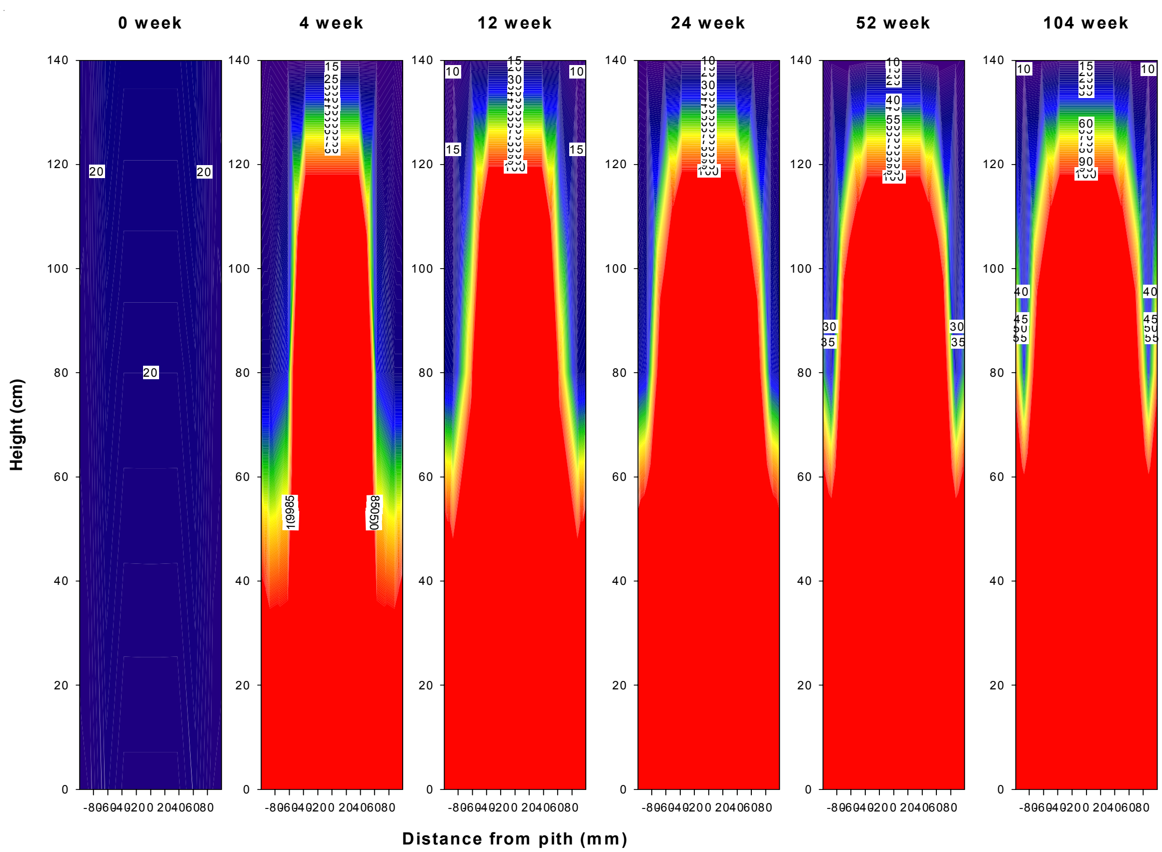

Figure III-6. Moisture contents of untreated western redcedar poles immersed in water for 0 to 104 weeks. Dark blue indicates moisture content below fiber saturation and red indicates moisture content above 80%.

the center of the poles in water were still well below those found in the untreated poles. Moisture levels of poles in soil tended to higher, but the moisture had not diffused as far upward as it had in the untreated poles suggesting that the oil-treated barrier was useful as a water repellent.

Moisture contents of copper naphthenate treated poles wrapped with the Biotrans system followed trends that were similar to the UPC wrapped poles, although moisture levels seemed to increase earlier with the Biotrans poles (Figures III-11, 12). Moisture levels also tended to be higher in water vs. soil immersed poles, which differed from the trend noted with the UPC poles. The reasons for the slight differences are unclear and, given the small numbers of poles involved, may reflect variations between poles rather than treatments. In all cases, however, the wraps did alter the moisture distribution with in the poles, although it is clear the wood in soil contact will become wetted over time, regardless of the presence of a barrier.

Moisture contents in penta poles wrapped with the Biotrans system followed the same trends found with the copper naphthenate treated poles, although the moisture contents in water tended to increase more rapidly with penta and move farther up the poles (Figures III-13, 14). Conversely, moisture distribution appeared to be more limited in penta poles in the soil. As with the other tests, individual pole characteristics may have influenced these results.

The results indicate that moisture uptake in wrapped poles is clearly slowed in comparison with untreated poles; however, it is not completely inhibited and the wood in the interior does eventually reach moisture levels that are suitable for decay development. This delay is relatively short and any subsequent lags in decay development would probably not be worth the added costs for these systems. So why might a utility consider barriers?
The barrier concept is certainly not new; it has been used for centuries in marine applications where copper sheathing was used as a physical barrier to limit entry of marine borers into the wood beneath. This concept of barriers has largely been ignored in terrestrial wood protection, but it has to potential advantages. First, a barrier could sharply limit the access of wood decay organisms to the wood. Soil is literally teeming with bacteria and fungi. While not all of them are capable of attacking wood, many can modify or detoxify wood preservatives or otherwise enhance the decay process. Removing the wood/soil interface would produce a major reduction in the risk of decay. This reduced decay risk could be exploited in a number of ways. The barrier could reduce the risk of external decay development, thereby reducing maintenance costs and extending service life. The systems could also allow for the use of lower initial levels of preservative, which could further reduce the potential concerns about migration of preservative from poles.

The barriers can also reduce the potential for migration of preservative from the poles into the surrounding soil. While previous tests have shown that preservatives used for utility poles migrate only a short distance into the surrounding soil at levels that do not pose an environmental risk, the use of barriers could further reduce these levels. However, it is important to understand that barriers at groundline can not completely eliminate migration since water running down the poles can solubilize preservative components on the wood and transport them into the surrounding soil. While these levels are small in comparison with the wood/soil zone, it is important to not overstate the role of these systems in containing preservative. Full length wrapping or encapsulation may be a consideration; however, this process would be both costly and likely to cause problems with climbing by line personnel. Finally, there is presently no data showing that the small amounts of preservative migrating from poles poses a risk.

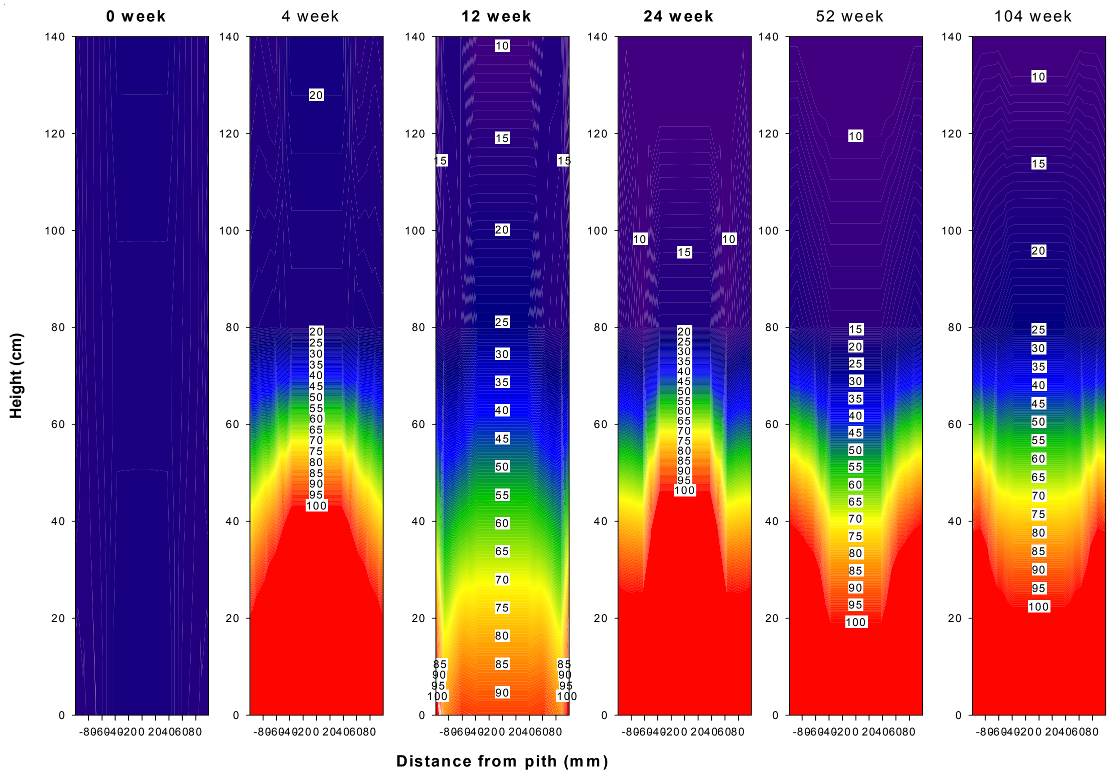

Figure III-7. Moisture contents of untreated western redcedar poles immersed in moist soil for 0 to 104 weeks. Dark blue indicates moisture content below fiber saturation and red indicates moisture content above 80%.

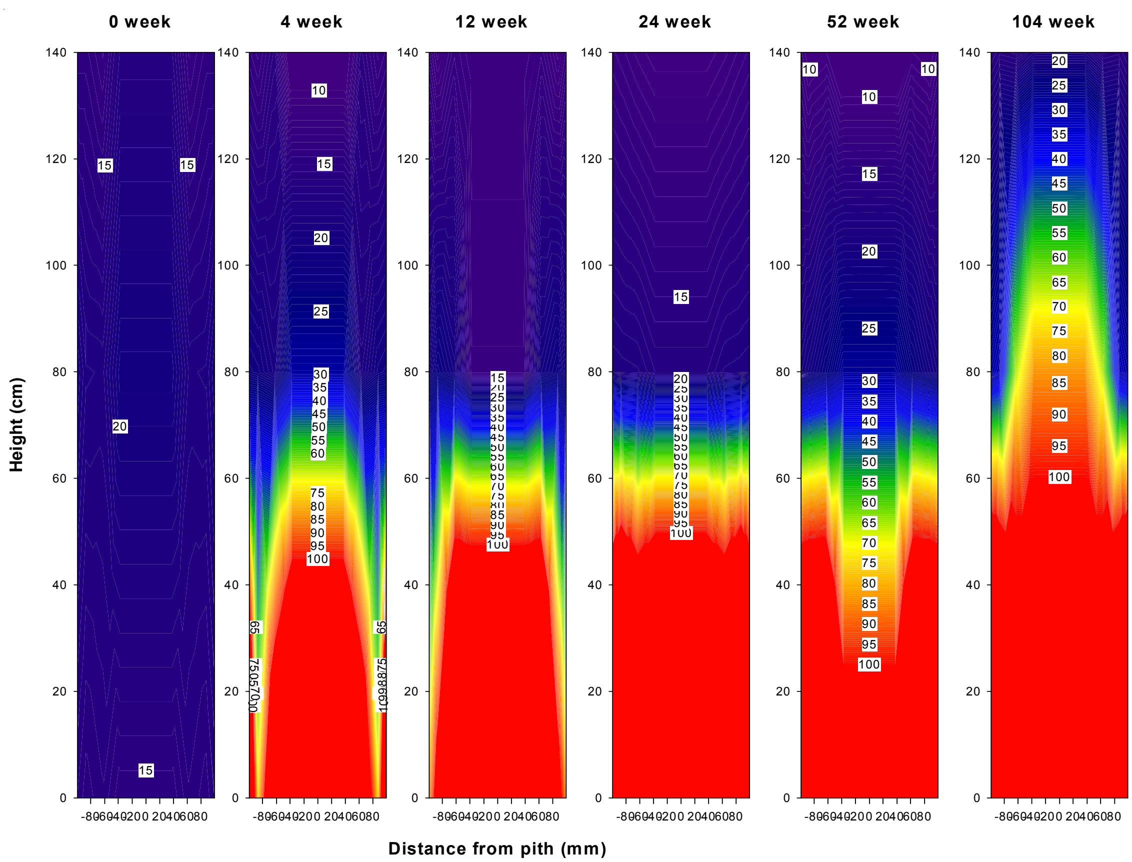

Figure III-8. Moisture contents of untreated western redcedar poles wrapped with a UPC liner from the butt to the groundline and immersed in moist soil for 0 to 104 weeks. Dark blue indicates moisture content below fiber saturation and red indicates moisture content above 80%.

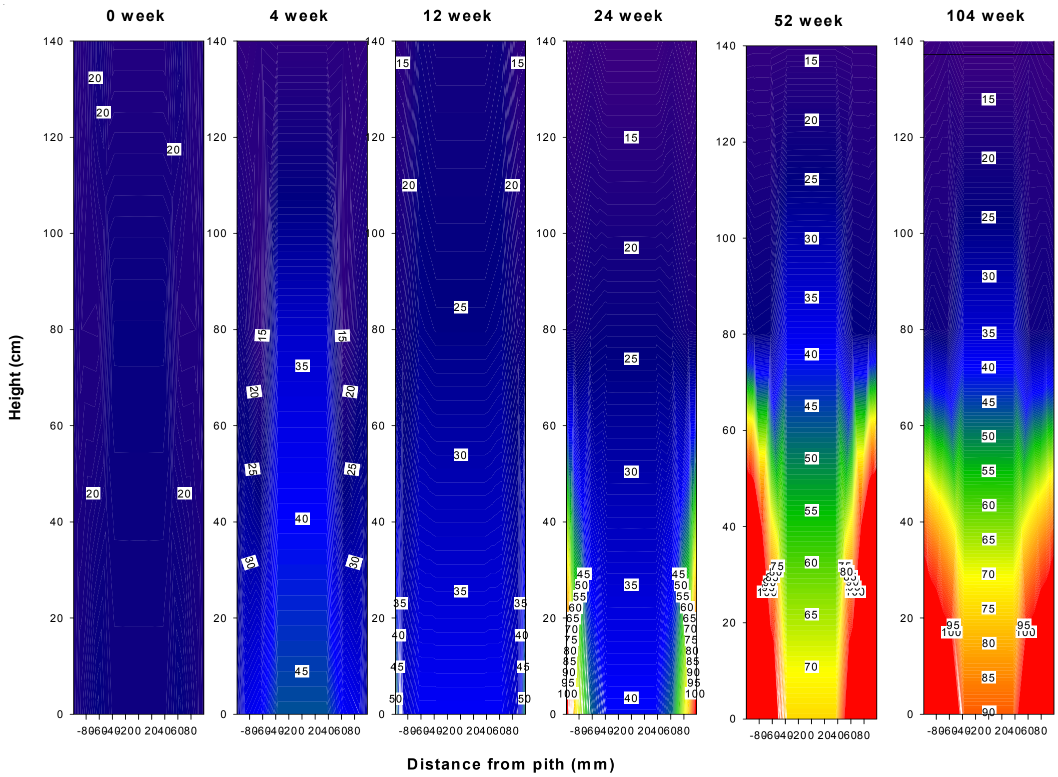

Figure III-9. Moisture contents of copper naphthenate treated western redcedar poles wrapped with a UPC liner from the butt to the groundline and immersed in water for 0 to 104 weeks. Dark blue indicates moisture content below fiber saturation and red indicates moisture content above 80%.

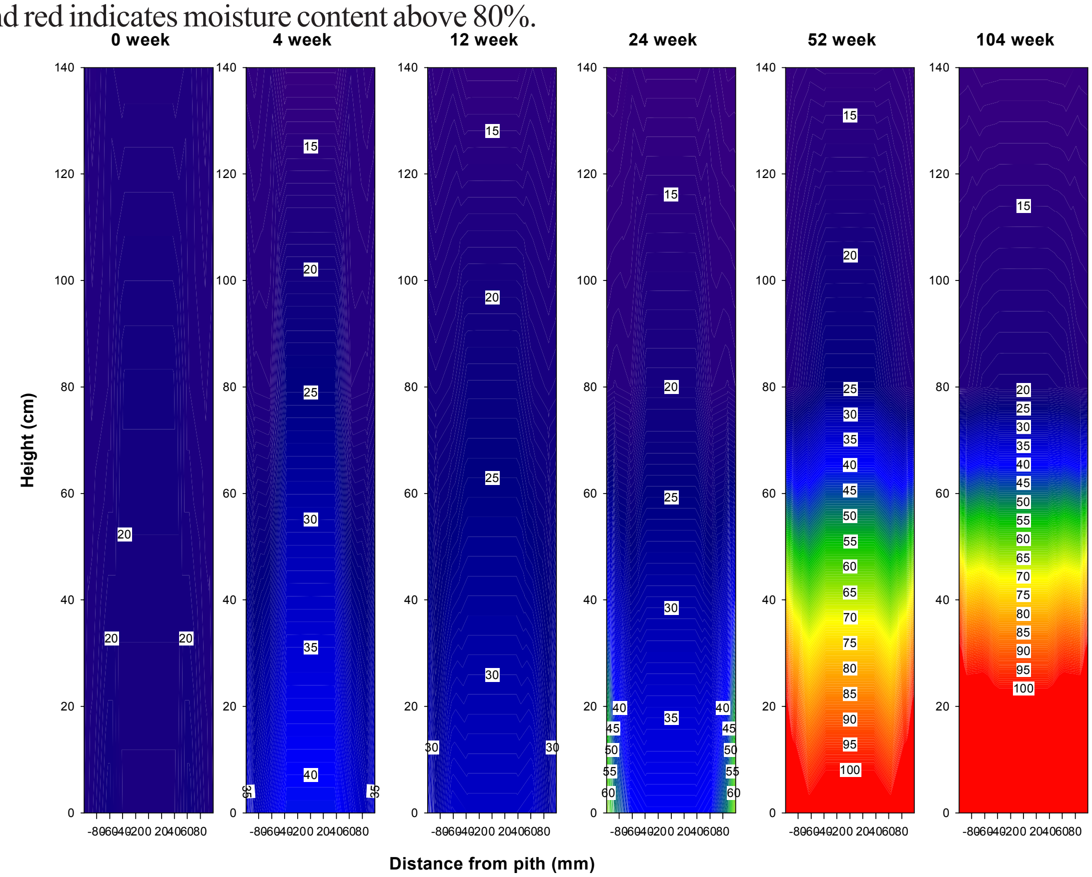

Figure III-10. Moisture contents of copper naphthenate treated western redcedar poles wrapped with a UPC liner from the butt to the groundline and immersed in moist soil for 0 to 104 weeks. Dark blue indicates moisture content below fiber saturation and red indicates moisture content above 80%.

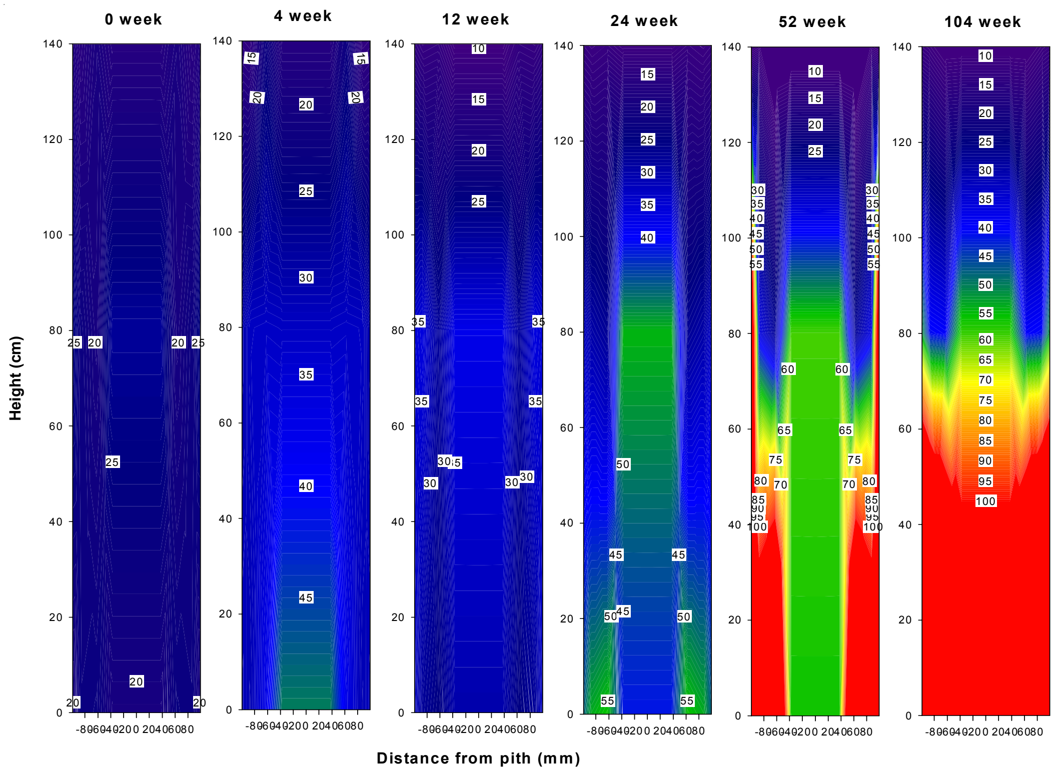

Figure III-11. Moisture contents of copper naphthenate treated western redcedar poles wrapped with a Biotrans liner from the butt to the groundline and immersed in water for 0 to 104 weeks. Dark blue indicates moisture content below fiber saturation and red indicates moisture content above 80%.

