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Department of Forest Products

OREGON STATE UNIVERSITY

COLLEGE OF FORESTRY

By:

J.J. Morrell
C. Freitag
R. Rhatigan
C. Love
M. Mankowski

Cooperators

* Bonneville Power Administration
* Central Hudson Gas and Electric
* CSI, Inc.
* Dr. Wolman, GMBH
* Hickson, Inc.
* ISK Biotech
* New York State Electric and Gas
* Osmose Wood Preserving, Inc.
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* Pacific Corp.
* Portland General Electric Company
* Rochester Gas and Electric
* Western Wood Preservers Institute

PERSONNEL

ADVISORY COMMITTEE

James Cahill, Bonneville Power Administration
Chris Damaniakes, Pacific Gas & Electric
Moira Fry, Pacific Gas and Electric Co.
Randy Gross, ISK Biotech
Dennis Hayward, Western Wood Preservers' Institute
Manfred Jung, Dr. Wolman GMBH
Al Kenderes, New York State Electric & Gas Corp.
Sunni Miani, Portland General Electric Company
Nick Ong, Pacific Power
Alan Preston, CSI, Inc.
Tim Wandell, Portland General Electric Company
Rich Ziobro, Osmose Wood Preserving, Inc.

RESEARCH

Principle Investigator:

Jeffrey J. Morrell, Professor, Department of Forest Products (Wood Preservation), Oregon State University

Research Associates:

Theodore C. Scheffer, Forest Products, (Forest Products Pathology) (Retired)

Visiting Scientists

Dongyi Cun, Kunming Animal and Plant Quarantine Bureau, PRC
Georg Oberdorfer, Austria

Research Assistants:

Hua Chen, Department of Forest Products, Oregon State University
Camille Freitag, Department of Forest Products, Oregon State University
Connie Love, Department of Forest Products, Oregon State University
Ron Rhatigan, Department of Forest Products, Oregon State University

Graduate Students:

Sung Mo Kang, Ph.D., Department of Forest Products, Oregon State University
Mark Mankowski, Ph.D., Department of Forest Products, Oregon State University
Ying Xiao, Ph.D., Department of Forest Products, Oregon State University

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INTRODUCTION

Wood poles have provided long, reliable and economical support for electric and telecommunication systems around the world. Like any material, wood can be degraded by both physical and biological agents. For decades, utilities understood that their poles decayed, but had few methods for effectively preventing or arresting this damage. Developing effective methods for slowing or preventing this degradation to improve safety, while enhancing reliability and reducing costs has become a major concern for most utilities. The Utility Pole Research Cooperative (UPRC) at Oregon State University was begun by a group of utilities, chemical companies, and wood treaters who recognized that they had similar interests with regard to the proper use of wood. The Coop began with three primary foci: fumigant development, determining the effects of air-seasoning on wood pole quality, and identifying pentachlorophenol replacements. It has evolved over the intervening 20 years to address a host of other issues germaine to utility operation. In this report, we describe results under five objectives.

I. Develop safer chemicals for controlling internal decay of wood poles

II. Identify chemicals for protecting exposed wood surfaces on poles

III. Evaluate properties and develop improved specifications for wood poles

IV. Performance of external groundline preservatives

V. Performance of copper naphthenate-treated western wood species

This report summarizes the progress made in each objective over the past 12 months.

SUMMARY

Field trials to assess the effectiveness of various internal remedial treatments are continuing. Field tests of basamid alone or amended with various copper compounds indicate that the copper naphthenate markedly increased the initial rate of MITC production. This increased initial rate may produce more rapid control of fungal attack, reducing the potential for wood strength losses.

Field trials of both boron/fluoride and fluoride rod formulations continue to show that the resulting chemical levels produced from these systems fall below the reported thresholds for preventing fungal attack in most locations. The exceptions are the near groundline areas, where moisture appears to be sufficient for chemical diffusion. Laboratory trials of both fluoride and boron, however, suggest that the reported thresholds may be a bit high for internal decay control. Both fluoride and boron have proven to be far more effective in non-leaching, non-soil exposures than would be suggested by previous lab trials. These results imply that boron and fluoride may be effective remedial treatments at lower retention levels than previously considered. Further evaluations are planned.

Previous field data on the activity of MITC-FUME on southern pine and Douglas-fir poles 10 years after chemical application suggested that few fungi were isolated from poles when the wood contained more than 5 ug/oven dried gram of MITC. For many years, we have used a conservative 20 to 25 ug/g oven-dried wood as a target level for MITC in wood. The isolation data would seem to reinforce the value of this conservative approach and provides a realistic target chemical level for determining when retreatment is advisable.

We continue to explore alternative treatments for protecting field damage of pressure treated wood. Our data continues to show that simple applications of boron or fluoride markedly reduce the rate at which fungi invade wood. Simple activities like kerfing can further reduce this risk.

The survey of utility specification, inspection, and remedial treatment practices was completed. It showed that most utilities were satisfied with the treatments they currently employ. The survey also showed that most utilities continued to rely on simple inspection methods and had not adopted many of the newer, non-destructive inspection techniques. Finally, the results suggested that most utility personnel charged with maintaining systems lacked formal training in wood as a material and depended upon short course, conferences, and suppliers for information on specifications.