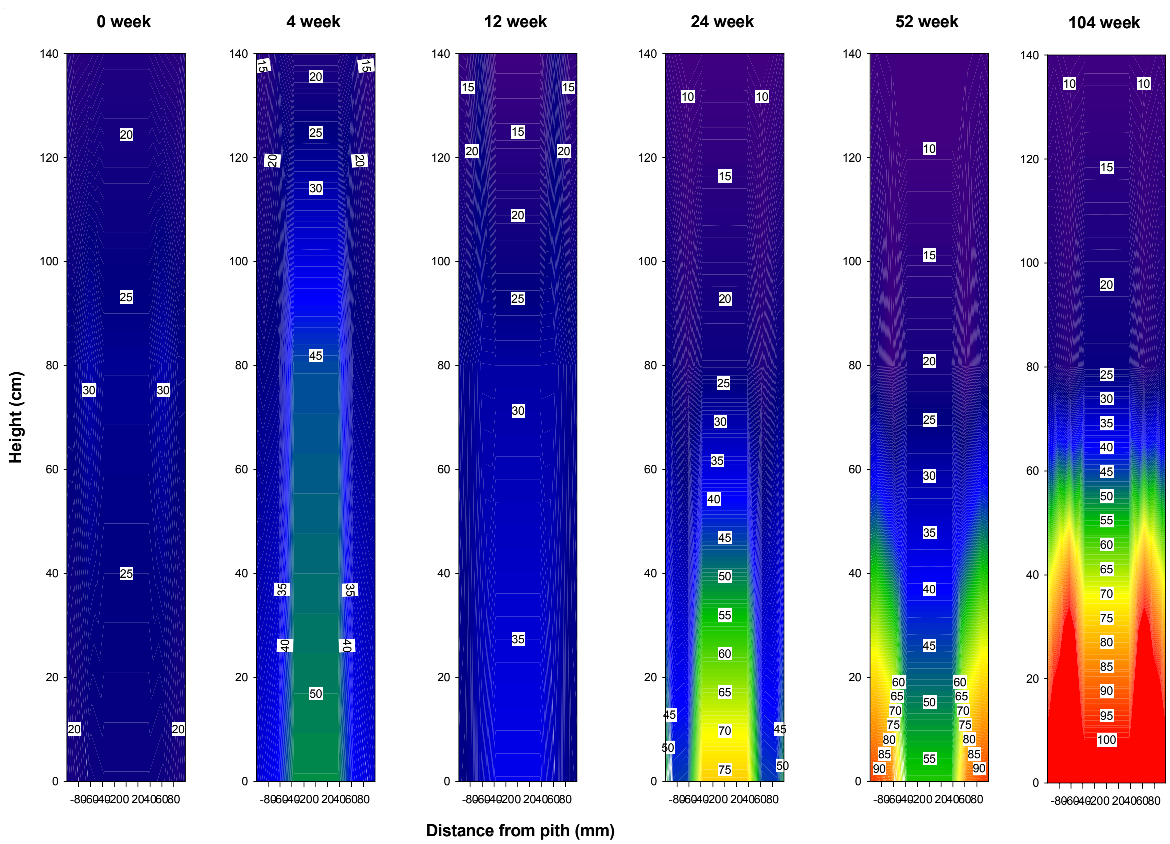

Figure III-12. Moisture contents of copper naphthenate treated western redcedar poles wrapped with a Biotrans liner from the butt to the groundline and immersed in moist soil for 0 to 104 weeks. Dark blue indicates moisture content below fiber saturation and red indicates moisture content above 80%.

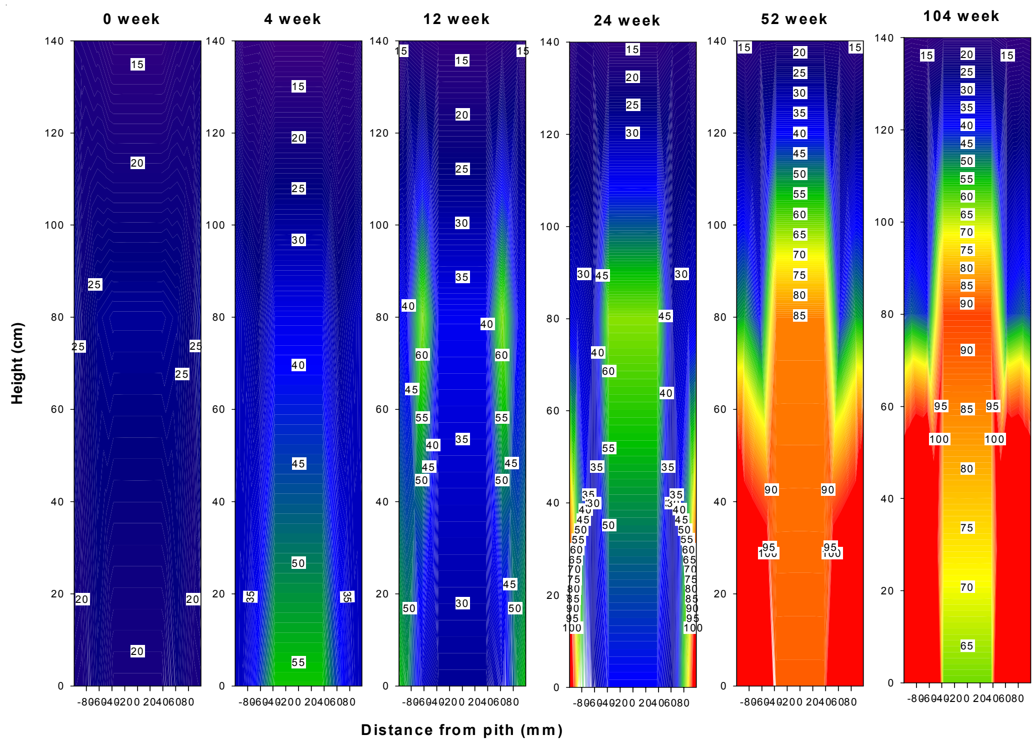

Figure III-13. Moisture contents of pentachlorophenol treated western redcedar poles wrapped with a Biotrans liner from the butt to the groundline and immersed in water for 0 to 104 weeks. Dark blue indicates moisture content below fiber saturation and red indicates moisture content above 80%.

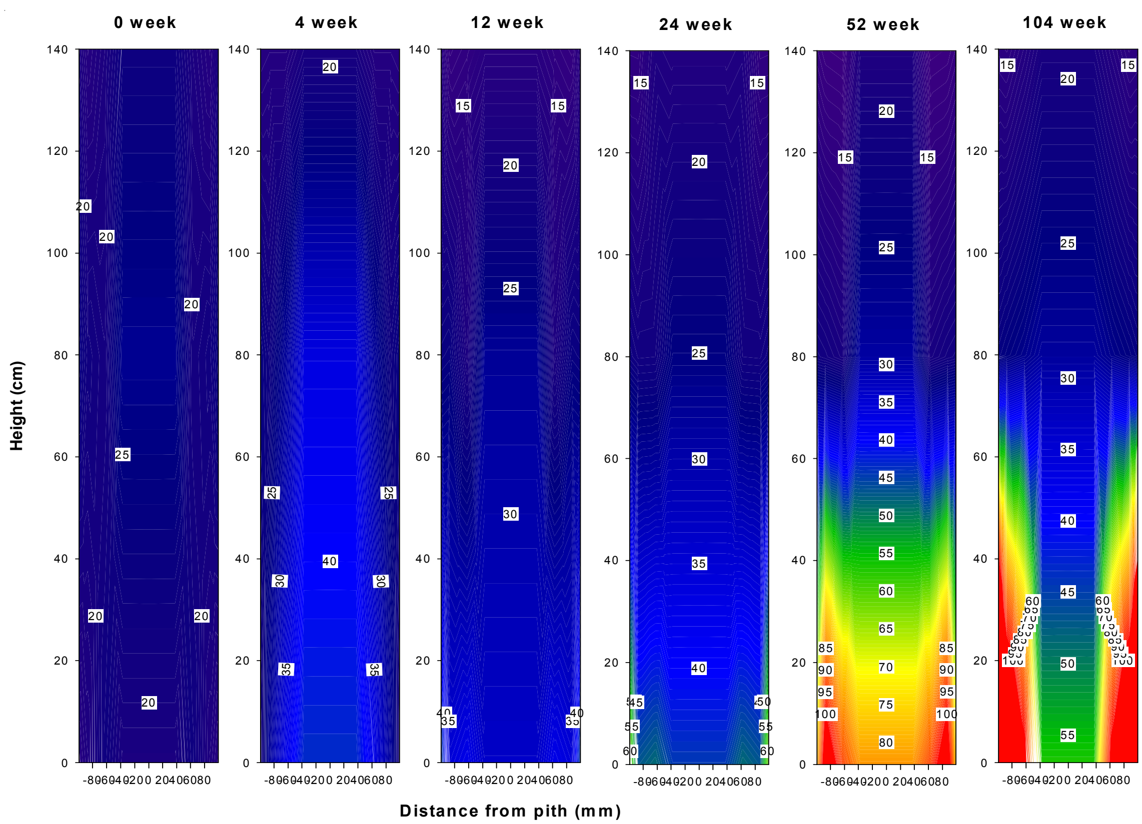

Figure III-14. Moisture contents of pentachlorophenol treated western redcedar poles wrapped with a Biotrans liner from the butt to the groundline and immersed in moist soil for 0 to 104 weeks. Dark blue indicates moisture content below fiber saturation and red indicates moisture content above 80%.

C. Residual Properties of Pentachlorophenol Treated Southern Pine Cross arms in Service for 35 Years in Southern New York

As noted in previous Annual Reports, adherence to regular inspection and maintenance programs promises to markedly extend the service life of the wood pole system. This effort, however, has been concentrated at the groundline which has the highest risk of fungal decay. The benefits of these efforts are evident in the low rejection rates most utilities experience in their second and third maintenance cycles as well as through the intangible benefits of reduced costs and liability from unexpected failures.

While the benefits of extending service life are clear, one aspect of this extended pole service life that has largely been ignored is the potential for development of deterioration issues above the groundline. Wood in soil contact is at a much higher risk of decay. Soil contains orders of magnitude more organisms, contains nutrients that can support the initial growth of fungi and provides a stable source of the moisture that is necessary for decay development. Wood exposed above ground tends to be wetter for shorter periods of time and the numbers of organisms capable of living in this more extreme environment are more limited. As a result, the rate of decay in above ground exposures is much reduced; however, eventually, these materials will decay. Although above ground decay of cross arms has always been present, the proportion of arms affected has been relatively small and mostly related to the development of deep, water trapping checks on the upper surfaces. The prolonged life cycles under which most wood pole systems are currently operating have finally created a sufficient amount of time to allow for above ground decay. This process has created a substantial number of questions for utility managers including how much strength does an older cross arm retain?

In previous trials, we have examined the residual strength of round and sawn pentachlorophenol treated Douglas-fir cross arms installed in wishbone configurations. The results showed that sawn arms retained acceptable properties, even after being in service for 40 to 50 years and having experienced substantial weathering. The results with round arms were less promising, reflecting the increased tendency for these materials to develop deep checks. The overall results, however, showed that arm appearance, as might be expected, was a poor indicator of properties. Wishbone configurations, while once commonly used, are increasingly rare and most arms are exposed with a direct horizontal orientation. This orientation is more likely to trap moisture and arms in this configuration should, therefore be more prone to decay. There are, however, few data on the material properties of cross arms. Last year, we were fortunate to obtain a collection of 96 penta treated southern pine distribution arms that had been in service in Central New York for over 30 years. The arms were part of a line upgrade and were collected and shipped to OSU for testing.

The arms were heavily weathered, particularly on the tops, and many had deep checks (Figure III-15). The arms were wet when received and were allowed to equilibrate to ambient conditions prior to testing. Once conditioned, the arm dimensions were measured, then each arm was tested to failure in four point loading at a loading rate of 0.5 inches/minute (Figure III-16). The load deflection data was collected and was used to calculate modulus of elasticity (MOE) and modulus of rupture (MOR). Finally to determine residual preservative content, increment cores were removed from 20 selected arms. The cores were assessed for preservative penetration and then the zone corresponding to 0 to 25 mm was removed from each core and retained for analysis. The core segments were combined, ground to pass a 20 mesh screen and analyzed for pentachlorophenol by x-ray fluorescence.

In order to further characterize the condition of the arms, cross sections were cut from each arm near the outermost bolt hole and from near the center bolt hole. These crosscuts were examined for preservative penetration as well as for the presence of any internal decay. In addition, to determine if the arms complied with the definition of "dense" lumber as defined in Paragraph 103 of the 1991 Grading Rules for Southern Pine Lumber, several measurements were taken to quantify density. The number of annual rings per inch and the percentage of latewood were calculated. These data are being compiled and will be available in the final version of the 2006 Annual Report.

Figure III-15. Cross arms evaluated for residual flexural properties in four point loading. The arms in the foreground are Douglas-fir, while those in the background are southern pine.

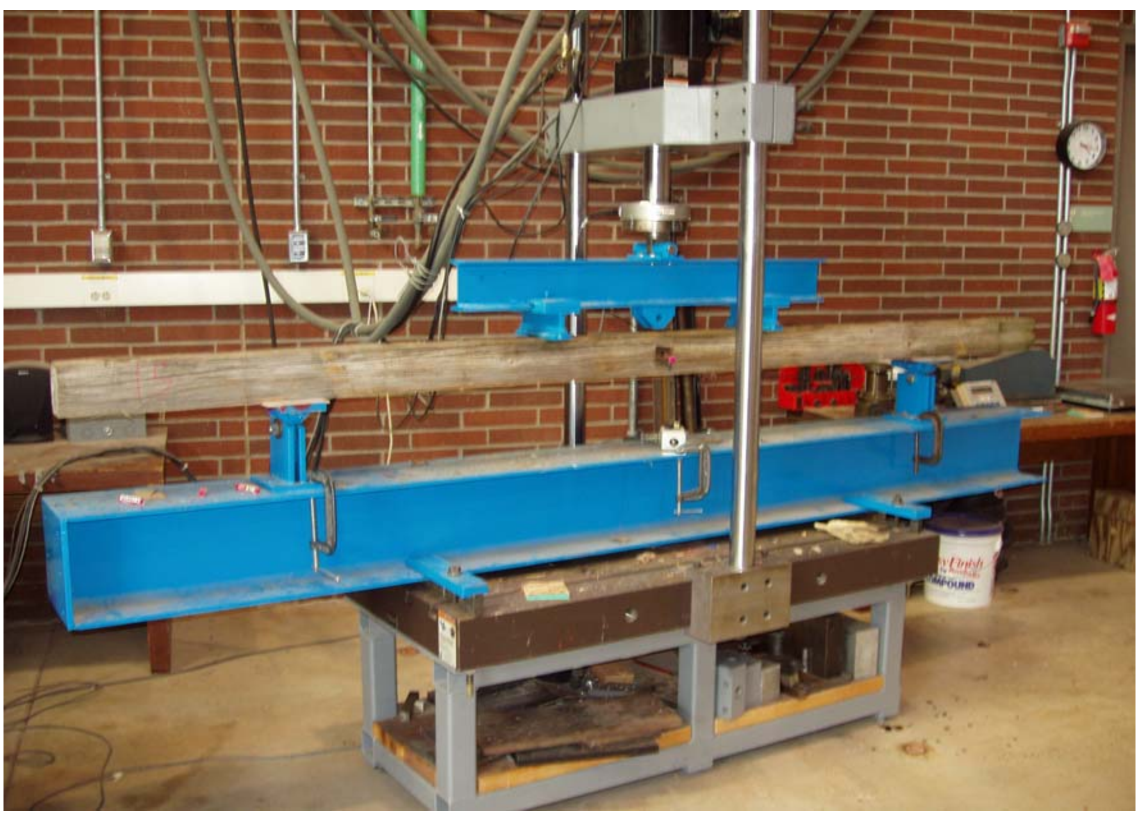

Figure III-16. Example of a cross arm in four point loading.

MOR for the southern pine arms ranged from 731 to 8869 psi (Figure III-17). The designated fiber stress for new distribution cross arms is 7800 psi (ANSI, 1995). Furthermore, the National Electric Safety Code specifies that materials must be replaced if their residual strength falls below 67 % of the original design value, which would mean that the MOR of an arm needs to be at least 5226 psi. We chose this value for our threshold with an understanding that the value is arbitrarily conservative since it ignores the fact that the ANSI design value is based upon the mean value for a population. Thus, in a normally distributed population, we would expect half of the arms in a large, normally distributed population to have MORs below the mean.

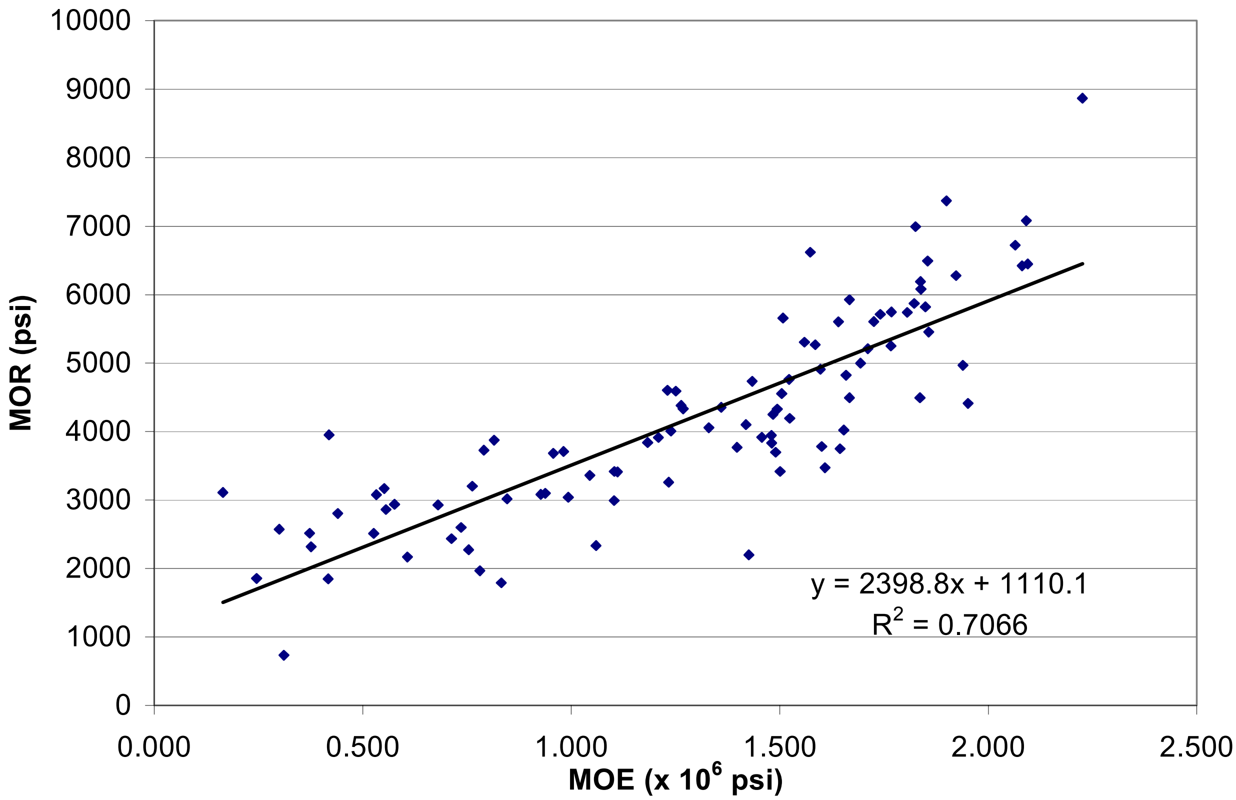

Figure III-17. Relationship between modulus of rupture (MOR) and modulus of elasticity (MOE) of weathered southern pine cross arms tested to failure in four point loading.

MOR values were below the minimum 5226 psi for almost 74 % of the arms tested, while 11 % of the arms broke at less than 2500 psi (Figure III-18). The results indicate that replacing the arms was a good decision, although more than a quarter of the arms could be reused for other applications. A high percentage of the arms had MORs in the range of 2500 to 3999 psi, well below their initial design value.

Although MOE is not specified in the ANSI standards, this property provides a good measure of the dynamic response of the cross arm during loading. MOEs for the southern pine arms ranged from 0.240 to 1.983 x 10^6 psi. As with the MOR data, there was considerable variation among the arms tested (Figure III-17).