Evaluation of samples removed from the poles subjected to simulated grass fires last year indicated that most had lost slight amounts of pentachlorophenol in the outer shell, but the remaining levels were still above those considered to be required for protection against fungal attack.

The evaluation of data from various NDE devices in comparison with full scale bending tests was completed. In general, the various devices and calculating tools tended to over-predict pole strength In addition, the correlations between actual and predicted strength were generally poor (r^2<0.6) even when the outputs from several devices were used to develop the predicted strength.

These results suggest that the various inspection tools should be considered as supplemental to conventional sounding and boring processes.

Inspections of the above ground regions of older distribution poles in the mid-Willamette Valley of Western Oregon suggested that many poles had experienced some above ground decay at some point along their length. In most cases, however, it was difficult to isolate active decay fungi from the wood. In addition, most of the decay appeared to be concentrated between the groundline and the first bolt hole or other connector. The lower levels of decay higher on the poles reflected the specifications of the cooperating utility, which included extensive pre-boring for attachments.

Studies are also underway to better understand the biology of carpenter ants in relation to the damage they cause on utility poles. Laboratory trials suggested that carpenter ant queens were capable of initiating new colonies in dry wood, but were incapable of rearing young in western redcedar. These results suggest that colonies in cedar may be satellites of colonies in other wood away from the pole. The ability to establish new colonies in the drier zones of poles give carpenter ants a decided advantage in attacking poles in service. Further tests are underway.

Moisture in poles in service has important implications on both material properties and the potential for the development of fungal and insect attack. Moisture levels in Douglas-fir and western redcedar poles were assessed at selected heights above ground. Moisture levels near the surfaces of both species were fairly high, and increased slightly with distance inward. Moisture levels were highest in butt treated western redcedar, suggesting that the absence of an oil treated shell enhanced moisture movement in the heartwood. The implications of a higher moisture content in a naturally durable heartwood species are unclear. Further assessments are underway to develop seasonal moisture distribution data.

Field trials of copper/boron/ copper, boron/fluoride and propiconazole based wraps produced mixed results. Chemical levels in both of the copper-based systems followed a reverse gradient. Further sampling is underway to determine if these results are representative. Propiconazole followed a typical gradient of declining levels inward from the surface. All propiconazole levels measured within the outer 25 mm of the surface were well above the threshold for fungal attack, indicating that this chemical has moved well into the wood. Laboratory tests of these same chemicals are also underway to better assess the effects of moisture content on chemical movement.

Fungus cellar trials of copper naphthenate treated western redcedar stakes continue to show that this chemical has provided excellent protection against fungal attack. Stakes that were cut from weathered western redcedar sapwood continue to provide lower levels of protection than stakes cut from freshly sawn wood, but both sets of samples are performing well at the currently specified retention levels.

OBJECTIVE I
DEVELOP SAFER CHEMICALS FOR CONTROLLING INTERNAL DECAY OF WOOD POLES

Internal decay is an important problem for many in service Douglas-fir and western redcedar poles. In Douglas-fir, this decay normally develops as drying checks open beyond the depth of initial preservative treatment, permitting the entry of moisture and spores into the untreated heartwood. Decay in western redcedar is most likely a combination of survival of decay fungi that were present in the standing trees and fungi that invaded through drying checks once the poles were placed in service. The development of safe, effective treatments for arresting this attack has been an important component of the Coop. This research has been divided into two approaches: volatile gases that can move through the normally impermeable wood to arrest fungal attack or water diffusible systems that move with moisture in the wood to the points where decay is occurring.

A. Develop Improved Fumigants for Control of Internal Decay

Fumigants were initially identified as remedial internal treatments through joint work by Bonneville Power Administration and Oregon State University which identified chloropicrin, metham sodium and Vorlex as capable of arresting internal decay of Douglas-fir poles within one year after application. More importantly, these treatments remained in the wood to protect poles for periods ranging from seven to 20 years. These results encouraged wide adoption of fumigant application in the specifications of utilities that had western redcedar and Douglas-fir within their systems. While these chemicals were highly effective, they had objectionable handling properties. Chloropicrin is extremely volatile, making it difficult to work with. Metham sodium causes skin burns and is highly toxic to fish. Vorlex was also highly toxic to fish and was difficult to handle. These handling properties encouraged a search for alternative fumigants. The two that have emerged from this search have been methylisothiocyanate (MITC) and basamid. MITC is a solid at room temperature, but must be encapsulated for safe handling. Field trials with MITC showed that it rapidly controlled established fungi and prevented reinvasion for seven to 12 years. MITC is sold as MITC-FUME, an aluminum encapsulated system that has been available for nearly 10 years. Last year, we reported on the 10 year performance of this system in Douglas-fir and southern pine poles. MITC-FUME appears to provide more protection than metham sodium, but less than the more volatile chloropicrin.

Basamid is a crystalline powder that decomposes in the presence of water to produce MITC and a range of other compounds. This formulation has only recently been registered. In this report, we describe two field trials with Basamid.