Cross cuts from the arms indicated that some had evidence of internal decay at the interface between the treated sapwood and untreated heartwood (most of the arms were boxed heartwood) (Figure III-19). The sapwood was generally well treated; however, there were often deep checks that extended beyond the treated shell into the untreated heartwood core. While the decay was not severe, it was apparently sufficient to separate the core from the external shell and this probably accounted for the lower overall strength observed. It is unclear how this decay could be

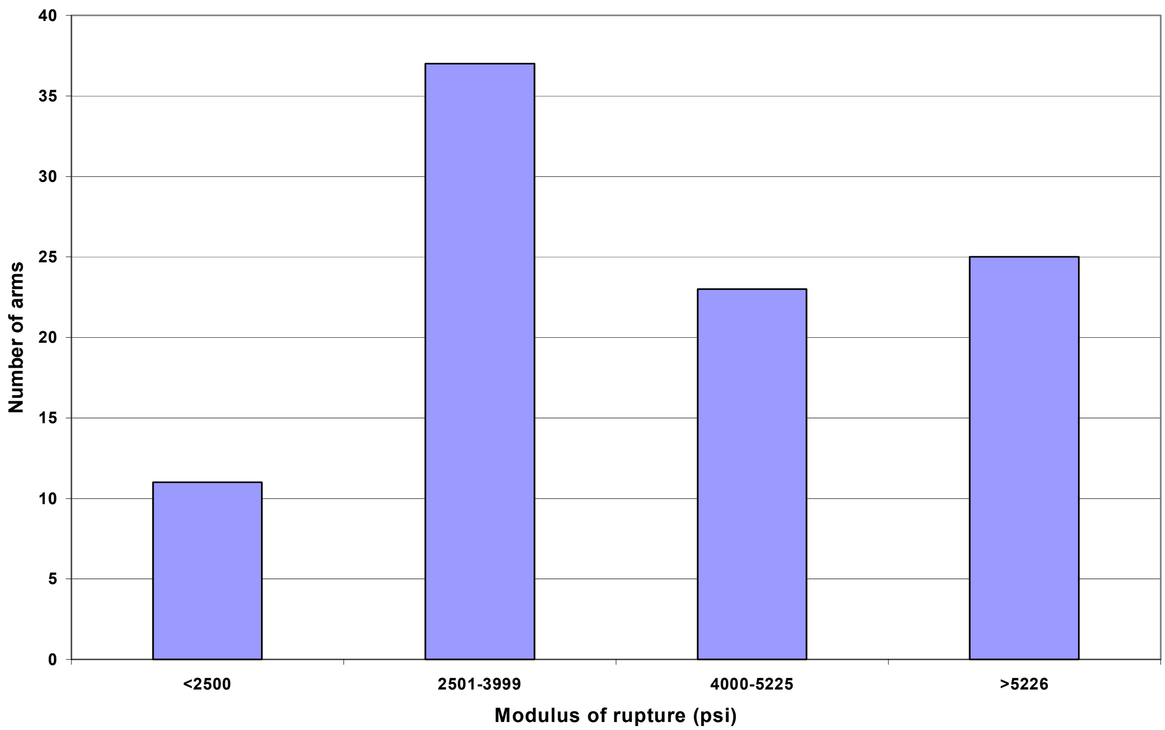

Figure III-18. Modulus of rupture distribution in a population of 96 weathered southern pine cross arms tested to failure in four point loading.

Figure III-19. Examples of cross sections cut from an older southern pine cross arm showing evidence of decay at the heartwood/sapwood interface.

prevented. Southern pine heartwood, like nearly all heartwood, is extremely resistant to preservative treatment, but it is classified as moderately durable and should be somewhat resistant to decay. The internal condition suggests that some type of remedial treatment might be useful, even for southern pine, a species that is generally thought to be easily treated. One possible preventative treatment would be an initial pressure treatment with boron followed by traditional oil-borne penta pressure treatment. This dual treatment would allow boron to diffuse inward to protect the heartwood, while the treated shell would act as both an external barrier as well as a mechanism for containing the boron in the wood. A similar approach has been taken by railroad tie producers and early reports suggest that the results are very promising.

MORs for the 18 Douglas-fir arms tested ranged from 283 to 5522 psi, while MOEs ranged from 0.112 to 1.175 x 10^6 psi (Figure III-20). Only one of the arms met the minimum 5226 psi for MOR, while 11 of 18 arms had MORs below 2500 psi. Clearly, these arms were in poor condition, as evidenced by the presence of advanced decay on the surfaces, decay around bolt holes and deep checks (Figure III-21). The condition of these arms differed substantially from the Douglas-fir wishbone cross arms previous tested. These arms had been exposed in a horizontal configuration that allowed water to collect on the upper surfaces. The difference in condition between these arms and the wishbone arms previously tested illustrates the benefit of avoiding horizontal exposures.

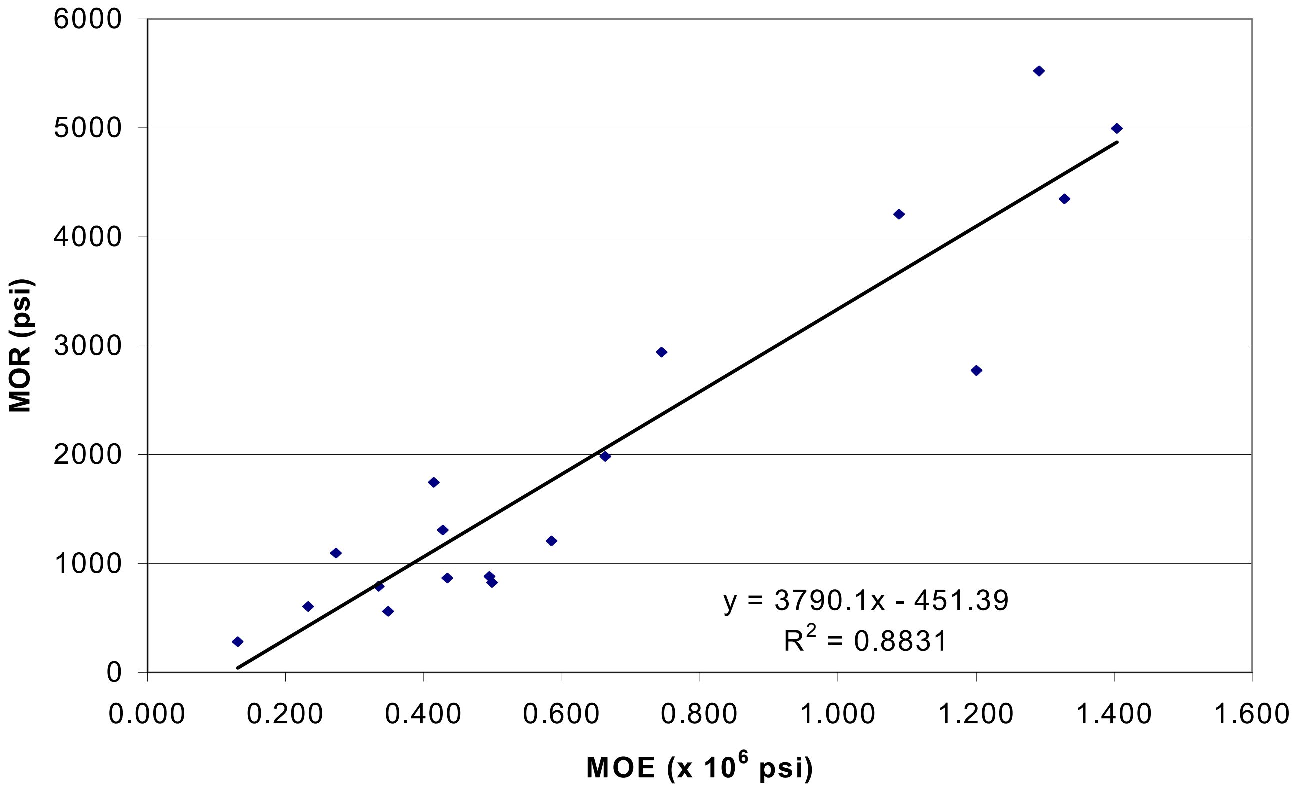

Figure III-20. MOR vs. MOE for weathered Douglas-fir cross arms tested to failure in four point loading.

Figure III-21. Examples of failures of southern pine (left) and heavily weathered Douglas-fir (right) cross arms tested to failure in four point loading.

D. Potential Influence of Juvenile Wood on Pole Strength

One property of wood poles that is particularly maddening to engineers is the variable nature of wood. Wood is a biological material whose properties can vary along the length of an individual tree as well as between trees. Wood can also vary depending upon tree age. Younger trees and the younger portions of older trees make wood that is very different than the wood produced by more mature trees. This younger wood, called juvenile wood, tends to be weaker, more prone to twisting or warping and has differential shrinkage properties than wood formed as the tree matures. In most cases, juvenile wood is only produced in the first 12 to 20 years of growth and is of little concern for utility engineers because poles are typically produced from older trees. However, engineers have expressed concerns about the potential influence of juvenile wood on smaller distribution poles, particularly near the tips where the proportion of juvenile wood is likely to be very high. While the highest stresses in a wood distribution pole typically occur at or near the groundline, weaker wood higher up could be a concern for heavily loaded or guyed poles.

As a result of the through-boring tests described in an earlier part of this objective, we obtained a large quantity of pole tips that could be used to assess the potential effects of juvenile wood on pole properties. We elected to use this material in the following test.

The original materials were Class 4, 12 m long poles. The lower 6 m was tested to failure, while the remaining 6 m was retained. We also retained a cross section cut from the groundline of these poles for later use. We selected all of the pole tips from poles that had not received any through-boring treatment along with 23 tips from other poles that had received one of the boring procedures at the groundline. A total of 53 poles were examined.

We had contemplated testing the 6 m tip sections in the same manner as was done for the butt sections, however, that would have provided us with only a measure of pole properties at one cross section. Instead, we sought to characterize exterior wood strength along the pole length. Pole condition was assessed using longitudinal compression strength testing (LCS) of small plugs cut from each pole. In previous tests, we found that LCS was reasonably correlated with pole bending strength. It also allowed us to characterize wood properties along the length of the pole section in relation to the proportion of juvenile wood present.

Plugs (9 mm diameter by 37.5 mm long) were taken from three equidistant locations around each pole beginning at the butt and moving upward at 1 m intervals. The plugs were pressure soaked with water, and then tested in longitudinal compression using a specially designed jig (Figure III-22). Load was applied at a rate of 2 mm per minute until the load deflection curve began to level off. Load/deflection data were continuously collected from each test and these data were used to determine load force, load stress and modulus of elasticity (MOE). Load force was simply the load required to produce 5 % compression. Load stress was calculated by dividing the load force by the area to which the force was applied and modulus of elasticity was determined by calculating the slope of the load-deflection curve in the linear or elastic portion of the curve. In addition, plugs cut from the section retained from the lower pole section will be tested in longitudinal compression.

Following plug sampling, 75 mm thick disks were cut from the butt and tip of each pole tip section. These sections were then used to determine the total number of annual rings present, the thickness of the outer 15 and 20 rings of the section, the percent of juvenile wood, and the proportion of latewood in the outer 50 mm of the cross section (Table III-8). These wood quality parameters were then compared with the LCS values for the poles. Similar data were collected from a corresponding cross section cut from the pole butt (Table III-9). Plugs cut from these cross sections will be tested in longitudinal compression at a later date.

The number of annual rings on the poles ranged from 13 to 33 at the tip and 21 to 46 in the butt sections. In most cases, the difference between tip and butt was 7 to 9 rings. Based upon the presumption that juvenile wood is produced in Douglas-fir trees for the first 15 to 20 years, 22 of the pole tips would be virtually all juvenile wood.

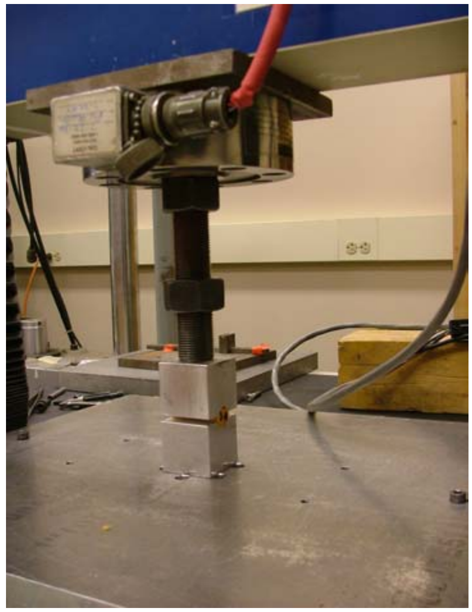

Figure III-22. Example of a longitudinal compression plug in the test jig prior to compression testing.

The ANSI specifications require that the number of rings per cm in the outer 50 mm be no less than 2.4 rings per cm for poles less than 95 cm or less in circumference 1.8 m from the butt (ANSI, 1995). The number of rings can also vary around the pole as a result of the peeling process. For this reason, we measured this characteristic at three locations around the pole at the tip and butt and averaged these numbers by location. Ring counts for the butt sections in this test ranged from 2.1 to 5.2 rings/cm in the outer 50 mm, with all but one pole within the tolerances allowed by ANSI (Table III-9). Ring counts were slightly lower in the outer 50 mm in tips, perhaps reflecting the proximity of this zone to the live crown in the tree (Table III-8).

The percentage late wood in a sample is generally related to the density, with a higher percentage of latewood translating to higher density. Density is well correlated with a number of wood properties. Faster growing trees tend to have lower proportions of latewood. Latewood percentages in the test poles ranged from 19.7 to 50.1%. Coincidently, the pole with the lowest percentage of latewood also had the fewest rings in the outer 50 mm.

Longitudinal compression tests indicated that there were substantial differences in properties among the various poles tested (Figures III-23-25). A portion of this variation reflected the difficulty in obtaining smooth cores from the poles, which had been air-seasoning for several months and were very dry when sampled. There were no significant differences between locations along the length of a pole in stress, or modulus. Although not a direct measure of pole flexural properties, LCS has been shown to be reasonably correlated with these properties. In addition, this test allowed comparisons between different vertical positions along a pole without the need to cut small clear beams. The lack of any significant effect on LCS with pole height suggests that even though the upper 6 m of these distribution poles contained high percentages of juvenile wood, this wood did not negatively affect material properties. Juvenile wood has been reported to have substantially different properties from mature wood; however, the materials tested in previous studies often differed substantial from materials used for poles. For example, much of the plantation grown juvenile wood has very high rates of growth and relatively low percentages of latewood. These materials would not be acceptable for poles under current ANSI standards. The poles in these tests were relatively slow grown and this may have contributed to the improved results.

The results indicate that wood properties in the outer 50 mm of a pole do not vary significantly with height. Since 90 % of the bending properties of a pole lie within this zone, the lack of effects in this zone would indicate that juvenile wood did not markedly affect overall pole properties for poles of this size.

Table III-8. Wood characteristics of Douglas-fir pole tip sections evaluated for the effect of juvenile wood quality.

Disk #	Top/ Bottom	Number of Rings	Zone Thickness (mm)			Rings in Outer 50 mm	Latewood Proportion (%)
			Total Radius	Outer 15 Rings	Outer 20 Rings		
1A	T	17	93.5	84.9		11.0	26.9
1A	B	24	123.2	96.1	113.5	14.0	38.1
2B	T	14	86.0	84.4		9.3	26.2
2B	B	21	115.8	92.4	110.3	12.3	32.2
3C	T	31	108.3	58.0	84.0	21.0	36.1
3C	B	34	117.3	75.8	91.8	21.3	37.4
4D	T	18	104.1	95.0	114.2	10.7	26.8
4D	B	23	125.4	101.7	117.6	13.3	38.8
5E	T	20	94.1	78.5		12.3	33.5
6A	T	18	112.0	96.7		10.7	50.1
6A	B	24	130.9	96.5	114.7	13.3	34.9
7B	T	26	96.0	70.0	81.0	19.0	36.8
7B	B	30	114.4	75.1	92.0	18.0	45.7
8C	T	13	90.4			7.7	34.4
8C	B	19	116.2	97.2		10.0	37.7
9D	T	17	88.4	80.0		12.3	35.8
9D	B	25	122.6	91.3	108.8	14.3	38.9
10E	T	25	100.8	74.2	89.3	16.0	33.2
10E	B	27	116.2	76.9	96.9	14.7	32.0
11A	T	21	106.1	78.8	106.0	11.0	31.3
11A	B	28	128.3	81.2	98.8	15.3	20.3
14D	T	22	106.1	78.3	97.3	12.8	28.1
14D	B	27	124.8	80.7	101.4	14.7	30.2
15E	T	18	90.8	80.5	99.2	12.0	31.4
15E	B	27	122.7	83.3	104.0	14.3	35.3
15E	B	24	117.8	92.3	106.1	14.7	39.0
16A	T	31	108.8	68.7	82.2	18.7	38.5
16A	B	34	125.4	80.2	94.9	20.7	42.6
18C	T	21	113.7	92.3	111.6	11.0	25.0
18C	B	26	133.9	89.3	113.3	12.3	26.8
19D	T	13	86.1			8.0	19.7
19D	B	19	117.1	95.3	118.6	9.3	25.0
21A	T	21	114.3	91.1	110.6	11.3	23.2
21A	B	26	132.3	90.0	113.8	13.7	24.3
22B	T	18	91.2	76.5	96.1	12.0	24.2
22B	B	22	124.0	94.0	115.4	11.7	31.1
23C	T	16	96.3	90.3		10.3	23.8
23B	B	23	124.8	98.6	115.8	14.0	42.9
23C	B	22	123.9	94.4	116.1	11.3	26.6
24D	T	30	119.6	82.0	96.3	18.3	31.1
24D	B	37	132.7	78.8	92.6	20.7	41.0
25E	T	16	90.3	85.7		9.0	30.5
25E	B	22	116.1	76.1	99.5	11.0	26.3
26A	T	19	105.6	90.6		11.7	37.3
26A	B	28	128.0	86.7	103.2	16.0	45.9

[a]Values represent the mean of three measurements taken at equidistant locations on the disk.

Table III-8 (cont.). Wood characteristics of Douglas-fir pole tip sections evaluated for the effect of juvenile wood quality.

Disk #	Top/ Bottom	Number of Rings	Zone Thickness (mm)			Rings in Outer 50 mm	Latewood Proportion (%)
			Total Radius	Outer 15 Rings	Outer 20 Rings		
27B	T	23	91.7	67.2	83.9	13.8	33.2
27B	B	28	127.9	87.4	107.3	15.3	31.2
28C	T	19	103.3	85.2	112.1	11.0	27.2
28C	B	24	120.7	93.2	112.4	13.3	33.2
29D	T	25	102.8	68.0	88.8	14.0	29.0
29D	B	32	122.7	71.1	87.5	17.0	38.1
29D	B	33	123.2	72.1	88.5	17.0	43.2
30E	T	26	96.7	65.2	80.8	15.0	33.3
30E	B	31	118.7	76.1	91.5	17.7	41.8
31A	T	26	95.4	64.4	80.2	16.0	28.9
31A	B	35	123.9	70.7	87.1	20.0	27.8
32B	T	20	97.6	84.2	101.9	12.3	29.7
33C	T	21	109.1	87.7	105.1	11.8	32.5
33C	B	26	125.1	85.7	106.5	13.3	33.3
34D	T	20	99.8	80.2	100.0	11.7	32.7
34E	B	27	123.8	85.4	102.3	15.3	46.9
35E	T	35	116.6	74.6	88.8	22.0	38.2
35E	B	36	127.2	81.2	95.0	21.3	33.9
36A	T	24	129.1	86.4	101.2	14.7	34.3
36A	B	28	133.2	99.1	113.2	17.0	42.7
37B	T	23	105.8	84.0	97.4	14.3	34.4
37B	B	33	119.1	82.9	97.8	20.0	39.9
39D	T	20	108.2	93.3	111.3	12.0	30.1
39D	B	26	121.2	87.9	106.2	15.7	34.7
40E	T	34	106.2	63.2	78.2	20.3	38.1
40E	B	42	121.5	61.6	77.1	23.7	44.1
42B	T	16	85.2	78.2		9.7	30.6
42B	B	27	114.4	71.6	90.6	13.7	38.1
45E	T	34	116.8	71.0	85.4	21.7	47.7
45E	B	40	108.2	67.2	83.2	23.7	40.2
50E	T	20	93.2	71.3	96.9	12.7	36.2
50E	B	27	115.3	83.1	96.2	15.0	41.2
55E	T	17	91.9	78.8		9.7	37.1
55E	B	25	124.2	78.0	99.8	11.3	35.9
60E	T	14	87.2	93.0		8.7	27.5
60E	B	20	117.9	88.6	113.6	10.0	33.3
65E	T	20	89.0	63.9	93.2	11.7	24.8
65E	B	30	122.7	69.8	83.9	15.0	43.1
65E	B	27	122.9	75.3	90.9	13.7	41.6
80E	T	26	112.3	77.8	95.9	14.3	34.0
80E	B	32	132.1	79.8	99.3	16.3	47.1
85E	T	17	95.2	87.4		9.0	29.3
85E	B	23	126.0	97.3	122.0	13.0	30.5
90E	T	29	107.9	65.0	84.6	16.3	33.0
90E	B	36	127.1	70.3	86.4	19.3	32.3
95E	T	21	97.4	78.4	93.6	12.7	28.6
95E	B	25	121.0	89.3	106.2	15.0	32.6

[a]Values represent the mean of three measurements taken at equidistant locations on the disk.

Table III-8 (cont.). Wood characteristics of Douglas-fir pole tip sections evaluated for the effect of juvenile wood quality.

Disk #	Top/ Bottom	Number of Rings	Zone Thickness (mm)			Rings in Outer 50 mm	Latewood Proportion (%)
			Total Radius	Outer 15 Rings	Outer 20 Rings		
100E	T	17	107.3	102.2		9.7	26.6
100E	B	22	128.0	100.3	122.1	11.3	30.0
105E	T	21	92.5	75.0	90.6	13.7	37.2
105E	B	28	122.6	82.8	100.4	15.0	35.4
110E	T	20	94.6	79.2	88.5	11.7	33.8
110E	B	27	122.7	90.0	106.3	16.3	33.5
115E	T	21	95.3	76.8	89.9	12.7	36.0
115E	B	28	117.8	76.6	95.2	14.7	36.6
120E	T	15	88.9	85.2		9.3	30.5
120E	B	22	123.2	96.1	116.8	11.0	31.6
125E	T	14	87.1			8.8	29.0
125E	B	20	128.4	100.6	127.2	9.3	32.3
130E	T	28	100.8	65.5	81.8	16.7	35.5
130E	B	32	121.5	73.8	92.2	17.7	36.9
135E	T	17	91.3	84.9		10.3	30.7
135E	B	23	119.1	89.6	108.6	12.0	29.1
140E	T	18	100.5	83.9		9.8	21.7
140E	B	27	133.6	88.2	110.2	12.7	24.6

[a]Values represent the mean of three measurements taken at equidistant locations on the disk.

Table III-9. Wood characteristics of Douglas-fir pole butt sections evaluated for the effect of juvenile wood quality.

Pole#	Thru-boring pattern	Number of Rings[a]	Zone Thickness (mm)			Rings in Outer 50 mm	Rings/ cm	Latewood Proportion (%)
			Total Radius	Outer 15 Rings	Outer 20 Rings			
1	A	27	139.1	49.1	81.8	15.0	3.0	45.1
2	B	24	137.1	54.1	89.4	14.0	2.8	31.2
3	C	39	125.7	23.9	35.6	23.0	4.6	38.7
4	D	26	130.5	52.5	85.1	15.0	3.0	34.5
5	E	31	134.9	41.8	62.5	17.0	3.4	37.5
6	A	29	134.9	46.4	71.4	16.7	3.3	36.4
7	B	35	131.0	33.0	50.0	19.7	3.9	56.9
8	C	23	131.9	69.0	101.1	10.7	2.1	36.7
9	D	28	134.5	50.9	79.9	15.3	3.1	35.7
10	E	33	131.1	36.6	53.4	19.0	3.8	34.7
11	A	34	140.0	40.5	58.9	18.0	3.6	35.7
12	B	28	126.4	48.7	73.8	15.7	3.1	38.9
13	C	31	132.3	29.3	47.2	21.0	4.2	41.1
14	D	31	142.6	47.6	73.1	16.0	3.2	34.9
15	E	27	133.6	46.1	74.8	16.0	3.2	41.3
16	A	33	124.5	29.5	45.5	21.0	4.2	45.4
17	B	29	152.2	63.7	90.8	12.3	2.5	36.1
18	C	32	137.8	72.9	47.8	13.0	2.6	40.3
19	D	23	134.1	65.8	101.5	12.3	2.5	27.1
20	E	35	138.4	33.1	51.8	19.7	3.9	35.0
21	A	27	131.3	56.0	85.7	14.0	2.8	32.7
22	B	27	151.0	62.4	91.4	12.3	2.5	33.9
23	C	27	136.1	56.5	84.8	14.0	2.8	35.0
24	D	40	135.5	31.8	43.9	22.0	4.4	44.3
25	E	27	136.1	56.7	83.4	13.0	2.6	30.9

[a]Values represent the mean of three measurements taken at equidistant locations on the disk.

Table III-9 (cont.). Wood characteristics of Douglas-fir pole butt sections evaluated for the effect of juvenile wood quality.

Pole#	Thru-boring pattern	Number of Rings[a]	Zone Thickness (mm)			Rings in Outer 50 mm	Rings/ cm	Latewood Proportion (%)
			Total Radius	Outer 15 Rings	Outer 20 Rings			
26	A	32	137.5	42.2	61.6	17.3	3.5	41.7
27	B	30	145.4	45.0	70.5	17.0	3.4	33.2
28	C	29	135.8	48.8	71.7	15.0	3.0	36.7
29	D	35	130.0	38.8	55.3	17.3	3.5	31.7
30	E	38	132.0	29.4	42.2	22.7	4.5	38.4
31	A	38	132.6	33.1	47.0	21.7	4.3	35.6
32	B	26	136.4	49.9	85.9	15.0	3.0	41.5
33	C	28	132.6	49.0	75.4	15.7	3.1	30.7
34	D	33	142.7	39.9	61.0	17.3	3.5	38.5
35	E	38	133.8	27.0	38.8	23.3	4.7	45.4
36	A	32	132.7	31.1	51.5	20.3	4.1	33.9
37	B	36	131.6	26.6	41.2	22.3	4.5	41.2
38	C	37	133.9	30.5	47.0	21.0	4.2	45.1
39	D	31	134.1	42.5	66.9	16.7	3.3	43.6
40	E	42	128.5	26.5	39.5	23.7	4.7	42.0
41	A	45	134.0	26.2	36.8	25.3	5.1	48.7
43	C	31	129.0	30.9	51.4	19.7	3.9	46.9
45	E	44	130.6	25.2	35.4	25.3	5.1	52.3
46	A	40	138.6	27.4	39.2	23.3	4.7	45.3
47	B	32	134.2	38.3	59.7	16.3	3.3	37.3
50	E	30	129.2	42.0	64.2	16.3	3.3	42.4
51	A	36	135.2	42.2	55.7	18.3	3.7	48.2
52	B	26	144.1	64.4	91.4	12.3	2.5	34.1
54	D	30	136.2	44.9	66.1	15.3	3.1	40.2
55	E	29	146.0	58.0	81.8	13.7	2.7	37.7
56	A	38	132.4	18.3	28.5	26.0	5.2	40.1
59	D	26	133.8	55.7	82.8	13.7	2.7	28.9
60	E	24	140.6	69.2	101.3	12.0	2.4	32.2
63	C	33	136.8	38.1	55.7	18.7	3.7	45.3
65	E	35	133.2	46.9	61.8	16.0	3.2	45.1
66	A	37	134.6	23.3	36.3	24.0	4.8	41.9
68	C	32	136.1	42.4	64.3	16.3	3.3	37.7
69	D	25	131.2	59.6	91.7	13.7	2.7	37.8
70	E	31	136.4	38.1	61.8	16.0	3.2	37.2
73	C	32	126.2	34.6	56.4	18.7	3.7	51.1
75	E	32	138.5	33.3	55.1	18.3	3.7	39.3
80	E	35	137.5	36.3	54.1	19.0	3.8	44.9
85	E	26	137.8	54.7	84.4	14.3	2.9	37.3
90	E	42	134.2	31.6	44.5	20.7	4.1	32.7
95	E	28	133.3	51.2	77.8	15.0	3.0	36.7
100	E	23	138.1	66.6	103.2	13.0	2.6	32.6
104	D	37	130.7	33.9	49.9	19.7	3.9	26.1
105	E	28	136.9	52.1	80.9	14.7	2.9	39.9
106	A	33	132.0	46.5	64.4	15.3	3.1	37.5
110	E	28	138.4	45.4	76.3	15.7	3.1	35.5
115	E	32	129.2	41.2	62.0	16.3	3.3	33.5
120	E	25	141.7	61.1	93.4	13.7	2.7	36.1
125	E	24	146.9	68.3	104.4	12.3	2.5	37.7
127	B	23	131.8	53.3	91.8	14.7	2.9	38.8
135	E	27	136.3	52.3	87.4	15.0	3.0	33.7
140	E	31	144.5	48.4	72.0	15.3	3.1	23.4

[a]Values represent the mean of three measurements taken at equidistant locations on the disk.

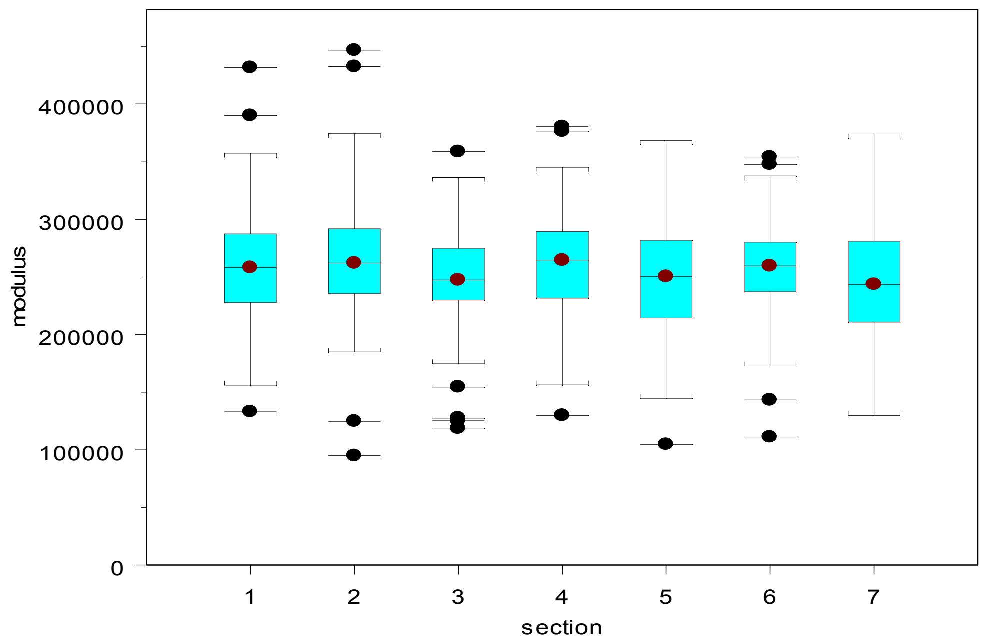

Figure III-23. Box and whisker plot of Modulus of elasticity (psi) of 9 mm diameter plugs removed at one meter increments along the length of Douglas-fir poles and tested in longitudinal compression.

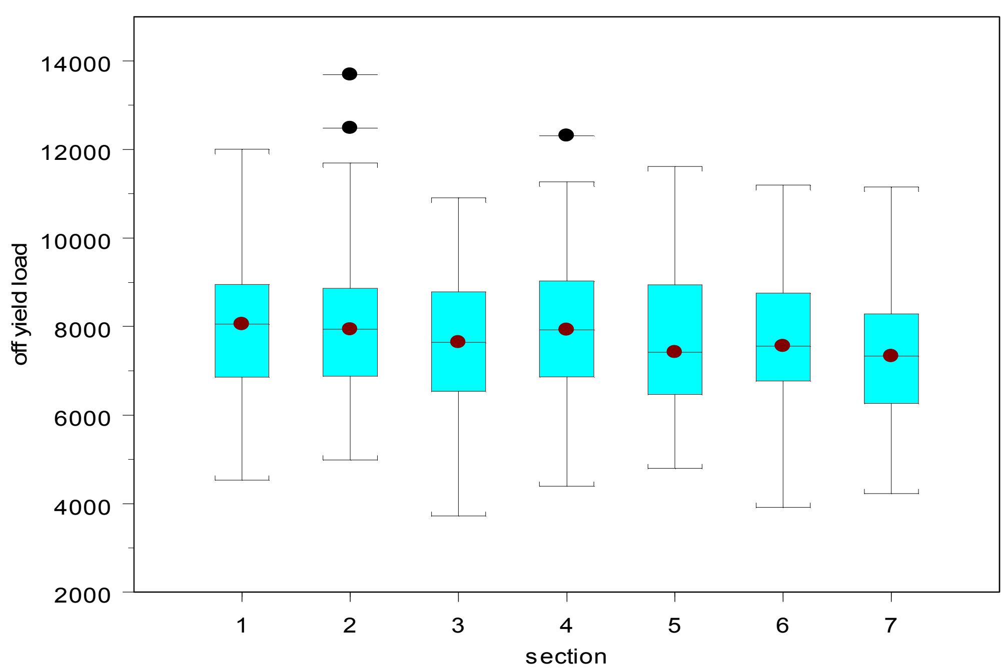

Figure III-24. Box and whisker plot of yield load (lbs of force) of 9 mm diameter plugs removed at one meter increments along the length of Douglas-fir poles as determined by testing in longitudinal compression.

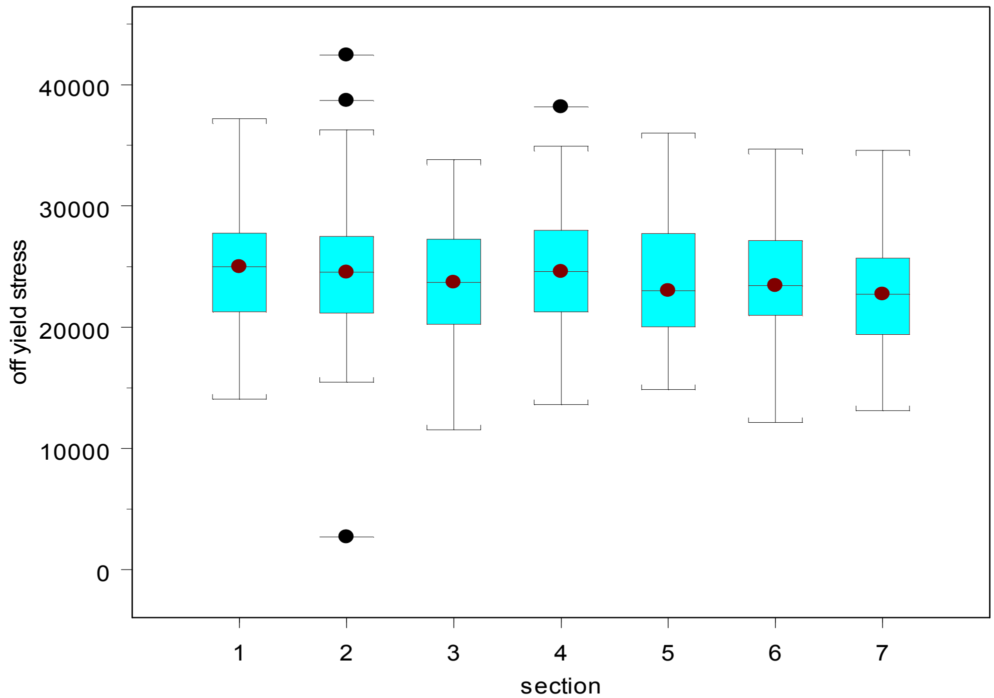

Figure III-25. Box and whisker plot of yield stress (psi) of 9 mm diameter plugs removed at one meter increments along the length of Douglas-fir poles as determined by testing in longitudinal compression.

E. Performance of Fire Retardants on Douglas-fir Poles

Transmissions lines, and to a lesser extent, distribution lines, often pass through forested areas. Vegetation control to limit the potential for trees contacting the lines is an important and expensive component of right-of-way maintenance. Despite these practices, poles in areas with heavy vegetation may still be vulnerable to rangeland or forest fires. There are a number of possible methods for limiting the risk of fires on poles. In the past, metal barriers were placed around poles in high hazard areas; however, this practice reduced pole service life because the barriers acted to trap moisture on the pole surface.

As an alternative, poles can be periodically treated with fire retardants. Some of these materials are designed for short term protection and must be applied immediately prior to a fire, while others are longer lasting and provide 1 to 3 years of protection. While these fire retardant treatments have been available for decades, there is little published information on their efficacy or their longevity. In order to develop this information, the following test was initiated.

Douglas-fir pole sections (200-300 mm in diameter by 1.4 m long) that had been removed from service were set in the ground to a depth of 0.6 m at our Peavy Arboretum test site. The poles were allowed to weather for approximately 8 months. The poles were allocated into treatment groups of 6 or 9 poles each. Each set of poles received one of the following treatments, either applied by the manufacturer or according to the manufacturer's instructions:

1. Osmose Fire-Guard
2. CuRap 20 as a below-ground treatment
3. Baxter Elastomeric Epoxy Roof Coating
4. No treatment

The circumference of each pole was measured at groundline. Originally, the intent was to test fire resistance immediately after treatment; however, fire restrictions at the time of treatment precluded this possibility. Instead, 3 poles in each treatment were subjected to fire 1.45 years after treatment. The fires in the first test were initiated by laying 3 kg of dry straw on one side of each pole at groundline. The straw was placed in burlap bags which were tied to the pole to ensure direct straw wood contact, increasing the likelihood of successful ignition (Figure III-26). The straw was ignited

Figure III-26. Example of straw fuel in burlap bags tied around Douglas-fir poles with or without a fire retardant barrier.

using a drip torch (being careful to avoid dripping fuel directly on the wood) and the poles were allowed to burn until either the fuel was exhausted or weather conditions changed (Figure III-27).

Figure III-27. Ignition of bagged straw with a drip torch at the Peavy Arboretum test burn site in 2005.

In the second burn, a 2.4 m circumference wire cage was placed around each pole, leaving about 0.3 m between the wire and the pole. This space was filled to a depth of 650 mm with 6.8 kg of dry straw (Figure III-28). This arrangement was designed to expose the entire pole circumference to a similar amount of straw. The dried grass at the edge

Figure III-28. Example of straw fuel in a wire basket around Douglas-fir poles with or without a fire retardant barrier.

of the test site was ignited with a flare and the fire was allowed to spread to each of the test poles, igniting the fuel (Figure III-29, 30). This resulted in near complete combustion of the fuel load around each pole and uniform burning around the poles (Figure III-31).

Figure III-29. Ignition of dried grass at the test burn site at Peavy Arboretum in 2006.

Figure III-30. Example of poles following ignition of the straw fuel.

Figure III-31. View of the site after Douglas-fir poles with and without a fire retardant barrier were burned.

Once the fires were extinguished, the degree of burning on each pole was assessed by scraping away the charred area. Pole circumference was measured at the deepest burned area and the average depth of charring was then measured. The effective circumference of each disk was measured and this data was compared with the initial circumference measurements. The relative circumference losses were compared with those from the non-fire retardant treated control poles (Figure III-32, 33).

Figure III-32. Example of charring on a non-coated control pole surface following fire exposure.

Figure III-33. Example of a fire retardant treated pole following fire exposure.

In the first test, the fuel load was apparently too low to produce a sustained fire. Poles were exposed to only 5 to 10 minute of flame. While some poles ignited, the fires lasted no more than 20 minutes. One reason for this low burn rate was the high relative humidity at the time of the test.

The second fire test 2.5 years after treatment produced much more aggressive fire conditions. The bundles of straw burned more intensely and the test was more representative of an aggressive field fire with an excess of fuel.

The remaining poles will be subjected to similar fire tests in future years to assess the protective period provided by each treatment. This test should be viewed as somewhat conservative since the fuel loading is fairly high and the exposure in western Oregon provides a higher risk of chemical leaching than might be found in many fire prone areas, such as the Inter-Mountain regions where rainfall levels are extremely low.

In general, fire conditions in the first year were not favorable, as evidenced by the short burn period and the relatively low amount of circumference loss on the untreated control poles (Table III-10). Despite the poor burn conditions, differences did emerge in both circumference loss and char depth. The control poles and those receiving CuRap 20 paste had slightly higher losses in circumference than either the Fire-Guard or the elastomeric paint (Table III-10). Fire Guard treated poles experienced no loss in circumference and only a slight degree of charring (0.8 mm) on the surface directly exposed to the fire. Char depth was lower for all of the treated poles compared with the untreated control.

The conditions for the second field burn were much more conducive and circumference losses as well as char depth were both substantially higher for all treatments. Fire Guard and elastomeric coated poles experienced similar, low losses in circumference in the second test, while CuRap 20 treated poles experienced circumference losses that exceeded those of the control poles. The results suggest that Fire Guard and the elastomeric paint continue to provide some protection to the poles, while the CuRap 20 has not enhanced the fire resistance of the pole at groundline.

Char depth also increased in the second test, with Fire Guard treated poles experiencing the lowest char depth, followed by the elastomeric paint treated poles. As with the circumference loss data, CuRap 20 treated poles experienced higher charring depths, suggesting that this treatment had failed to provide long term fire protection at groundline. CuRap 20 was originally included in the test under the belief that the boron in this system would provide some fire protection; however, it is likely that there is an insufficient level of boron present to substantially affect fire performance. Fire retardant treatments based upon boron typically contain pounds of chemical per cubic foot of wood. We have never found boron present at these levels in previous groundline wrap tests, suggesting that it is unlikely that CuRap 20 would provide substantial fire resistance to poles (a purpose for which it was never intended).

Table I-10. Effect of flame testing on reduction in circumference and average depth of charring of pentachlorophenol treated Douglas-fir poles left alone or treated with various fire retardant systems.

Treatment	Circumference Loss (%)[a]		Char Depth (mm)	
	2005	2006	2005	2006
None	2.3 (0.9)	5.2 (2.1)	8.5 (3.6)	10.6 (3.6)
Fire-Guard	0	2.0 (1.8)	0.8 (0.8)	2.1 (0.9)
Elastomeric paint	0.3 (0.4)	2.2 (1.3)	1.3 (0.5)	5.6 (6.3)
CuRap 20	2.0 (1.9)	7.7 (5.0)	1.3 (1.7)	18.8 (5.9)

[a]Values represent means of 3 poles per treatment. Figures in parentheses represent one standard deviation.

F. Effect of End Plates on Checking of Douglas-fir Cross arms

The environmental conditions in a cross arm present a much lower risk of decay than would be found at groundline; however, the arms are subjected to much wider fluctuations in wood moisture content. Arms expand as they wet and then shrink when dry. This repeated cyclic moisture behavior can lead to mechanical damage and the development of deep checks. These checks can lead to splits that cause bolts and other hardware to loosen and fail. The incidence of splits in cross arms is generally low, but the cost of repairs can be significant. Thus, the development of methods for limiting splitting in cross arms would be economical in many utility systems.