<u>1. Effect of copper naphthenate on performance of Basamid in Douglas-fir poles</u>

Previous field tests have shown that copper sulfate markedly increased the release of MITC from Basamid. One drawback to the use of copper sulfate for this purpose, however, is that it is not labeled for wood application. One alternative to copper sulfate is copper naphthenate, which is widely used as a topical treatment of an array of wood products. Copper naphthenate, however, is an oil-based system, while copper sulfate is water soluble. We were concerned that the oil-based formulation might not have the same effect on basamid decomposition and established the following test to evaluate the ability of this chemical to enhance basamid performance.

Douglas-fir poles (250-300 mm in diameter by 3.0 m long) were pressure-treated with pentachlorophenol, then set in the ground to a depth of 0.6 m at the Corvallis test site. Three steeply angled holes were drilled beginning at groundline and moving upward 150 mm and around the pole 120 degrees. Two hundred grams of Basamid was equally distributed among the three holes. One set of three poles received no additional treatment, three received 20 g of copper sulfate and three others received 20 g of 2% (as Cu) copper naphthenate. The treatment holes were then plugged with tight fitting wood dowels.

The poles were sampled one and two years after treatment by removing increment cores from three equidistant points around each pole at sites 0.3, 1.3, and 2.3 m above the groundline. The outer and inner 25 mm of each core was placed into 5 ml of ethyl acetate and extracted for 48 hours at room temperature. The core segment was then removed, oven-dried (60 C) and weighed. The extract was analyzed for MITC using a Varian 3600 Gas Chromatograph equipped with a flame photometric detector with filters specific for sulfur. The remainder of each increment core was briefly flamed and placed on the surface of 1.5 % malt extract agar. These cores were observed for evidence of fungal growth which was examined for characteristics typical of basidiomycetes, a class of fungi containing many important wood decayers. The resulting isolates were then classified as either "decay" or "non-decay" fungi.

Fumigant levels were generally elevated near the groundline and declined with distance above that zone. MITC levels tended to be slightly higher in poles treated with either copper compound (Table I-1). MITC levels differed little between the two copper compounds, suggesting that the oil did not interfere with the copper-basamid interaction. This suggests that a small amount of copper naphthenate could be added to the treatment hole prior to plugging to increase the rate of MITC release.

Fungal isolations revealed that decay fungi were present in one pole treated with copper naphthenate and two poles treated with copper sulfate (Table I-2). Decay fungi were absent from the copper naphthenate treated poles two years after treatment. The isolations from copper sulfate-amended Basamid treatments were made from 1.3 meters above the groundline, where chemical levels were very low. No decay fungi were isolated from poles treated with Basamid alone. While the results suggest that the copper sulfate diminished the effectiveness of Basamid, we suspect that the isolations represent areas where the chemical has not yet migrated at fungitoxic levels.

Isolations of non-decay fungi can also provide clues concerning chemical effectiveness. Non-decay fungi were present in nearly all treatments one year after chemical application, but were absent 0.3 m above the groundline after two years. These results suggest that MITC had eliminated both decay and non-decay fungi from these locations. Isolation levels above this zone were variable, suggesting that chemical levels remained below the threshold for these fungi.

The results indicate that Basamid amended with copper naphthenate is slightly out-performing the non-amended Basamid treatments.

Table I-1. Residual levels of MITC in Douglas-fir poles one or two years after treatment with Basamid alone or amended with copper sulfate or copper naphthenate.

	Residual MITC Content (ug/g wood)[a]											
	0.3 m				1.3 m				2.3 m			
	Inner		Outer		Inner		Outer		Inner		Outer	
	Yr 1	Yr 2	Yr 1	Yr 2	Yr 1	Yr 2	Yr 1	Yr 2	Yr 1	Yr 2	Yr 1	Yr 2
None	21 (14)	72 (47)	18 (37)	36 (33)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	3 (8)	0 (0)
CuNap	34 (19)	94 (45)	43 (54)	94 (64)	0 (0)	6 (7)	0 (0)	0 (0)	2 (5)	0 (0)	6 (19)	0 (0)
$CuSO_4$	103 (78)	101 (36)	55 (86)	32 (17)	4 (6)	7 (7)	0 (1)	3 (7)	0 (0)	0 (0)	0 (0)	0 (0)

[a] Values represent means of 9 analyses. Values in parentheses represent one standard deviation.

Table I-2. Isolation frequency of decay and non-decay fungi from Douglas-fir pole sections one and two years after treatment with Basamid alone or amended with copper sulfate or copper naphthenate

Treatment	Frequency of decay/non-decay fungi of cores or poles (%)[a]					
	0.3 m		1.3 m		2.3 m	
	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2
None	0^{11}	0^{0}	0^{11}	0^{33}	0^{11}	0^{33}
Copper naphthenate	33^{33}	0^{0}	0^{22}	0^{0}	0^{44}	0^{67}
copper sulfate	0^{11}	0^{0}	22^{33}	44^{56}	0^{44}	0^{33}

[a] Values represent means of 9 isolations per position. Values in superscript represent percentage of cores containing non-decay fungi

2. Performance of Basamid rods in Douglas-fir poles

Basamid is currently registered for wood use in a granular form. While this formulation is relatively safe to handle, some utilities have raised concerns about dust during application. In addition, the granular formulation can be spilled during transport or application. In previous Coop studies, we explored the production of small Basamid pellets which appeared to provide equivalent protection in small block tests, but the results were never commercialized. Recently, however, a rod formulation of Basamid has been produced. The rods are larger than those produced under our laboratory conditions, raising concerns that the reduced surface area of the rods (in comparison with the extremely high surface area of the granular formulation) would reduce water-Basamid interactions, resulting in diminished MITC release.

Pentachlorophenol treated Douglas-fir poles, sections (250-300 mm in diameter by 1.8 m long) were set in the ground to a depth of 0.6 m. Three steeply angled holes were drilled into each pole beginning at groundline and moving upward 150 mm and around the pole 120 degrees. Basamid rods (six or nine 17.6g rods per pole) were applied to each hole along with 100g of amine-based copper naphthenate, then the holes were sealed with tight-fitting plastic plugs.

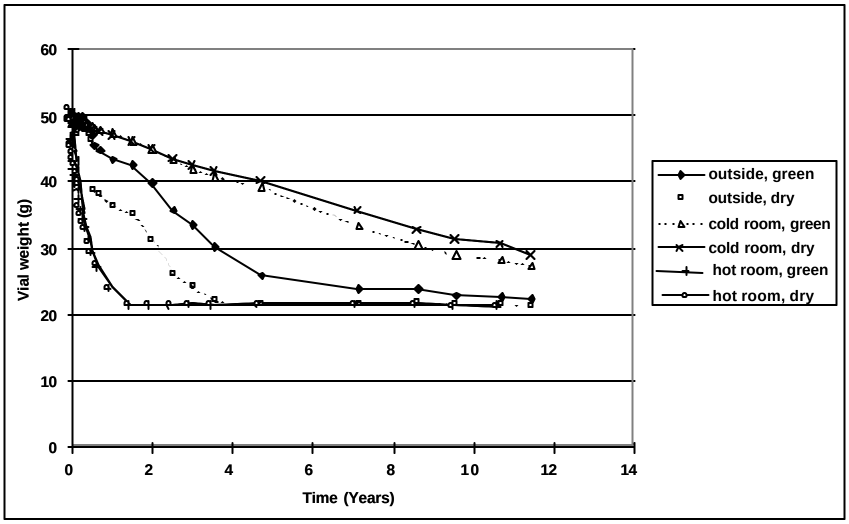
The tests were established in the Winter of 1999 and will be sampled this coming winter to determine MITC content of the wood.

3. Performance of MITC-FUME in Douglas-fir and southern pine poles

MITC-FUME has been in tested on Douglas-fir poles since 1989. Last year, we reported on the 10 year results from this test. While these poles were not sampled this past year, we also have a second test assessing MITC release from ampules under varying climatic conditions. Small Douglas-fir pole sections cut from either seasoned or green logs, were end-sealed with an elastomeric paint. A single, steeply sloping hole was drilled into the pole at the approximate midpoint and one MITC-FUME ampule was added. The holes were plugged with rubber stoppers to allow for periodic ampule removal. The pole sections were then exposed under hot, humid (90% relative humidity, 32 C), ambient temperature (outdoors in Corvallis), or cool (5 C). The ampules were periodically removed and weighed to assess the rate of MITC release.

Initially, there were slight differences in release rate between green and dry poles exposed under the same conditions (Figure I-1). These differences largely disappeared in poles exposed under hot, humid conditions as well as those exposed to the ambient climate. However, green poles continue to lose chemical more slowly under cooler conditions. The reasons for these continued differences are unclear, although they may reflect differences in pit aspiration as a result of the drying conditions. Ampules exposed under both ambient and hot conditions have largely lost their MITC, while those exposed to the cooler temperatures retained nearly one third of chemical 10 years after treatment. While few poles in the field will be exposed to 5 C continuously, the results illustrate the role of temperature in MITC release.

Figure I-1. Effect of initial wood moisture condition and subsequent exposure conditions on releases rate of MITC from MITC-FUME vials exposed in seasoned and green Douglas-fir pole sections.



B. **Ability of Water-Based Diffusibles to Move Through Selected Wood Species to Eliminate Established Decay Fungi**

Boron and fluoride are both water soluble fungicides that have been used for many years for arresting internal decay in various wood species. Both of these chemicals are relatively nontoxic to humans, making them especially attractive for remedial treatments. In general, these systems have been evaluated in a variety of field and laboratory trials on European species, but there is relatively little data on their ability to move through North American conifers.

<u>1. Effect of glycol additives on performance of boron in fused borate rods</u>

Boron has been widely studied as a wood preservative because it effectively controls insect and fungus infestations in wood and has a low toxicity to non-target organisms. This chemical can be applied in a fused rod form that will diffuse through wood from the point of treatment if sufficient water is available (Dickinson et al., 1988; Dietz and Schmidt, 1988; Dirol, 1988; Edlund et al., 1983; Ruddick and Kundzewicz, 1992). Diffusion through Douglas-fir heartwood occurs slowly at moisture contents below the fiber saturation point, but does not usually produce levels necessary for wood protection (Morrell and Freitag, 1995; Morrell et. al. 1990). Diffusion occurs rapidly at moisture contents above 40% (Smith and Williams, 1969; Morrell et. al. 1990). Adding water at the time of boron rod application has been shown to have little effect on boron levels away from the treatment application point or on the isolation frequency of decay fungi (Morrell and Schneider, 1995). One approach for enhancing boron diffusion is to add glycol (Bech-Anderson, 1987; Edlund et al., 1983).