One approach to limiting splitting is end-plating. Endplates have long been used to limit splitting of railroad ties and many rail lines routinely plate all ties. End-plates might provide similar benefits for cross arms; however, there is little data on the merits of these plates for this application. In order to develop this data, the following test was established.Twenty five pentachlorophenol treated Douglas-fir cross arm sections (87.5 mm by 112.5 mm by 1.2 m) long were end-plated on one end and left non-plated at the other (Figure III-34). The objective was to compare checking with and without plates on comparable wood samples. The plates were developed by Brooks Manufacturing (Bellingham, WA). The

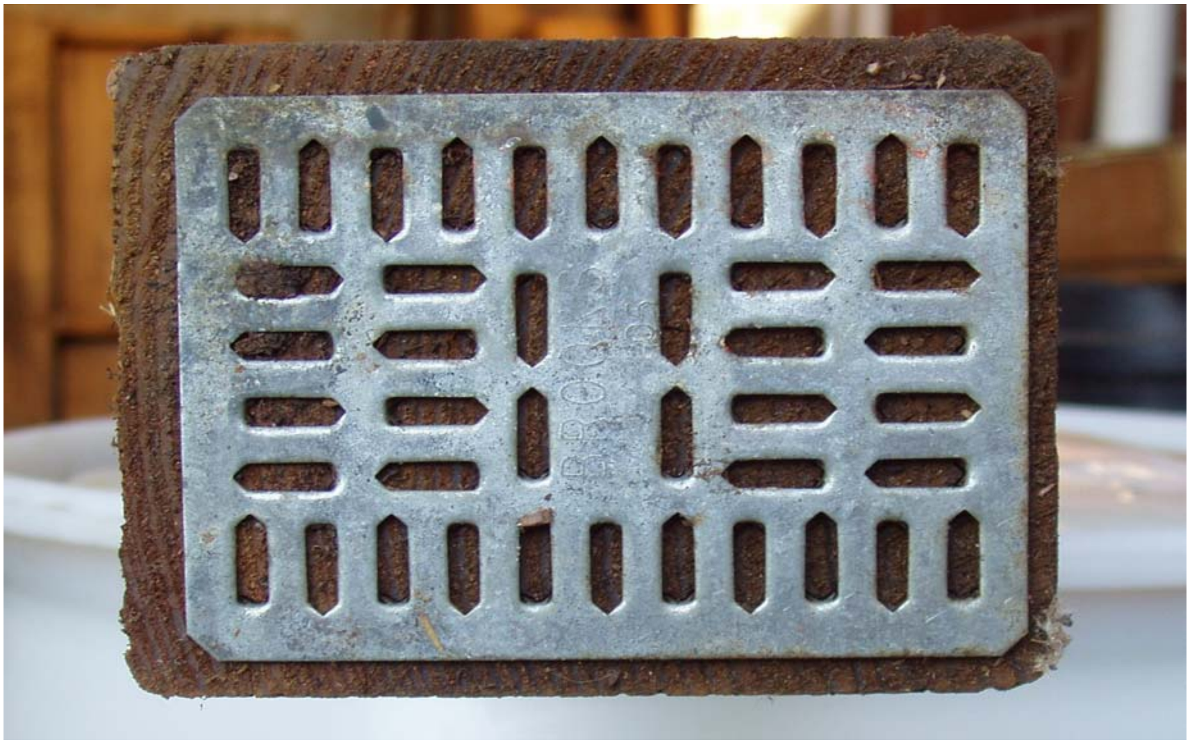

Figure III-34. Example of an end-plate on a penta treated Douglas-fir cross arm.

arms were initially examined for the presence of checks. The arms were then immersed in water for 30 days before being removed and assessed for check development. The total number of checks longer than 2.5 cm on each face as recorded, and the width of the widest check on each face was measured. The arm sections were then dried and measurements were made again. The arms were then returned to the water tank for an additional 30 days before the cycle was repeated. The arms were air dried in the first cycle, then the arms were kiln dried for the remaining three cycles.

Check measurements tended to vary over time, reflecting the tendency for different checks to open in different cycles (Table III-11). As a result, the average number of checks per arm was sometimes greater on non-plated ends, then reversed at the end of the next cycle. Check width also varied widely, although there was a general tendency for the plated arms to have slightly larger checks. The inconsistency in the data suggests that the arms have not been subjected to a sufficient number of cycles to show any difference between the plated and non-plated ends. We will continue to cycle the arms and monitor check development over the coming year.

Table III-11. Degree of checking on penta treated Douglas-fir cross arm sections with and without end plates.

Number of Wet/Dry Cycles	Check Frequency (#/arm) [a]		Maximum check width (mm)	
	No Endplate	Endplate	No Endplate	Endplate
3	1.12	0.50	0.83	0.95
4	0.25	0.25	0.81	1.06
5	0.50	0.96	0.74	0.76

[a]Values represent means of 25 arms per treatment.

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Objective IV

PERFORMANCE OF EXTERNAL GROUNDLINE PRESERVATIVE SYSTEMS

While preservative treatment provides excellent long term protection against fungal attack in a variety of environments, there are a number of service applications where the treatment eventually loses its effectiveness. Soft rot fungi can then decay the wood surface, gradually reducing the effective circumference of the pole until replacement is necessary. In these instances, pole service life can be markedly extended by periodic below ground application of external preservative pastes that eliminate fungi in the wood near the surface and provide a protective barrier against reinvasion by fungi in the surrounding soil.

For many years, the pastes used for this purpose incorporated a diverse mixture of chemicals including pentachlorophenol, potassium dichromate, creosote, fluoride and an array of insecticides. The re-examination of pesticide registrations by the U.S. Environmental Protection Agency in the 1980's resulted in several of these components being listed as restricted use pesticides. This action, in turn, encouraged utilities and chemical suppliers to examine alternative preservatives for this application. While these chemicals had prior applications as wood preservatives, there was little data on their efficacy as preservative pastes and this lack of data led to the establishment of this objective. The primary goals of this objective are to assess the laboratory and field performance of external preservative systems for protecting the below ground portions of wood poles.

A. Performance of External Preservative Systems on Douglas-fir, Western redcedar, and Ponderosa Pine Poles in California

The field test in California is now completed. The final results were provided in the 2002 annual report.

B. Performance of Selected Supplemental Groundline Preservatives in Non-Treated Douglas-fir- Poles Exposed Near Corvallis Oregon

The pole sections in the field test of copper/boron and copper/boron/fluorides have declined to the point where they can no longer be sampled and this test was terminated in 2003.

C. Performance of External Treatments for Limiting Groundline Decay in Southern Pine Poles near Beacon, New York

Date Established:	October 2001
Location:	Beacon, New York
Pole Species, Treatment, Size	Southern pine, penta, 4-35 to 2-55
Circumference @ GL (avg., max., min.)	104, 119, 80 cm

Eighty southern pine transmission poles in the Central Hudson Electric and Gas system were selected for study. The poles were randomly allocated to groups of 10 and received one of the following treatments:

Osmose Cop-R-Plastic (previously Osmoplastic)
Osmose PoleWrap RTU
Wolman Wrap with Cu/F/B
Wolman Wrap with Cu/B
Genics Cobra Wrap
Genics Cobra Slim (an experimental wrap)
Triangle Laboratories Biological Treatment

The treatments were applied 0 to 450 mm below the groundline, and then the soil was backfilled. The total amount of chemical applied to each pole was determined by weighing containers before and after chemical application or by measuring the total amount of prepared wrap applied. An additional set of ten poles served as untreated controls. Sets for treatment were divided into two groups of five poles and then were sampled in alternate years.

Since the time of the test installation, the Cobra Slim, which was an experimental product, has been removed from the market. The chemical has been kept in the test because it can provide useful information about the effects of the bandage material on performance; however, the material used for the backing differs with that used in the commercial system.

The poles were sampled 2, 3 and 5 years after treatment by removing increment cores from selected locations below groundline. The cores were cut into two different patterns, depending on the remedial treatment chemical involved. For copper based systems, the cores from a given treatment were cut into zones corresponding to 0-6, 6-13, and 13-25 mm. These assays zones were kept nearer the surface in recognition of the limited ability of copper to move into the wood.

The samples from poles treated with systems containing either boron or fluoride were divided into zones corresponding to 0-13, 13-25, 25-50 and 50-75 mm from the surface, in recognition that these chemicals are capable of moving rather deeply into the wood with moisture. Two sets of cores were removed from poles treated with systems containing both copper and a water diffusible component. In addition, at the time of treatment and two years after treatment, wood from each pole was cultured for the presence of fungi by placing small chips cut from each pole on plates of malt extract agar and observing for evidence of fungal growth. Any fungi were examined under a microscope and identified using the appropriate keys. The Genics Cobra Slim and the Triangle Laboratory treated poles were not sampled in 2006.

Copper levels in the poles varied widely among the four copper containing systems (Figure IV-1). As expected, copper levels were generally highest in the outer 6 mm and declined with distance from the surface. The lowest copper levels 5 years after treatment were found with the Cobra Wrap, followed by the Wolman CFB. The latter system had excellent copper distribution 3 years after treatment, but has apparently begun to deplete in the intervening two years. One contributor to these differences may be the alternate sampling of five-pole groups. We will have a better idea about this after the next sample. The comparator treatment from Wolman that contains only copper and boron also showed a sharp decline in the copper level, but the copper levels were still approximately 8 times those found with the Cobra Wrap. Copper levels in the Cop-R-Plastic system were above the threshold near the surface 2 and 3 years after treatment and declined sharply at the 5 year point. Despite this decline, the copper levels associated with this system are still higher than those found with the other treatments and were 2/3 of the ground contact threshold. This system also contains fluoride which should provide additional protection to the interior of the poles.

Boron levels in the two systems containing this compound barely reached the threshold for internal protection 2 years after treatment and were extremely low in both systems 5 years after application (Figure IV-2). Boron is extremely mobile and the loss of chemical in this system from the surface is not surprising. The levels inward may be useful for protecting wood away from the pole surface.

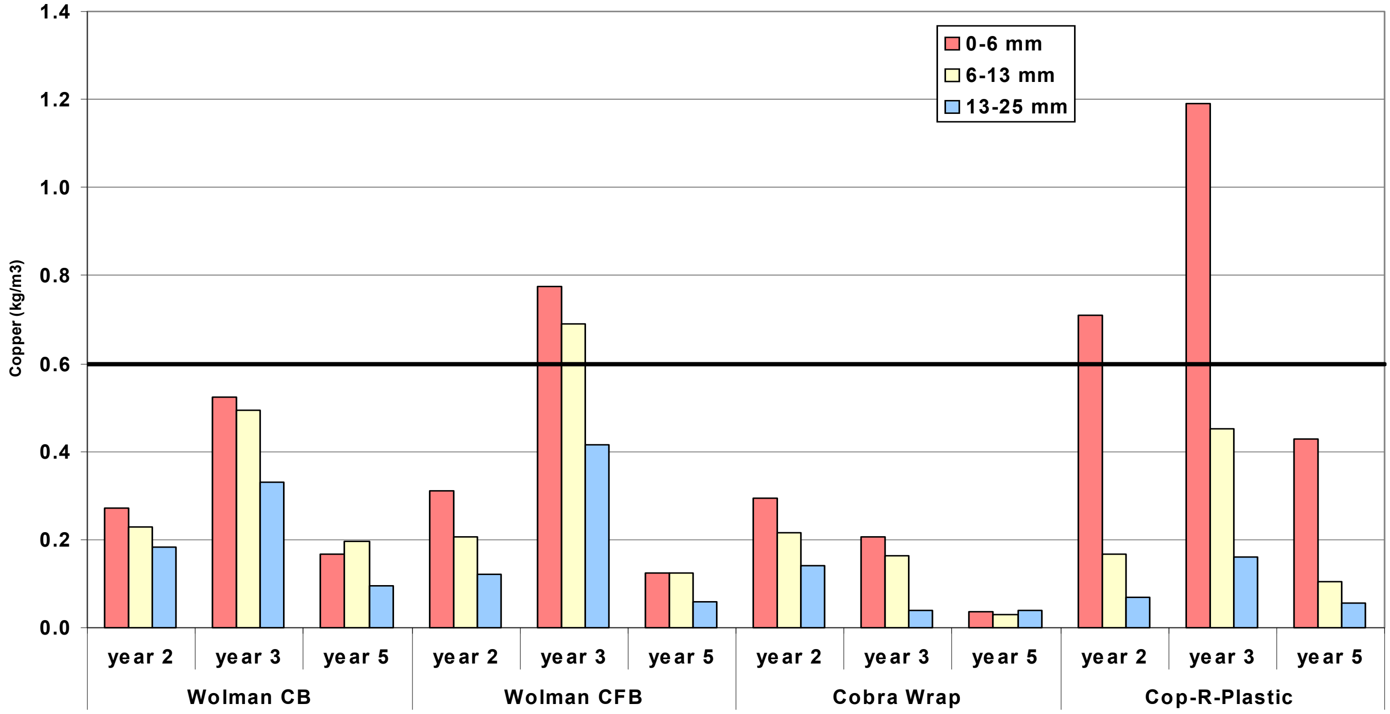

Figure IV-1. Residual copper levels at selected distances from the wood surface 150 mm below groundline on southern pine poles 2, 3 and 5 years after treatment with selected external supplemental preservative bandage systems.

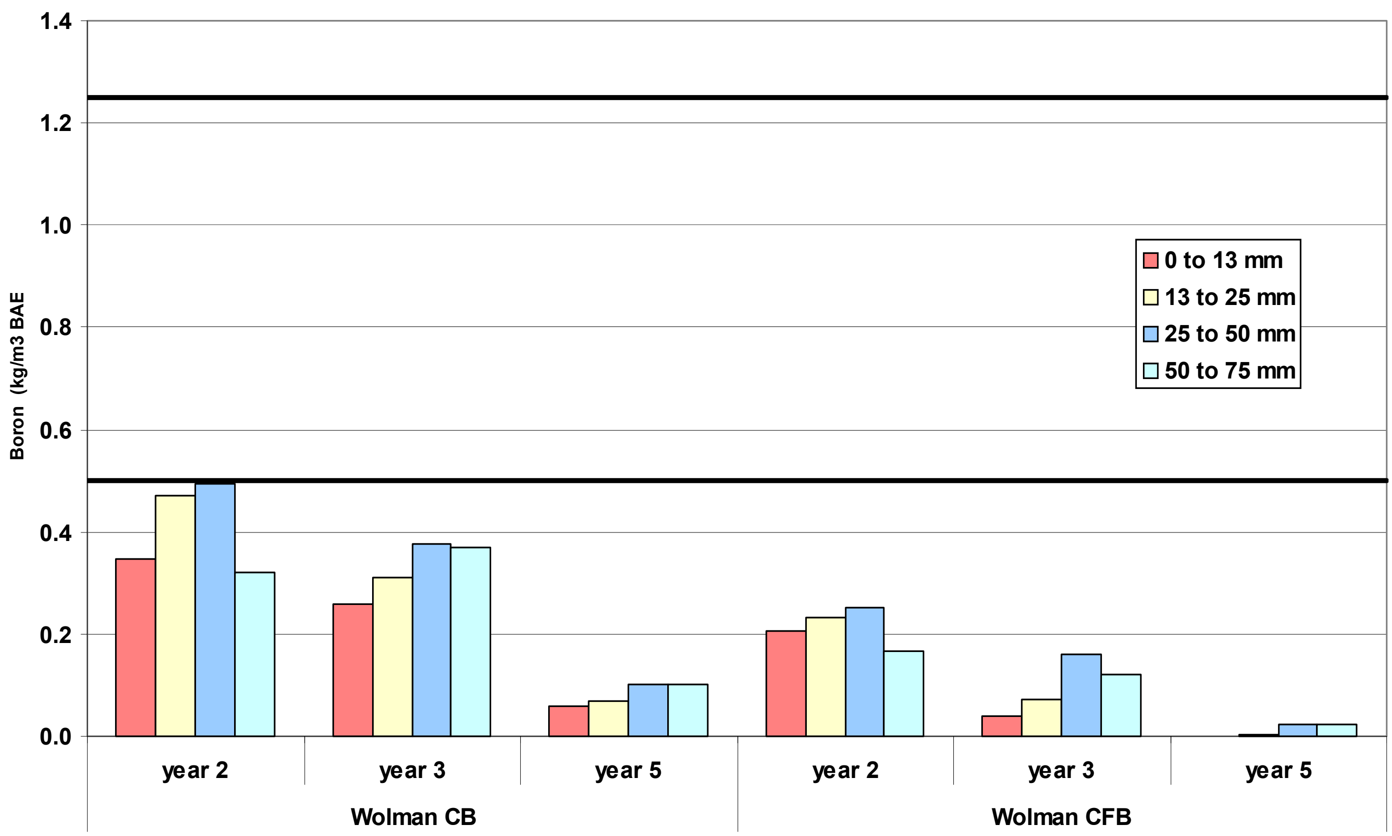

Figure IV-2. Residual boron levels at selected distances from the wood surface 150 mm below groundline on southern pine poles 2, 3 and 5 years after treatment with selected external supplemental preservative bandage systems.

Fluoride levels tended to follow a steady gradient from the surface inward for all three systems tested (Figure IV-3). Fluoride levels were extremely low in the Wolman CFB system and much higher in the Cop-R-Plastic and Pole Wrap treated poles. Levels had declined substantially in all three systems between three and five years after treatment. Fluoride levels in the Cop-R-Plastic and Pole Wrap treated poles had fallen below the soil contact threshold but were still above the level required for internal protection.

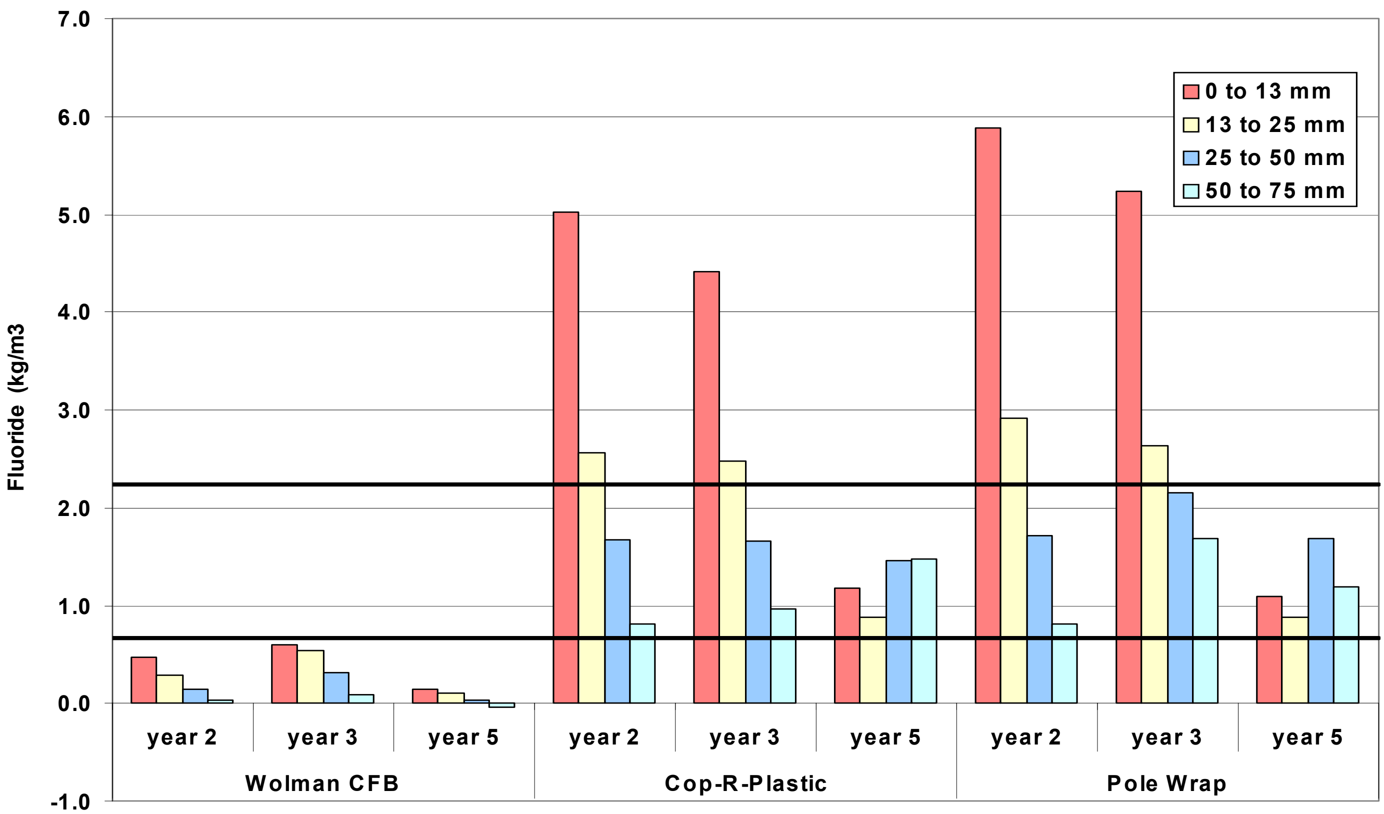

Figure IV-3. Residual fluoride levels at selected distances from the wood surface 150 mm below groundline on southern pine poles 2, 3, and 5 years after treatment with selected external supplemental preservative bandage systems.

One interesting performance feature of the systems evaluated was the tendency for self-contained wraps to produce lower chemical loadings. These systems have advantages in terms of ease of application and are often used by utility line crews when moving poles or setting poles in concrete. While these systems are simple and easy to use, it is sometimes difficult to obtain the same degree of physical contact between the wood and the bandage that can be produced with a brush-on paste. The paste can be forced into checks and voids, improving the likelihood that chemical will diffuse into the wood. It is far more difficult to obtain continuous contact with the pole using a bandage, although the soil surrounding the structure should eventually exert pressure.