Several commercially available formulations of boron and glycol have been shown to enhance the diffusion of boron into drier wood (Edlund et al 1983). These products have been used in buildings, but their use in larger structures, such as utility poles, has not been investigated. The objective of this study was to determine the effect of various boron/glycol formulations applied in conjunction with Impel rods® on the diffusion of boron through Douglas-fir utility poles.

Pentachlorophenol treated Douglas-fir pole sections (25 to 30 cm in diameter by 2.1 m long) were set to a depth of 0.6 m in the ground at the Oregon State University test site near Corvallis OR, USA. The pole test site in Corvallis receives average yearly rainfall of 1050 mm with 81% falling between October and March. The soil around the poles is an Olympic silty-clay loam and is saturated during much of the year.

Four 20 mm diameter holes were drilled at a 45° downward-sloping angle in each pole, beginning at 75 mm above groundline, then moving 90° around and up to 230, 300 and 450 cm above groundline. An equal amount of boron (227g BAE) was added to each pole, but was delivered from a combination of sources in the different treatments (Table I-3.) The Impel® rods were 100 mm long by 12.7 mm in diameter and weighed 24.4 g each. An equal weight of boron rod composed of one whole rod and a portion of another was placed in each hole followed by the appropriate liquid supplement or left dry. The holes were then plugged with tight fitting, preservative-treated wooden dowels. Each treatment was replicated on five poles.

The pole sections were treated in March 1995 and were sampled after 1, 2 and 3 years by removing two increment cores 180^0 apart from 300 mm below groundline, and 3 increment cores spaced 120^0 apart at groundline, 150 and 300 mm above groundline. The pentachlorophenol-treated portion of each core was discarded and the remainder of each core was divided into outer (0-50 mm), middle (51-100mm) and inner (101-150 mm) sections. The three core sections from the same depth and height taken at groundline and above were combined and ground to pass a 20 mesh screen. The boron content of the sawdust was determined by ion coupled plasma spectroscopy for the first year samples and by the azomethine method (American Wood Preservers Association Standard A2) for the remaining samples (AWPA 1999).

Wood moisture content was assessed gravimetrically one year after treatment on all poles. Moisture content cores were taken at the same heights and zones as those removed for boron analysis. This single moisture measurement does not reveal seasonal variations, but provided an internal moisture profile at one point during the test.

Table I-3. Combinations of boron treatments applied internally to Douglas-fir pole sections in 1995. All treatments deliver 227 g boric acid equivalent per pole.						
Impel® Rod (g)	Supplement	Supplement (g)	Total Glycol (g)	Total water (g)	Supplement Source	Supplement Formulation
156	None	0	0	0		
137	Bora-Care® 1:1 in water	118	28	65	Nisus Corp. Rockford, TN	Disodium octaborate tetrahydrate plus poly and monoethylene glycol
137	Boracol 20®	122	77	20	CSI Inc. Charlotte, NC	Disodium octaborate tetrahydrate plus polyethylene glycol (20%)
104	Boracol 40®	164	95	0	CSI Inc. Charlotte, NC	Disodium octaborate tetrahydrate plus polyethylene glycol (40%)
156	Ethylene glycol	100	100	0	VanWaters and Rogers, Seattle, WA	
146	Timbor® 10% in water	118	0	106	U.S. Borax Inc.	Disodium octaborate tetrahydrate

The toxic threshold required for boron to kill fungi in wood in contact with soil has been estimated to be between 0.4 and 0.5% BAE (Williams and Amburgy 1987). However, levels as low as 0.10 %BAE may be sufficient to prevent colony formation from spores and hyphal fragments (Morrell et. al. 1998).

<u>Boron levels 300 mm below groundline</u>: One year after treatment, the wood moisture content 300 mm below groundline was above the fiber saturation point (~25%) in all core sections (Figure I-2). The boron content of the wood was below the toxic threshold value of 0.5% BAE in all but one sample (Figure I-3). The Boracol 40® treatment produced a level of 0.56% BAE in the inner core sections one year after treatment (Table I-4). Boron levels were generally higher in the inner segments probably because most of the treatment was at the bottoms of the sloping holes, near the center of the pole. The bottom of the lowest treatment hole was approximately 230 mm above the lowest sample zone. Boron levels below ground

remained fairly steady over three years with most treatments. Boron levels in poles treated with Boracol 40® declined in the inner segments, but increased in the middle and outer segments.

<u>Boron levels at groundline</u>: Wood moisture contents at groundline one year after treatment were slightly above the fiber saturation point in the inner sections, but slightly below in the middle and outer sections (Figure I-2). Boron levels were above the toxic threshold in the inner sections in all treatments except the rods alone in all 3 sample years (Table I-4). The middle and outer segments did not reach the threshold with most treatments. Boron levels in the middle zones of the Boracol 40® treated cores again exceeded 0.5% BAE in all 3 years while levels in the outer sections rose above the threshold in the third year. All three segments from the Boracol 20® treated poles also exceeded the threshold in the third year as well. Boron levels in the Boracol 40® treated poles followed the same trend over time as found with the below ground sample (Figure I-3). Levels in the middle and outer sections increased each year. The Impel rod® treatment without any supplement resulted in levels of boron approaching the threshold after 3 years. The groundline sampling zone was approximately 50 mm above and 100 mm below the first and second treatment holes.

<u>Boron levels 150 mm above groundline</u>: Wood moisture content 150 mm above groundline averaged 27%, with a significant moisture gradient from the outer to the inner segments (Figure I-2). Boron levels in this zone were lower than at groundline despite the close proximity to the treatment holes. Inner core segments from this zone were taken approximately 50 mm above the bottom of the second and 50 mm below the bottom of the third treatment holes. Boron levels above 0.5% BAE were consistently found in the inner core segments of the Bora-Care®, ethylene glycol and Timbor® treatments (Figure I-3). Levels in the Boracol 20® treatment were variable, but rose with time in the middle core segments. The ethylene glycol treatment also resulted in higher boron levels over time, exceeding the threshold in the outer and middle segments by the third year. The Boracol 40® treatment resulted in uniformly low boron levels 150 mm above groundline. The boron rod without supplemental treatment resulted in boron levels approaching 0.5% BAE by the third year.

Figure I-2 Moisture content of Douglas-fir poles at various distances from groundline and the pole surface one year after being set in the ground near Corvallis, OR (I = inner, M = middle and O = outer sections).

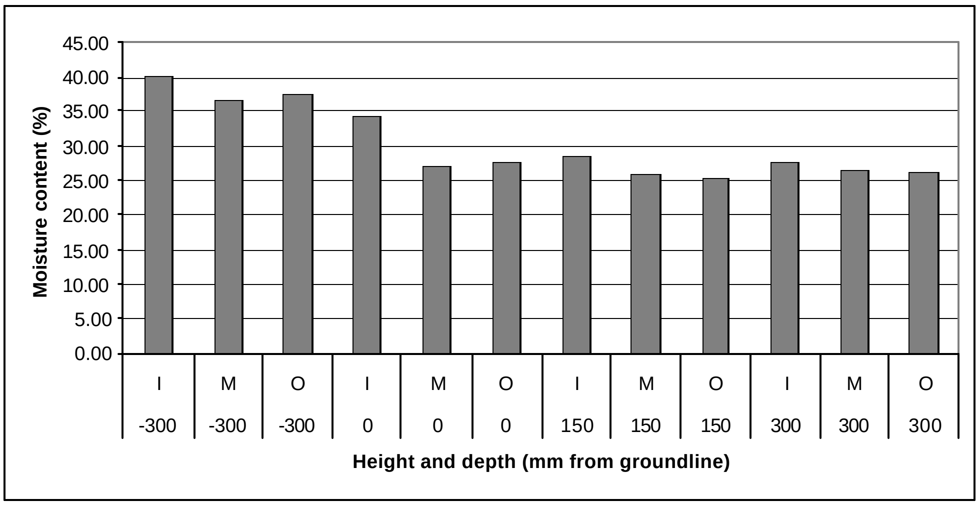
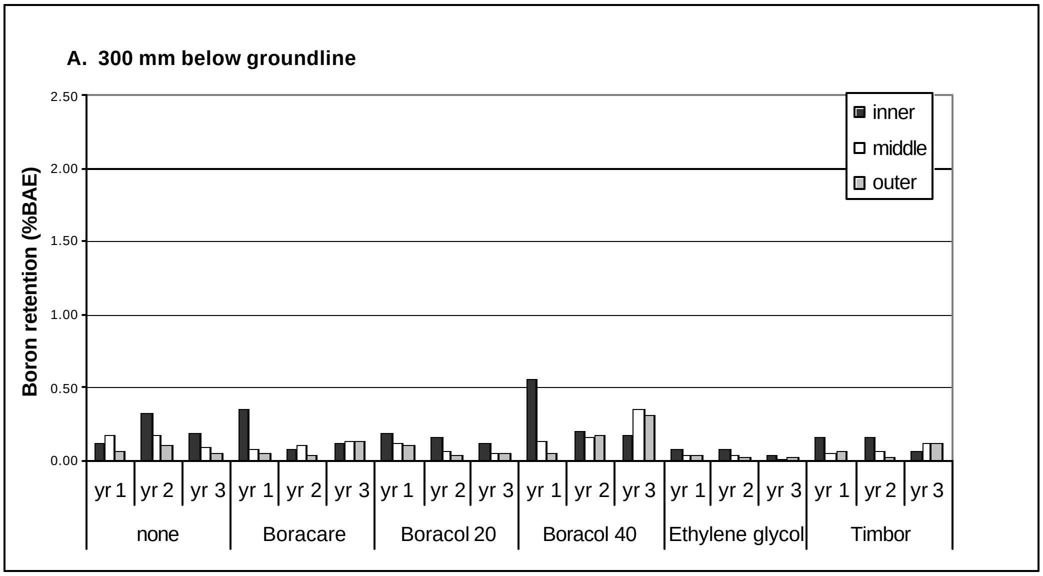


Figure I-3 Average boron retention at (A) 300 mm below groundline, (B) groundline, (C) 150 mm or (D) 300 mm above groundline in Douglas-fir pole sections 1, 2 or 3 years after treatment with combinations of boron and glycol.