The results also show that chemical levels in these poles have declined more sharply than in previous external preservative tests, including some on southern pine. It is unclear why this has occurred although copper levels in several of the systems remain in the range where they would be protective in concert with existing residual preservative.It is important to note that the declines in chemical content do not mean that fungi will immediately begin to attack the wood. Instead, we would expect to see a continued decline in chemical levels coupled with a gradual reinvasion by fungi from the surrounding soil. Despite this decline it is important to remember that these levels were capable of protecting the surface on non-treated poles at our Corvallis site (Section B). This test is next scheduled for examination in 2 years, which should give us a chance to better assess chemical loss rates in this system and help to define a realistic treatment cycle.

D. Performance of External Treatments for Limiting Groundline Decay in Southern Pine Poles in Georgia

Date Established:	November 2004
Location:	Douglas, Georgia
Pole Species, Treatment, Size	Southern pine, creosote
Circumference @ GL (avg., max., min.)	101, 119, 83 cm

Over the past decades, the UPRC has established a series of tests to evaluate the performance of external supplemental preservative systems on utility poles. Initially, tests were established on non-treated Douglas-fir pole sections. The tests were established on non-treated wood because the absence of prior treatment limited the potential for interference from existing preservatives, and the use of non-decayed wood eliminated the variation in degree of decay that might be found in existing utility poles. Later, we established tests on western redcedar, western pine and Douglas-fir poles in the Pacific Gas and Electric system near Merced, CA. The poles in this test had existing surface decay and were sorted into treatment groups on the basis of residual preservative retentions. Within several years, we also established similar trials in western redcedar and southern pine poles in Binghamton, New York and southern pine poles near Beacon, New York. In the second test, we altered our sampling strategies in consultation with our cooperators and attempted to better control application rates. The chemical systems evaluated in these trials have varied over the years as a result of corporate changes in formulation and cooperator interest. One other drawback of these tests is that none have been performed under truly high decay hazards. In this section, we describe procedures used to establish a test of currently registered formulations in the Georgia Power system.

Southern pine poles that were in service for at least 10 years were selected for the test. The poles were located in easily accessible right-of-ways to minimize the time required to travel between structures, were treated with oil-based treatments (CCA would interfere with analysis of copper containing systems) and would not have been subjected to prior supplemental surface treatment. Unfortunately, we could not locate poles in the Southern Company system that had not been previously treated. All of the poles in this test had previously been treated with OsmoPlastic in 1980 and/or 1994. While the oilborne components in this formulation will not interfere with future analysis, this system also contains fluoride. This necessitated some prior sampling of poles to assess residual fluoride levels for the poles that were to be treated with the two fluoride containing Osmose formulations. We recognize that it would have been better to have poles that had not received prior treatment; however, this was not possible within the system. Prior treatment can have a number of potential effects. Obviously, residual fluoride can increase the amounts of fluoride found in the test poles; however, we hope to be able to factor this chemical loading out using our pre-treatment sampling. The presence of residual chemical may have other effects on diffusion of newly applied chemicals (potentially both positive and negative); however, this subject has received little attention.

Fluoride levels in poles receiving either Cop-R-Plastic or Pole Wrap averaged 1.18 and 0.96 kg/m^3, respectively, in the outer 25 mm prior to treatment (Table IV-1). These levels are well above the internal threshold for fluoride (0.67 kg/m^3) but still below the level we have traditionally used for performance of fluoride based materials in soil contact (2.24 kg/m^3). Fluoride levels further inward ranged from 0.46 to 0.62 kg/m^3. These levels are at or just below the internal

Table IV-1. Fluoride levels at selected distances from the surface of southern pine poles 10 years after application of a fluoride-containing external preservative system.

Proposed Treatment	Distance from Surface (mm)	Fluoride Level (kg/m^3)
Cop-R-Plastic	0-25	1.18 (1.77)
	25-50	0.46 (0.35)
	50-75	0.53 (0.36)
Pole Wrap	0-25	0.96 (0.89)
	25-50	0.54 (0.25)
	50-75	0.62 (0.28)

threshold. It is clear that we will have to use caution in interpreting the results from these tests. On the positive side, however, the results suggest that some re-examination of the retreatment cycle might be advisable to determine if the period between treatments might be extended.

Poles in the test were allocated to a given treatment and each treatment was replicated on a minimum of 10 poles. An additional 10 poles were included as non-treated controls.

The treatments in this test were:

CuBor (paste and bandage)
CuRap 20 (paste and bandage)
Cobra Wrap
Cop-R-Plastic
Pole Wrap (Bandage)

Each pole was excavated to a depth of 450 mm (18 inches) and any weakened wood was scraped away. The residual circumference of the pole was measured at groundline then the chemical was applied according to the manufacturer's recommendations. In cases where the label allows for a range, it was agreed in the field to use the same thickness for all paste systems (see discussion below). The amount of chemical applied to each pole was determined by weighing the container and brush applicator before and after treatment. The difference was used, along with the surface area to which chemical was applied, to calculate a rate per unit area of pole surface. The treated areas were covered with whatever material was recommended by the manufacturers of that formulation, then the soil was replaced around the pole. In the case of the CuBor, which allows a range of thicknesses to be used, the thinnest paste thickness was used. The remaining systems allow for only one thickness.

Chemical movement from the pastes into the wood was assessed in 5 poles per treatment one year after treatment by removing increment cores from approximately 150 mm below the groundline. A small patch of the exterior bandage and any adhering paste was scraped away, then increment cores were removed from the exposed wood on one side of the pole. The cores were cut into two different patterns. Chemicals containing copper-based biocides were segmented into zones corresponding to 0-6, 6-13 and 13-25 mm from the wood surface. Wood from a given zone from each pole was combined and then ground to pass a 20 mesh screen. Copper was assayed by x-ray fluorescence spectroscopy (XRF). Cores removed from poles treated with boron and fluoride containing systems were cut into zones corresponding to 0-13, 13-25, 25-50 and 50-75 from the wood surface. These segments were processed in the same manner as described for the copper containing cores. Boron was analyzed by extracting the ground wood in hot water, then analyzing the extract using the azomethine-H method, while fluoride was analyzed by neutron activation analysis.

Several months after this test was installed, a number of questions were raised by various cooperators about aspects of the treatment including the application of a pasture wrap to the tops of some poles but not others, the possible interference of prior fluoride presence on the new treatment, and most importantly, the decision to use a single thickness for all of the paste systems. The pasture wrap was apparently offered to all cooperators and is required in the Georgia Power Specification for poles in livestock fields, but was not used on all poles. The effect of this wrap on subsequent paste performance is probably marginal, but we will set up some small scale tests at OSU over the winter to assess possible effects. The potential fluoride interference was a known when the test was established. While we recognize that fluoride levels vary by location in the poles, we believe that, as a composite of the poles in the test, we can develop a correction factor to apply to those poles treated with the fluoride containing systems.

There was considerable discussion about this test at the Fall Advisory committee meeting. After much discussion, it was agreed that we would proceed with the test with the understanding that we would note that the CuBor was applied at the lowest label recommendation, that there were objections to the presence of the original fluoride and that we would continue to assess the effects of variables such as the presence of the pasture wrap on wrap performance. Finally, at the time, the producers of CuRap asked that we not sample their poles in this test. Although they later changed their mind, this decision was made after the one year sample. As a result, no CuRap data will be presented in this report; however, 2 year data will be included in next year's report.

Copper levels in the four copper containing systems ranged from 0.35 to well over 1.5 kg/m^3 in the outer 6 mm (Figure IV-4). Copper levels were highest in the two CuBor systems which use copper hydroxide, while copper levels were lower in the Cobra and CRP systems which both use copper naphthenate. Copper hydroxide is more water soluble than copper naphthenate and might be expected to move more readily into the wood. This increased water solubility might also make it more susceptible to loss over time. Copper levels in the Cobra system were below the threshold for copper naphthenate in soil contact. Copper levels fell off sharply from the 0 to 6 mm segments to the 6 to 12 mm segments for all treatments, particularly with the prepared CuBor bandage. The lack of copper penetration deeper into the wood with the prepared wrap may reflect poor contact between the paste on the bandage and the wood since copper levels in the same system applied in paste form directly to the poles had copper levels in the 6 to 12 mm zone that approached the threshold. Copper levels in the Cobra and CRP treatments were generally low in the 6 to 12 mm zone. Copper levels were low in the zone 12 to 25 mm from the surface for all four systems. The sharp drop-off in chemical loading with distance from the surface is typical of copper based systems, which will tend to migrate for only short distances from the wood surface. Since the primary function of the copper component is surface protection, the immobilization of copper in the outer zone is a useful attribute for these systems.

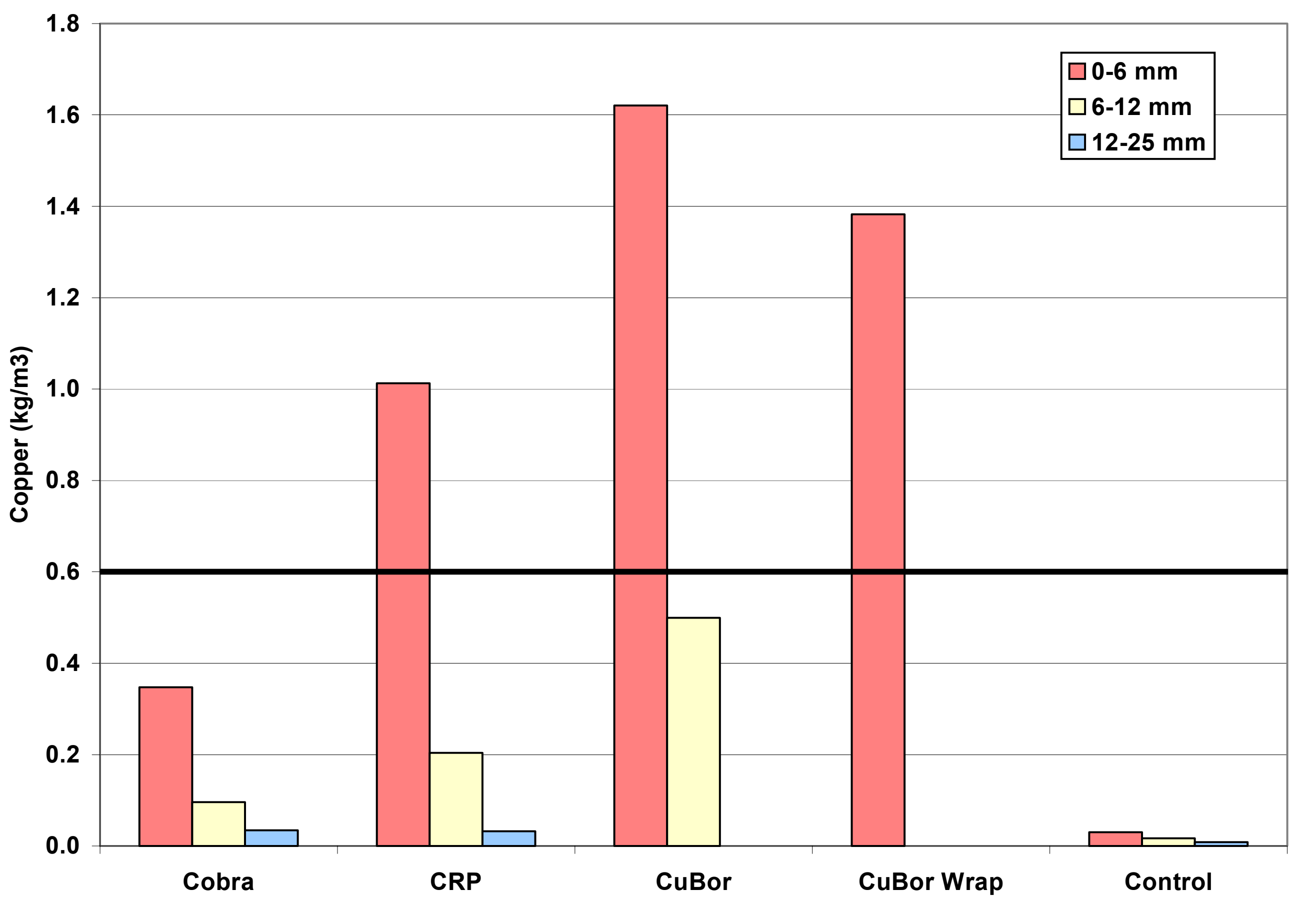

Figure IV-4. Residual copper levels at selected distances from the wood surface 150 mm below groundline on southern pine poles 1 year after treatment with Cobra Wrap, Cop-R-Plastic or CuBor in paste or bandage form.

Boron was a component of the CuBor paste and bandage systems. Boron levels in poles receiving these treatments were well over the threshold for fungal attack in the outer 13 mm of the pole (Figure IV-5). As with the copper levels, boron concentrations were much higher in poles receiving the paste. Once again, the improved preservative contact with the wood would be the reason for the better performance of the paste. Boron levels dropped steadily with distance from the surface, but were still above the threshold 13 to 25 mm from the pole surface with both the paste and the bandage. Boron levels 25 to 50 mm from the surface were also above the threshold for the paste, but not for the bandage and both systems produced boron levels below the threshold 50 to 75 mm below the surface. The results show that boron has moved well into the wood over the first year.

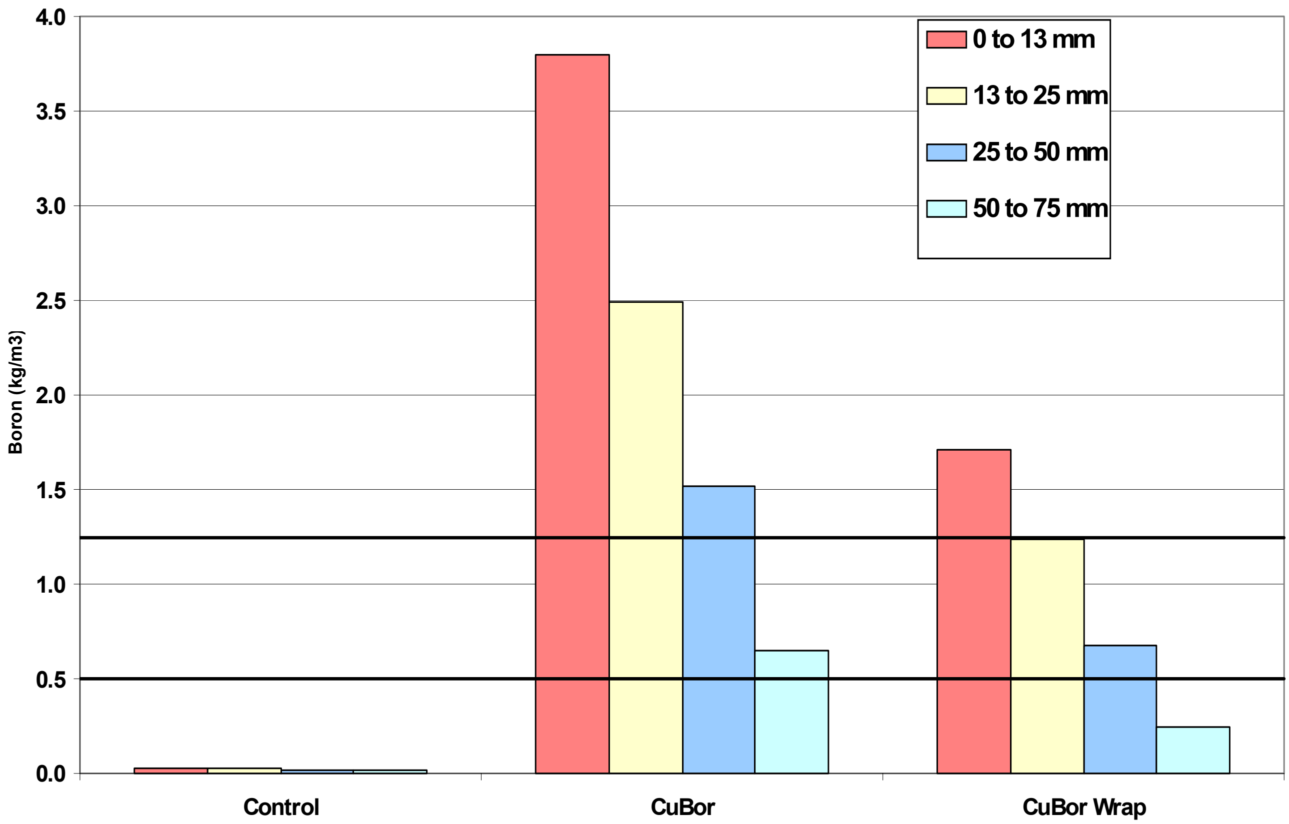

Figure IV-5. Residual boron levels at selected distances from the wood surface 150 mm below groundline on southern pine poles 1 year after treatment with CuBor in paste or bandage form.

Fluoride levels in poles treated with Cop-R-Plastic and Pole Wrap were all well above the threshold from the surface to 75 mm inward (Figure IV-6). As noted earlier, all of the poles in the test had received a fluoride containing groundline treatment (OsmoPlastic) 26 and/or 13 years earlier. Initial sampling indicated that fluoride remained in these poles, albeit at low levels. Fluoride levels in the outer zones of the same poles one year after treatment were 4 to 6 times higher than the background levels. Fluoride levels declined somewhat inconsistently further inward, but levels in all of the zones were above the threshold.

The one year results with all five systems inspected indicate that all of the systems have moved into the wood.

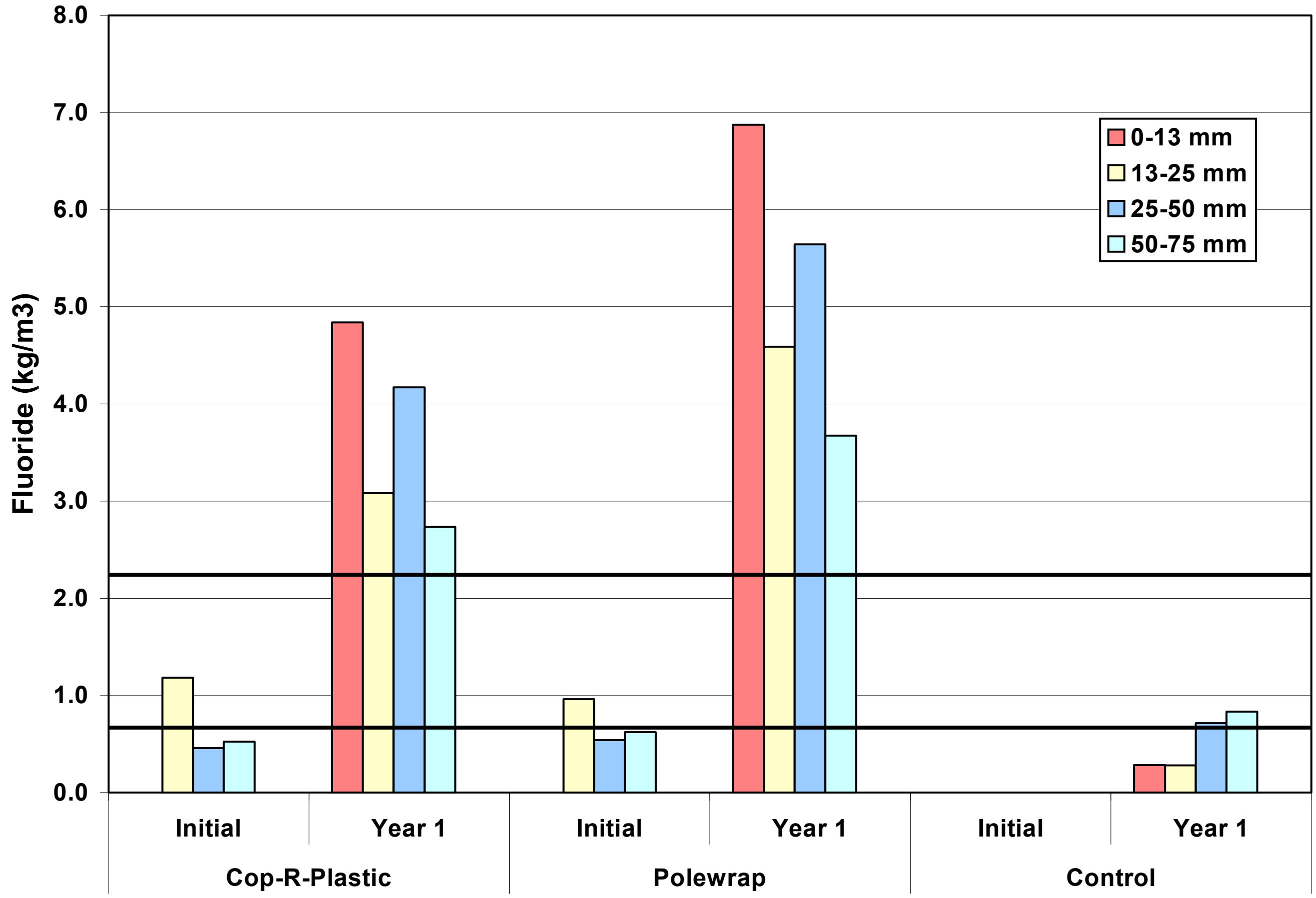

Figure IV-6. Residual fluoride levels at selected distances from the wood surface 150 mm below groundline on southern pine poles 1 year after treatment with Cop-R-Plastic or Pole Wrap.