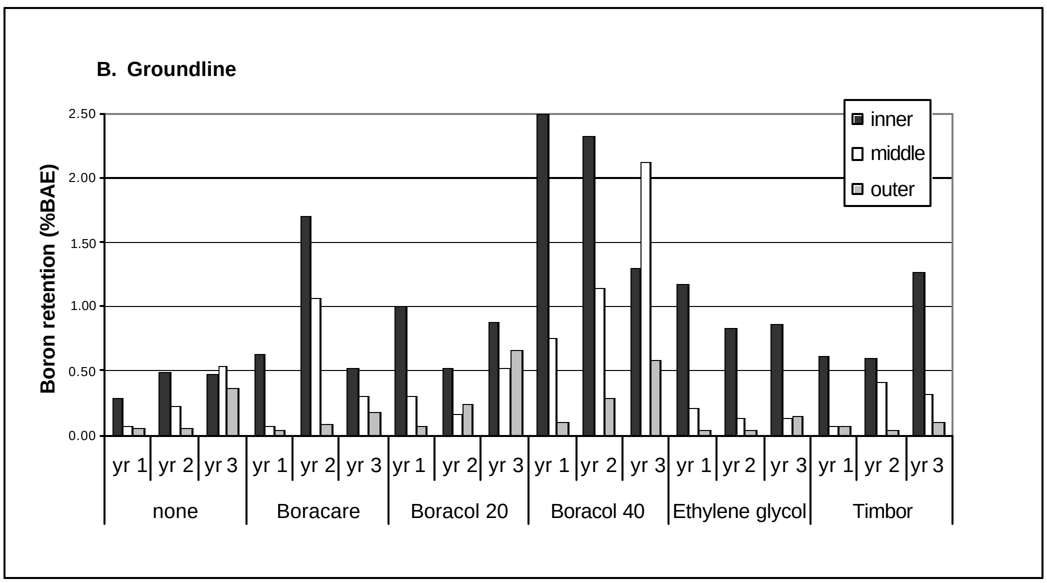
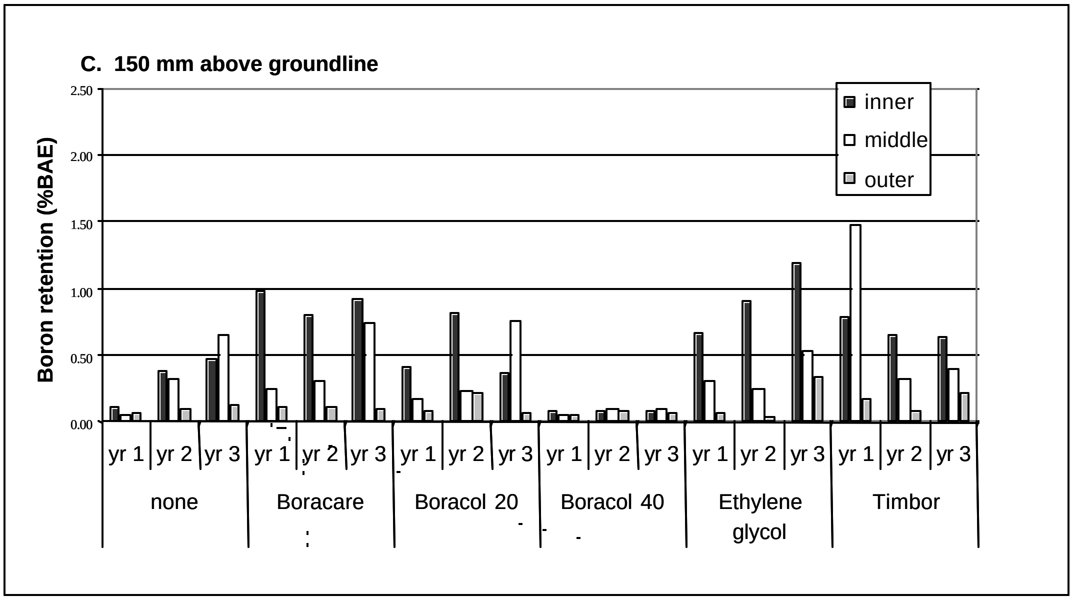


Figure I-3. (continued)