E. Effect of Moisture Content on Movement of Copper and Boron from CuBor Treated Douglas-fir Sapwood

Over the years, we have established both laboratory and field trials to assess the ability of various external preservative paste components to move into the sapwood of various wood species. The field trials provide excellent long term performance data and, because many of these tests take place on in-service utility poles, the data generated is directly applicable to the utility system. At the same time, the discussion in Section D highlights the problems associated with field tests. To partially address these issues, we have often established laboratory trials of external preservative systems to better understand the rates of chemical movement under more controlled conditions.

Last year, we reported on test results with a copper hydroxide/boron paste tested at two moisture levels. The results from these tests were somewhat confusing and the test is currently being repeated. The results will be included in the next annual report.

F. Develop Thresholds for Commonly Used External Preservative Systems

Over the past decade, we have assessed the ability of a variety of external preservative pastes and bandages to move into treated and untreated wood. While these tests have produced data showing that the systems can move into the wood, one of the short-comings of this data is the difficulty in determining just how much chemical is required to confer protection.

This is a particularly difficult topic because of the groundline environment. In most cases, the wood still has some level of initial preservative treatment present and the goal is to supplement that chemical loading. At the same time, the environment is fairly aggressive and the wood may already be colonized by fungi. Finally, most of the previous data on fungal thresholds has been developed for traditional wood decay fungi, while surface decay below ground is dominated by soft rot fungi. Soft rot fungi tend to be more chemically tolerant and their location within the wood cell wall makes them potentially less susceptible to chemical action. Finally, a number of these systems contain both water diffusible and oil soluble components which move at different rates into the wood.

In previous tests, we have attempted to develop threshold data on diffusible systems using bocks treated with various combinations of preservatives and then exposed in soil burial soft rot tests. These tests have produced extremely variable results, most probably because the chemicals tended to move from the wood during the tests. While this would also happen in service, the changing chemical environment during the test made it difficult to develop reasonable threshold estimates. In an effort to develop this information, we plan to perform the following trial.

Southern pine sapwood wafers (5 by 20 by 30 mm long) were either left uncoated, coated on the cross sections, or coated on all but one wide face with an elastomeric paint that retards moisture movement. The samples will then be treated with selected concentrations of boron or amine copper naphthenate. Following treatment, the samples will be oven dried and weighed.

The samples will then be exposed to soft rot attack in 454 ml glass bottles containing vermiculite, sterile soil, non-sterile soil, sterile soil with a water–sorbing gel or vermiculite mixed with non-sterile soil. The sterile soil treatments will be inoculated with a mixture of common soft rot fungi including *Chaetomium globosum*, *Alternaria alternata*, and *Phialophora fastigiata*. The fungi will be inoculated onto 25 mm square filter paper samples placed on the surface of the media. The test blocks will then be placed directly on this paper or will be buried in the media. The chambers will be incubated at 26 or 32 C for 8, 16, or 24 weeks. At the end of the test period, 6 blocks will be removed from each treatment, oven dried and weighed to determine wood weight loss. The blocks will then be examined for evidence of soft rot attack (as Type 1 cavities or Type 2 erosion), then the remainder the blocks will be ground to pass a 20 mesh screen and analyzed for residual chemical according the appropriate method.

The goal of this first test is to identify the most important variables for a larger scale test using combinations of the various systems.

Objective V

PERFORMANCE OF COPPER NAPHTHENATE TREATED WESTERN WOOD SPECIES

Copper naphthenate has been available as a wood preservative since the 1940's but the real commercial use of this system has only occurred in the last decade, as utilities sought less restrictively labeled chemicals. Copper naphthenate is currently listed as a non-restricted use pesticide, meaning that this chemical does not require special licensing. This has little bearing on the use of preservative treated wood, since there are no restrictions on who can use any of the preservative treated wood products currently on the market (although there are recommended applications for each product); however, some users have sought to soften their environmental image by shifting to alternative preservatives such as copper naphthenate.

Copper naphthenate has provided reasonable protection in a variety of field stake tests, but there is relatively little long term data on western wood species. To help develop this information, we established the following test.

Western redcedar sapwood stakes (12.5 by 25 by 150 mm long) were cut from either freshly sawn lumber or from the outer surfaces of utility poles that had been in service for approximately 15 years. The latter poles were butt treated, but had not received any supplemental treatments to the above ground portion of the pole.

The stakes were conditioned to 13 % moisture content, then weighed prior to pressure treatment with copper naphthenate diluted in diesel oil to produce target retentions of 0.8, 1.6, 2.4, 3.2, and 4.0 kg/m^3. Each retention was replicated on 10 freshly sawn and 10 weathered stakes. The stakes were then exposed in a fungus cellar maintained at 28 C and approximately 80 % relative humidity. Soil moisture was allowed to cycle between wet and dry conditions to avoid favoring soft rot attack (which tends to dominate in soils that are maintained at high moisture levels). The condition of each stake was visually assessed annually using a scale from 10 (completely sound) to 0 (completely destroyed).

Freshly sawn stakes continue to outperform weathered stakes at a given retention level. (Figures V-1, 2). All of the freshly sawn stakes treated with copper naphthenate continue to provide excellent protection after 196 months with even the lower retention still having a rating of 8.0. Weathered stakes tended to exhibit much greater degrees of damage at a given treatment level. Weathered stakes treated to the two lowest retentions had ratings below 6.0. Clearly, prior surface degradation from both microbial activity and UV light tended to sharply reduce the performance of the weathered material. Weathered stakes required almost five times the copper naphthenate to produce a performance level comparable to that found with the lowest retention on freshly sawn wood.

Weathered wood was originally included in this test because the cooperating utility had planned to remove poles from service for retreatment and reuse in other parts of the system. While this process remains possible, it is clear that the performance characteristics of the weathered retreated material will differ substantially from that of freshly sawn material. The effects of these differences on overall performance may be minimal since, even if the outer, weathered wood were to degrade over time, this zone is relatively shallow on cedar and would not markedly affect overall pole properties. The copper naphthenate should continue to protect the weathered cedar sapwood above ground; allowing line personnel to continue to safely climb these poles and any slight decrease in above ground protection would probably take decades to emerge. As a result, retreatment of cedar still appears to be a feasible method for avoiding pole disposal and maximizing the value of the original pole investment.

The results with freshly sawn and treated western redcedar clearly show good performance of this system and these results were consistent with field performance of this preservative on western species. Last year, we had planned to

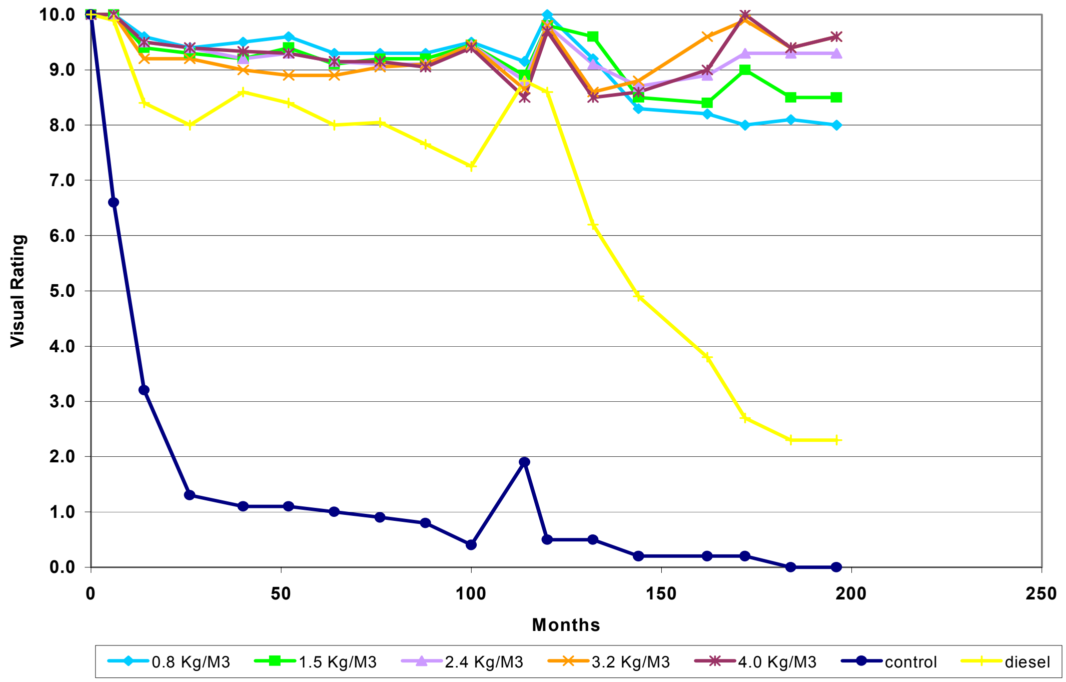

Figure V-1. Condition of freshly sawn western redcedar sapwood stakes treated with selected retentions of copper naphthenate in diesel oil and exposed in a soil bed for 196 months.

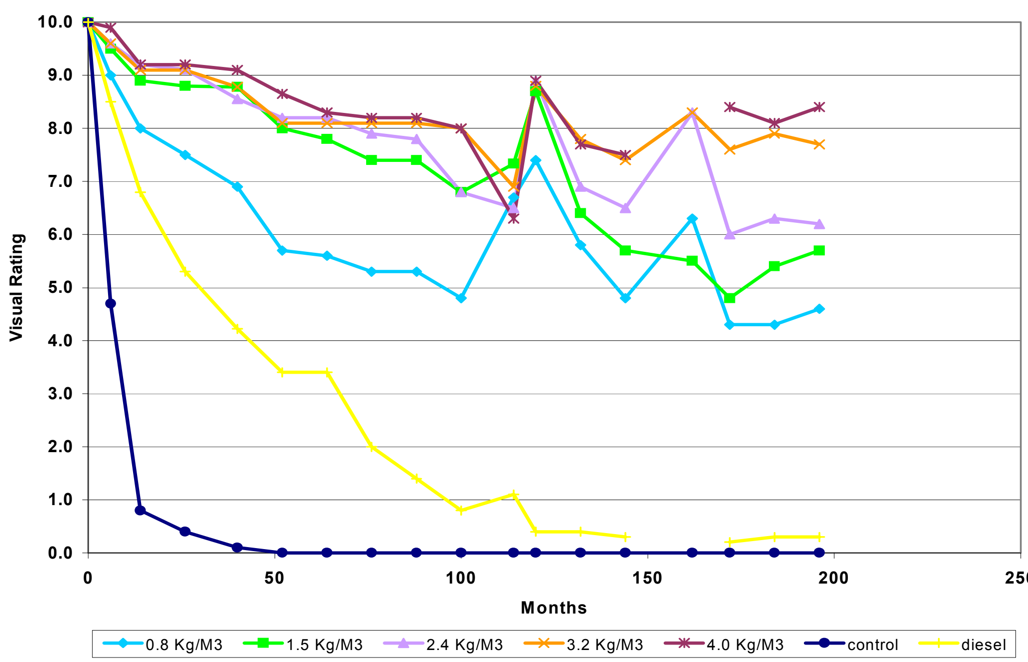

Figure V-2. Condition of weathered western redcedar sapwood stakes treated with selected retentions of copper naphthenate in diesel oil and exposed in a soil bed for 196 months.

inspect 12 to 15 year old copper naphthenate treated Douglas-fir poles located in Northwest Oregon to better assess field performance of this system; however, we have had difficulty locating these poles within the cooperating utility's system. We will endeavor to locate additional poles this coming year.

Objective VI

ASSESS THE POTENTIAL ENVIRONMENTAL IMPACTS OF WOOD POLES

Preservative treated wood poles clearly provide excellent service under a diverse array of conditions, but the increasing sensitivity of the general public to all things chemical has raised a number of questions concerning the preservatives used for poles. While there are no data indicating that preservative treated wood poles pose a risk to the environments in which they are used, it is important to continue to develop exposure data wherever possible. The goal of this objective is to examine usage patterns for preservative treated wood (specifically poles) and to develop exposure data that can be employed by utilities to both assess their use patterns and to answer questions that might arise from either regulators or the general public.

A. Assess the Potential for Preservative Migration from Pentachlorophenol Treated Poles in Storage Yards

In an ideal system, utilities would only receive poles as needed for specific activities; however, most utilities must stock poles of various sizes at selected depots around their system so that crews can quickly access poles for emergency repairs that result from storms or accidents. In previous studies we examined the potential for decay in these stored poles and made recommendations for either regular stock rotation of poles so that no single pole was stored for longer than two to three years, or for a system of periodic remedial treatment of stored poles to ensure that these structures did not develop internal decay during storage. These recommendations were primarily based upon long term storage, but there was little concern about the potential for any preservative migration during this storage period.

The potential for preservative migration from stored poles has received little attention, but could be a concern where large numbers of poles are stored for long periods. Preservative present on the wood surface could be dislodged or solubilized during rain events and subsequent heating in sun could encourage further oil migration to the wood surface. There is, however, little data on the potential for migration of preservative from poles in storage. Treating plants have less concern about this issue because surface water from their sites is already regulated and must be treated prior to discharge (or be shown to contain less than permissible levels). Pole storage facilities, however, are not currently regulated, nor are there recommendations or best management practices that might help utilities minimize the potential for chemical loss.

The purpose of this section was to assess the levels of preservative migrating from pentachlorophenol treated Douglas-fir poles sections subjected to natural rainfall in Western Oregon with the ultimate goal of developing recommendations for pole handling and storage by utilities.

Douglas-fir poles sections (250 to 300 mm in diameter by 1.0 m long) were air-seasoned and pressure-treated with pentachlorophenol in P9 Type A oil to a target retention of 9.6 kg/m^3 in the outer 6 to 25 mm of the poles. Treatment conditions followed the current Best Management Practices as outlined by the Western Wood Preservers' Institute. Following treatment, one end of each pole was end sealed with an elastomeric paint designed to reduce the potential for chemical loss from that surface, while the other end was left unsealed. The idea was to simulate a longer pole section where some end-grain loss was possible, but the amount of exposed end-grain did not dominate the overall surface area exposed. Six poles were then stacked on stainless steel supports in a stainless steel tank designed so that all rainfall striking the poles would be captured. The poles were set 150 mm above the tank bottom to reduce the risk that the wood would be submerged and, therefore, have the potential to lose more chemical. The poles were then exposed outside the Richardson Hall laboratories where they were subjected to natural heating and rainfall. We allowed this system to operate for approximately 1 year, then we removed the poles, cleaned the system and reset the tank so that different pole surfaces were exposed.

Three pole configurations have been examined using this system (Figure VI-1). These configurations were designed to vary the surface area exposed directly to rainfall. We altered our design to produce varying amounts of exposed treated wood after it appeared that penta water solubility was the primary factor in runoff concentrations.

a.

b.

Figure VI-1. Photo showing the two 6 pole configurations a.) configuration 1, b.) configuration 2, and c.) the 4 pole configuration evaluated in our small scale preservative migration chamber.

c.

Figure VI-1. Photo showing the two 6 pole configurations a.) configuration 1, b.) configuration 2, and c.) the 4 pole configuration evaluated in our small scale preservative migration chamber.

The tank was sampled whenever there was measurable rainfall by draining all of the water collected in the tank bottom as soon as possible after the rainfall event had concluded, or daily when storms continued for more than one day. In some cases, the rainfall, while measurable, did not result in collectible water samples because the conditions were so dry prior to rain that the falling moisture was either sorbed by the wood or evaporated. In addition, early in the process, it became obvious that debris (primarily leaves) was falling into the tanks between collections. Since these materials had the potential to sorb any chemical solubilized by the rainfall, we placed a large mesh screen around the tank to limit the potential for debris entering the tank, while still allowing rainfall to strike the wood.

Tank sampling involved collecting all liquid and weighing this material. Approximately 230 ml of this material was then retained for penta analysis. Two extractions were required for the separation of PCP from an oil contaminated aqueous environment. The aqueous sample, or filter solid, was first adjusted to a high pH with sodium hydroxide to form pentachlorophenate anion in the aqueous phase. An extraction with iso-octane then removed the petroleum oil residues from the water phase, leaving the PCP in the aqueous phase. The water phase was then acidified, converting the pentachlorophenate back to pentachlorophenol. A second extraction with iso-octane now removed the PCP from the aqueous phase. This second extraction was analyzed for PCP content using high resolution gas chromatography with low resolution mass spectrometer detection system (HRGC-LRMS).

Reagents

a. DI water: Deionized water from Richardson Hall DI water line
b. Sodium Hydroxide: VWR, reagent grade
d. Hydrochloride acid: JT baker, Baker analyzed
e. Ethanol: McCormick, absolute-200 proof
f. Iso-octane: Fisher, Optima grade
g. Methanol: Fisher, HPLC grade
h. Pentachlorophenol: Aldrich, 98%
i. [$^{13}C_6$] labeled Pentachlorophenol: Cambridge Isotope Laboratories 99%, internal standard (IS)
j. P9A oil (Imperial): Shell, 124 process

Extraction from base: A 50 ìL portion of 200 ìg/mL IS was spiked into the two volumetric flasks. Then 2.4 mL 0.1N NaOH was added to each of the two flasks using an Oxford pipette yielding a pH of approximately 11. Water was added to bring the total volume to the bottom of the neck of the volumetric flask. The flasks were placed on a stirring plate. The stirring speed was increased until a vortex was obtained and continued for 1 minute. The flasks were then allowed to stand for 30 minutes, after which 2.4 mL of iso-octane was added to the #1 flask using a bottle top dispenser. Both flasks were stirred for one minute. The solvent layer was removed with a disposable glass pipette and discarded. The stirring and separation were repeated; except the stirring time was reduced to 30 seconds and 2.0 mL iso-octane was added. After the second separation, the weight of the two flasks was recorded. A 3 mL of aqueous solution was removed with an Oxford pipette.

Extraction from acid The solutions were acidified to a pH of approximately 3 by adding 3 mL of 0.5M H_2SO_4 to the flask with an Oxford pipette. The flask was stirred for 1 minute and allowed to stand for 30 minutes, then 2.4 mL of iso-octane was added. The flask was stirred for one minute. The extract was collected using a new glass pasture pipette and transferred to a 20 mL HRGC-LRMS vials. The procedure was repeated, except using 2.6 mL of solvent and 30 seconds stirring. The second extract was transferred to the same vial as the first and mixed.

HRGC-LRMS analysis: The HRGC-LRMS analysis was carried out on a Shimadzu HRGC-LRMS system class 5000 with injector AOC-17 and capillary column XTI-5 from Restek. This column is composed of fused silica with a 0.25 ?m thick film of 95% dimethyl, 5% diphenyl polysilarylene. The column dimensions were 0.25 mm ID X 30 m long.

HRGC parameters

Carrier gas: Helium grade 5.0
Flow rate: 1.2 mL/min
Split rate: 5
Injector temperature: 250°C
Detector interface temperature: 280°C
Temperature program: 2 min. hold, 35°C to 260°C at 25°C/min
Injection volume: 1 µL
Solvent wash: methanol

The National Institute of Science and Technology (NIST) Mass Spectral Library #107 software was installed on the system. The PCP standard (50 ìg/mL) and [$^{13}C_6$] PCP internal standard (50 ìg/mL) were scanned and identified by the Library search function of the HRGC-LRMS instrument. The retention time for PCP was 9.70 min. The selected ion for PCP quantitative analysis was m/z = 266, the reference ions were 264 and 268. The selected ion for the internal standard [$^{13}C_6$] PCP was m/z = 274, the reference ions were 276 and 172.

HRGC-LRMS auto-tuning was performed with perfluorotributlyamine. The calibration was carried out with PCP concentrations of 0.1, 0.2, 0.5, 1.0, 2.0, 5.0, 10.0, and 20.0 ug/mL; 2 ug/mL IS was added for each standard solution or sample. Five point calibration was employed, i.e., for each single batch a minimum of 5 consecutive standards were selected depending on the range of concentration of the samples.

Each sample was diluted to bring the PCP concentration into the selected calibration range. Linear regression software was chosen for the calculation of the calibration curve.

The volume of water collected was measured by weight. A density of 1.00 g/mL was used for water. The limit of detection (LOD) of this method was estimated to be 0.025 ng/mL cm^2. The LOD is defined according to Part 136, Appendix B, procedure (b) (Federal Register, 1984), as three times the standard deviation of replicate analyses of the analyte.

We quantified penta in the runoff on a ug/mL of runoff basis, then used these values to assess the amount of runoff in ug/ml/cm^2 of exposed surface area. Exposed surface area was quantified by observing poles during several rainfall events. We noted that water did not always run around poles, but instead struck the pole surface, then dripped off the edges to strike the pole below. As a result, much of the pole surface was not in direct contact with the rainfall. We combined these surface area measurements with the surface area exposed on the non-sealed end of each pole to produce a total exposed area per tank, then divided this area by the total tank area. These values for Configurations 1, 2, and 3 were 79.5, 59.6 and 79.5 % of the total tank area, respectively. These values were then used to express runoff values on a ug/ml/cm^2 basis.

Penta levels in runoff from the stored poles in the original 6 pole alignment ranged between 1 and 2.5 ug/ml of water over 62 rainfall events (Figure VI-2). Penta levels in the runoff from the first 6 rainfall events were lower than almost all

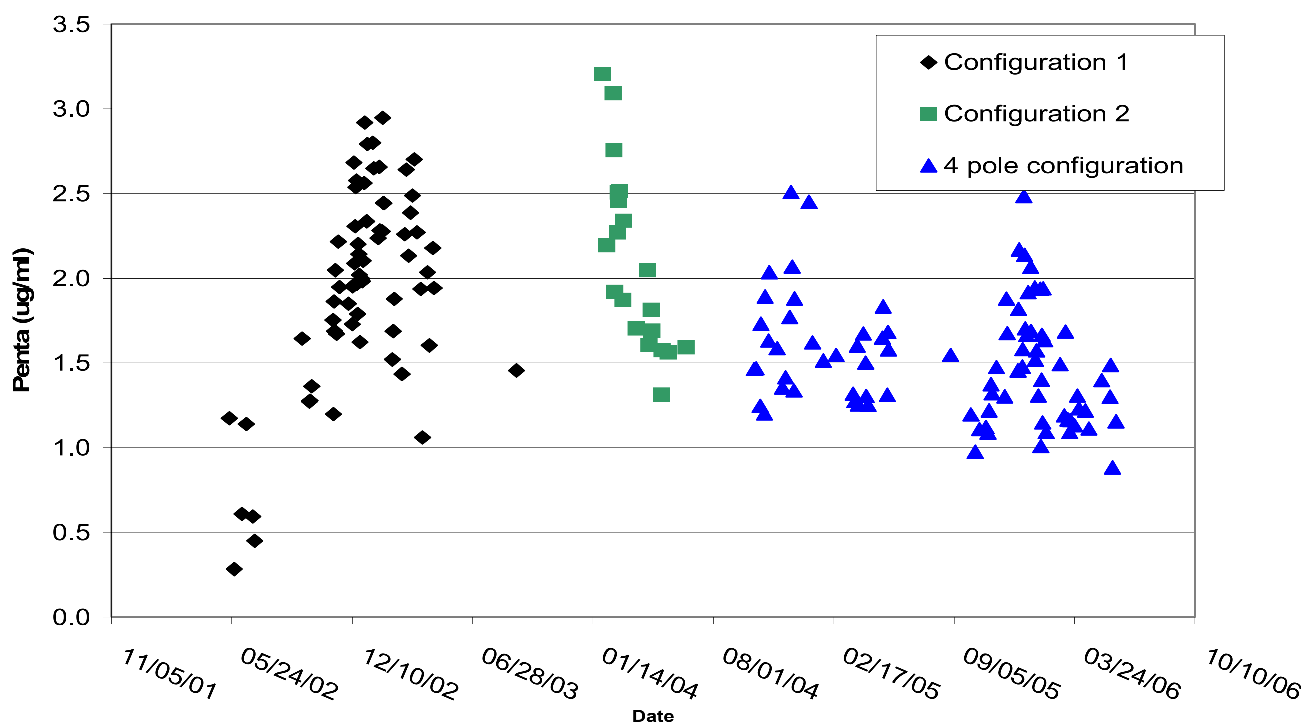

Figure VI-2. Penta concentrations as a function of sampling date in leachate collected from penta treated Douglas-fir poles following rainfall events over a 4.5 year exposure period showing data for three stacking configurations of poles.

other samples; however, there was a delay in analysis of these samples and we believe the lower levels were due to degradation or sorption of the penta during storage time. The remaining samples were processed within 3 days of collection, limiting the potential for degradation or loss in storage. The relatively narrow range of concentrations suggests that penta solubilization in rainwater is relatively predictable. Penta levels in the runoff from 13 rainfall events for the realigned 6 pole stack were slightly higher than those in the original 6 pole stack (2.3 to 2.9 ug/ml of water) (Figure VI-2), but the differences were small. The penta levels in the 4 pole array were similar to those found with the first two configurations, ranging from 0.8 to 2.6 mg/ml of water. The four pole configuration exposed a slightly lower surface area to direct rainfall, but did not have excess area beneath the directly exposed samples on which the resulting runoff water could strike the wood.

In addition to the apparent lack of concentration change with time or pole configuration, the total amount of rainfall did not appear to affect the runoff concentration for any of the three pole stack configurations. Instead, increased rainfall was associated with an overall increase in total penta migration, but the runoff concentrations did not vary (Figure VI-3). These results suggest that migration from the poles is a function of water contact with the pole and penta solubility in the rainwater. The similarity in runoff concentrations over time suggests that losses can be predicted based upon the rainfall amounts and total surface area exposed to direct rainfall to some limit (i.e. at some point penta concentrations would reach saturation and increasing pole surface area would not impact subsequent levels).

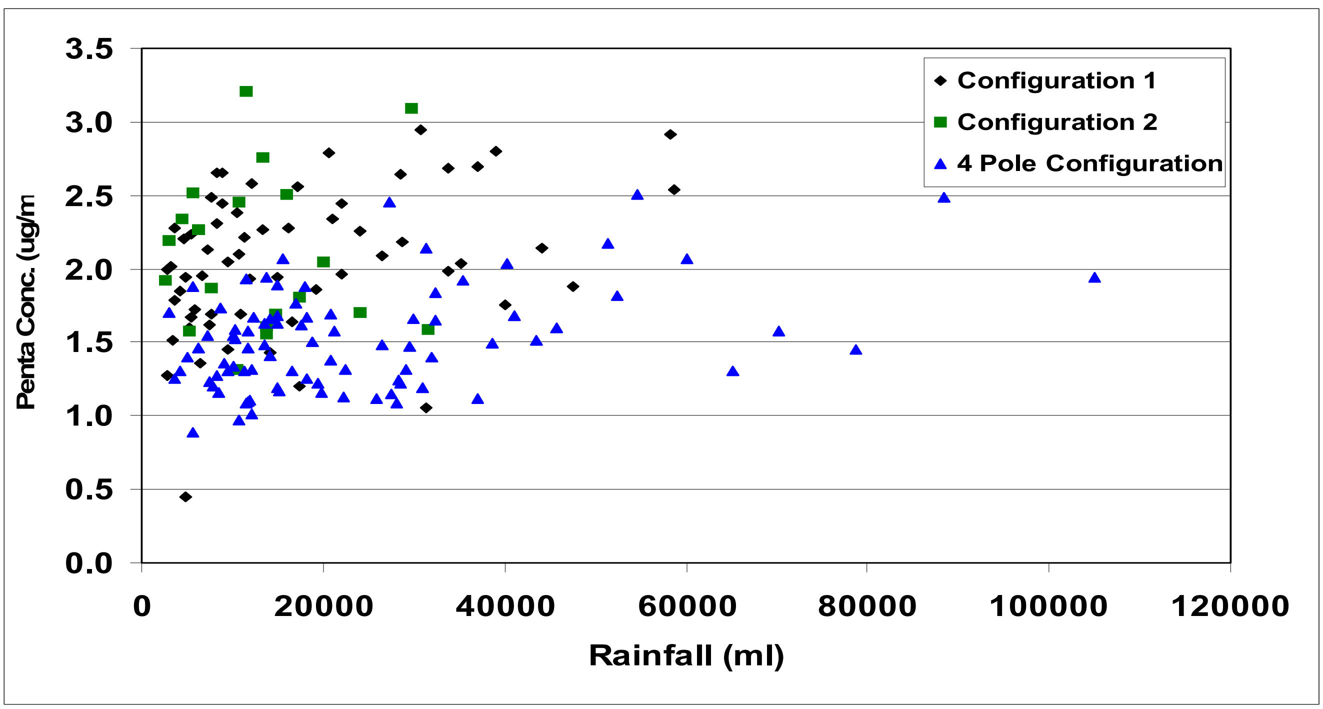

Figure VI-3. Penta concentrations as a function of total amount of rainfall collected in leachate from penta treated Douglas-fir poles following rainfall events over a 4.5 year exposure period showing data for three stacking configurations of poles.

Another factor that was assessed was whether time between rainfall events affected penta concentrations in the runoff. Long term storage in the absence of precipitation might allow chemical to migrate to the surface, where it would be more prone to migration. Once again, however, the time between rainfall events appeared to have little effect on runoff concentration (Figure VI-4). This effect is clearly illustrated by the final sampling of the 6 stack configuration in September 2003 where the previous measurable rainfall event was 5 months prior to the sampling, yet runoff concentrations were similar to those found in the wet season.

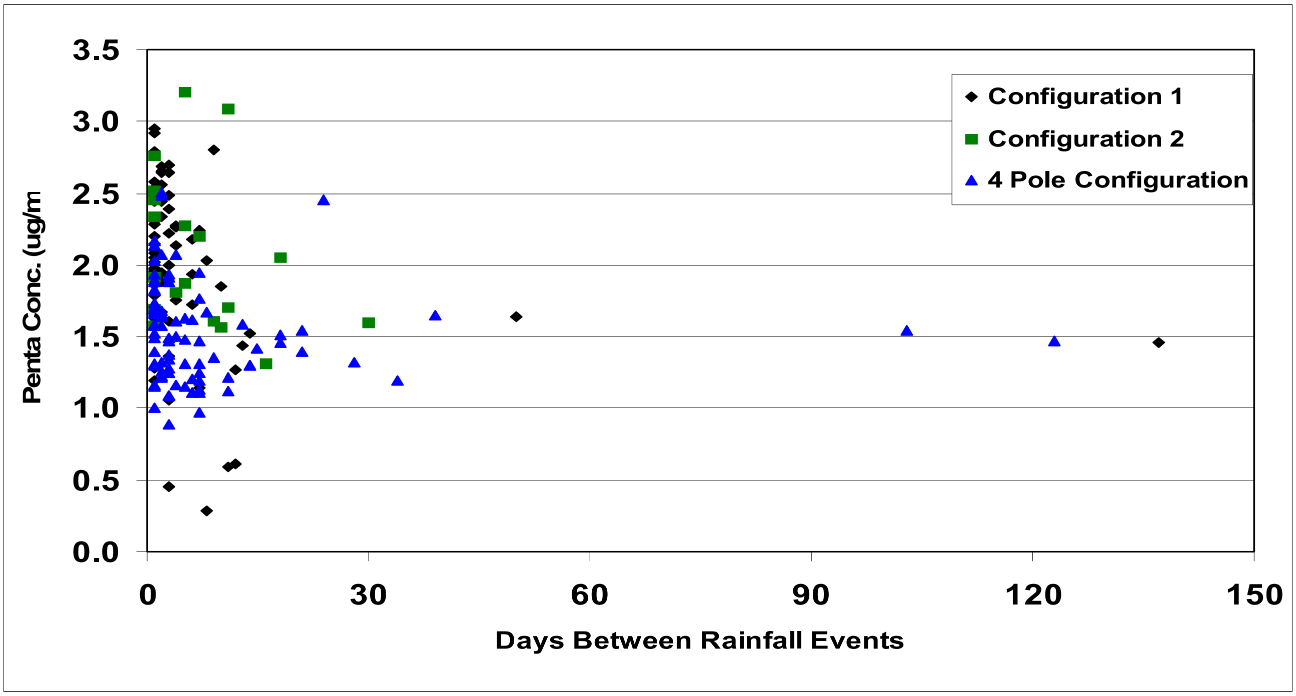

Figure VI-4. Penta concentrations as a function of intervals between collections (# of dry days) in leachate collected from penta treated Douglas-fir poles following rainfall events over a 4.5 year exposure period showing data for three stacking configurations of poles.

A similar lack of a time between rainfall events effect has been noted in the two other summer dry periods. These results suggest that penta migration from poles is affected more by the exposed surface area and total rainfall than other environmental factors such as temperature. The total area exposed on the pole sections in the 6 pole configuration was approximately 6.21 square meters including the ends. A large proportion of this surface was on the underside of the poles and was not actually exposed to rainfall. While small streams of water flowed over these under-surfaces, the actual area exposed to potential rain contact was estimated to be approximately 5.3 square meters. If we convert our 6 short pole sections to 6 Class 4 forty-foot poles, we would multiply our total penta losses by approximately 12 to arrive at the amount of migration from these poles. We collected a total of 1910 mg of penta from all of the rainfall events. This would translate to a total of 22.9 g of penta for the poles over the past year. A typical Douglas-fir pole would contain approximately 2.89 kg of penta (calculated by considering 25 mm thick treatment zone and multiplying this volume by an assumed 9.6 kg/m^3 retention) and the 6 poles would contain 17.34 kg of penta. This translates to a loss of 0.13 % of the total available penta in the approximately 1.5 year exposure period.

An additional factor to consider in these calculations is the potential flow path of water on poles in solid piles. In our first two tests, the poles were stacked in tiers which tended to protect the lower poles from wetting. In a larger stack, this protective effect would be even greater. Thus, it may be possible to examine the potential for loss on the basis of the exposed upper portions of the stack rather than considering all the poles in an individual stack.

Evaluation of penta in the runoff on the basis of exposed pole area clearly showed that configuration can make a difference with regard to runoff per event (Figure VI-5 and VI-6). Factoring runoff on a total pole area basis produced a nearly 50 % reduction in concentration per ml of runoff per unit pole area. Our observations suggest that runoff is neither on all pole surfaces nor merely on the upper exposed faces. Precipitation runs along pole surfaces and the patterns of water flow change seasonally. For example, the first rainfalls after our dry summers tend to run to the pole edges then drip downward. In later rainfall events, the poles were wetter and, therefore less water repellent. The water at these times can run around the pole. It is difficult to tell whether this has any effect on maximum penta concentration in the runoff; however, prior rainfall tests on penta treated lumber suggest that maximum penta concentrations in runoff water are achieved quickly and any additional wood/water contact does not measurably increase penta concentrations. As a result, using exposed wood surface area is probably a very conservative approach for estimating total penta in runoff from stored poles.

The evaluations clearly show that penta can migrate from stored poles, a finding supported by previous studies of lumber exposed in aquatic environments. Unlike aquatic environments however, the migrating chemical winds up in the soil beneath the poles where it can be trapped and slowly degraded. There is also the potential for application of absorbent materials beneath the storage area to capture any migrating chemical. These materials could then be removed from the site once the operations are completed. As a result, the loss of chemical should have minimal impact on the surrounding environment.

Our data also suggests that stacking poles to minimize the area exposed to rainfall is probably an effective approach to limiting preservative migration. Spreading poles out allows more rainfall to strike pole surfaces, solubilizing a proportionally higher total amount of penta. In addition, pole rotation (i.e. last in, first out inventory approaches) does not appear to affect losses which appear to be largely driven by the solubility of penta in water. In previous studies we have advocated for regular rotation of stored poles to avoid the development of deep checks and limit the potential for internal decay development during prolonged storage. Our current findings should not affect that recommendation.

We will continue our tests using poles treated with ammoniacal copper zinc arsenate using the WWPI Best Management Practices. These poles were installed in October and have only been monitored for a few weeks. The results will be reported in the next Annual Report.

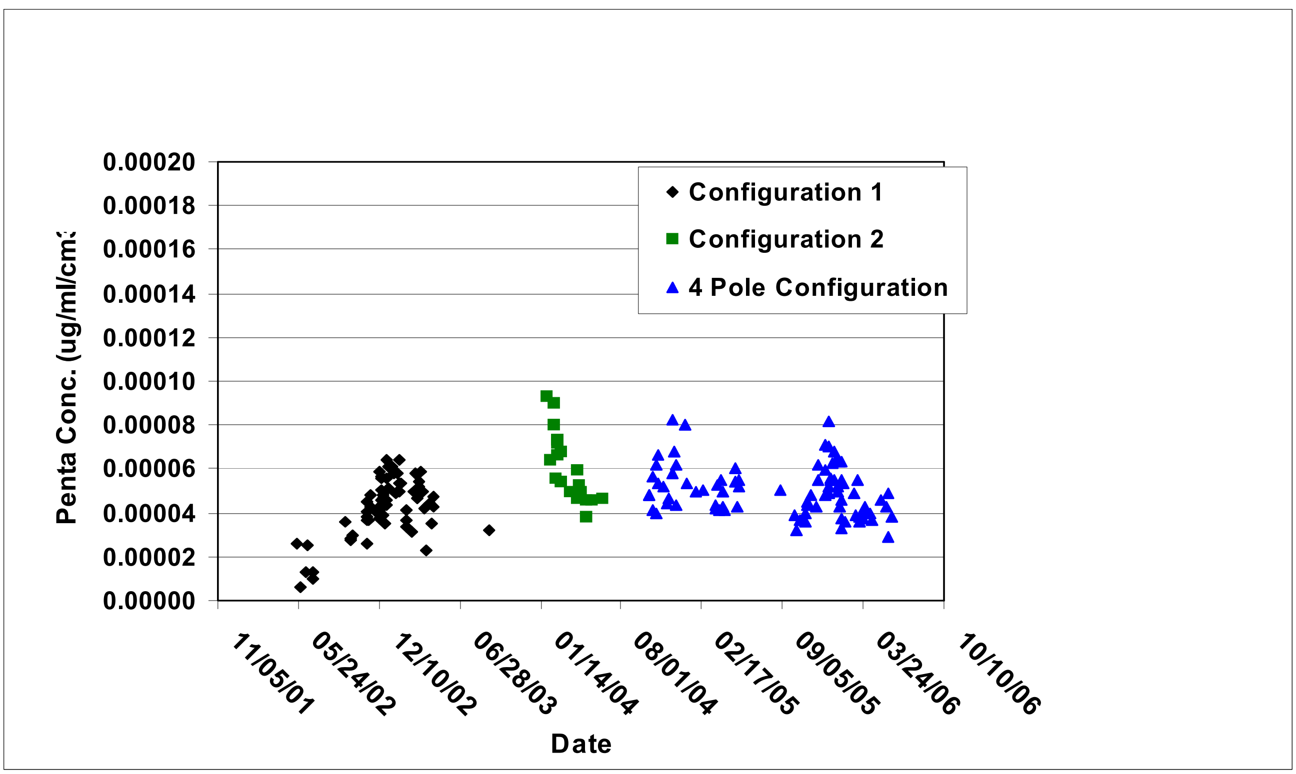

Figure VI-5. Concentration of pentachlorophenol in rainfall runoff from pentachlorophenol treated Douglas-fir pole sections stored in three stacking configurations as a function of total pole surface area.

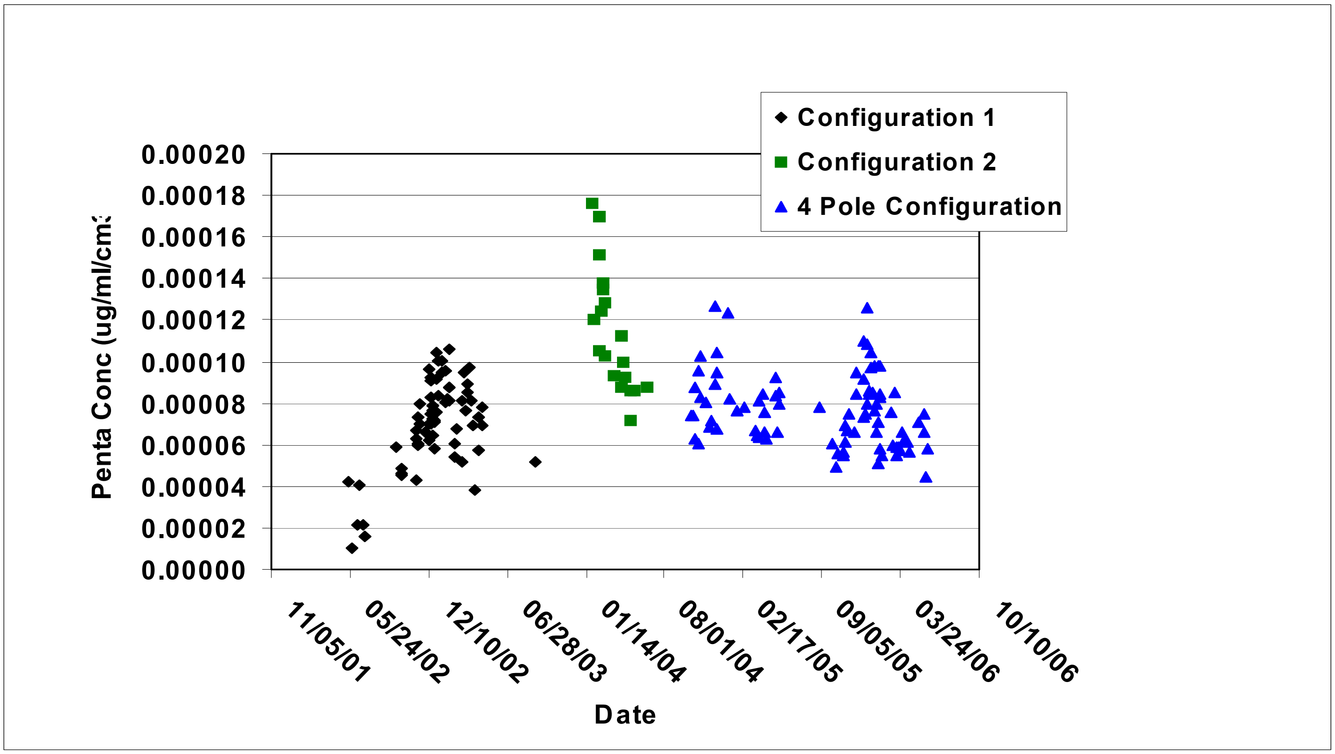

Figure VI-6. Concentration of pentachlorophenol in rainfall runoff from pentachlorophenol treated Douglas-fir pole sections stored in three stacking configurations as a function of only pole surface area exposed to direct rainfall.

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