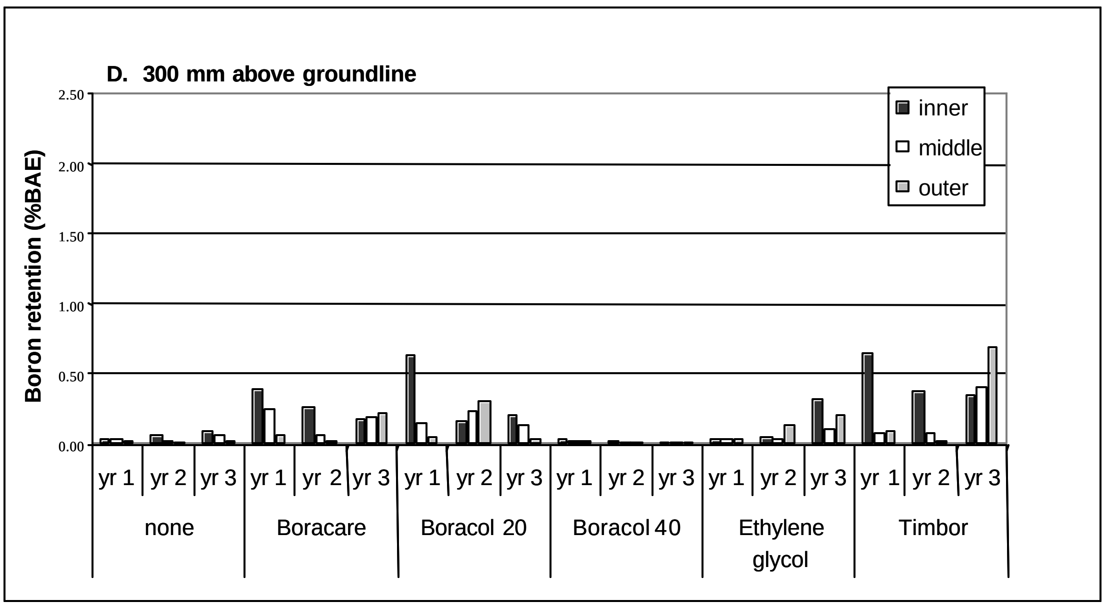


Table I-4. Boron retentions (% BAE) above and below groundline in Douglas-fir pole sections 1 to 3 years after treatment with combinations of boron and glycol or boron alone.

Treatment	Year	-300 mm			0 mm			150 mm			300 mm		
		Average Boron Content (%BAE)[a]											
		Inner	Middle	Outer	Inner	Middle	Outer	Inner	Middle	Outer	Inner	Middle	Outer
Impel Rods	1	0.12 (0.10)	0.18 (0.30)	0.07 (0.02)	0.29 (0.43)	0.08 (0.05)	0.05 (0.03)	0.10 (0.06)	0.05 (0.01)	0.07 (0.04)	0.05 (0.03)	0.05 (0.01)	0.04 (0.02)
	2	0.31 (0.27)	0.18 (0.20)	0.10 (0.13)	0.48 (0.22)	0.24 (0.19)	0.05 (0.06)	0.37 (0.50)	0.31 (0.55)	0.10 (0.19)	0.07 (0.12)	0.04 (0.04)	0.02 (0.02)
	3	0.19 (0.18)	0.08 (0.07)	0.05 (0.05)	0.48 (0.44)	0.54 (0.59)	0.37 (0.47)	0.47 (0.36)	0.64 (0.74)	0.12 (0.19)	0.11 (0.13)	0.07 (0.08)	0.02 (0.02)
Impel Rods + Bora-Care®	1	0.35 (0.40)	0.08 (0.04)	0.05 (0.01)	0.63 (0.42)	0.07 (0.04)	0.05 (0.01)	0.97 (0.81)	0.34 (0.24)	0.11 (0.08)	0.40 (0.26)	0.26 (0.43)	0.07 (0.04)
	2	0.08 (0.06)	0.10 (0.08)	0.04 (0.01)	1.69 (1.42)	1.06 (1.07)	0.09 (0.09)	0.79 (0.27)	0.30 (0.37)	0.11 (0.20)	0.27 (0.24)	0.07 (0.07)	0.03 (0.04)
	3	0.11 (0.07)	0.13 (0.06)	0.13 (0.13)	0.54 (0.34)	0.30 (0.21)	0.19 (0.21)	0.92 (1.04)	0.73 (0.96)	0.09 (0.07)	0.18 (0.23)	0.20 (0.30)	0.22 (0.40)
Impel Rods + Boracol 20®	1	0.35 (0.40)	0.08 (0.04)	0.05 (0.01)	0.63 (0.42)	0.07 (0.04)	0.05 (0.01)	0.97 (0.81)	0.24 (0.24)	0.11 (0.08)	0.04 (0.26)	0.26 (0.43)	0.05 (0.01)
	2	0.15 (0.17)	0.06 (0.06)	0.04 (0.05)	0.54 (0.16)	0.18 (0.12)	0.25 (0.47)	0.81 (0.89)	0.22 (0.14)	0.21 (0.32)	0.16 (0.16)	0.24 (0.26)	0.31 (0.55)
	3	0.11 (0.12)	0.06 (0.05)	0.05 (0.03)	0.88 (0.66)	0.53 (0.52)	0.66 (0.65)	0.37 (0.40)	0.76 (1.12)	0.07 (0.06)	0.21 (0.25)	0.13 (0.18)	0.05 (0.05)
Impel Rods + Boracol 400®	1	0.56 (0.53)	0.12 (0.09)	0.05 (0.02)	2.49 (1.56)	0.76 (0.60)	0.10 (0.07)	0.08 (0.05)	0.05 (0.01)	0.04 (0.02)	0.04 (0.03)	0.03 (0.02)	0.03 (0.02)
	2	0.21 (0.14)	0.16 (0.24)	0.17 (0.22)	2.32 (2.12)	1.15 (0.72)	0.28 (0.33)	0.07 (0.07)	0.10 (0.10)	0.07 (0.06)	0.02 (0.02)	0.02 (0.01)	0.02 (0.01)
	3	0.16 (0.14)	0.34 (0.57)	0.30 (0.59)	1.30 (0.72)	2.13 (2.40)	0.59 (0.49)	0.08 (0.07)	0.09 (0.07)	0.06 (0.02)	0.02 (0.02)	0.02 (0.02)	0.02 (0.02)

Impel Rods +	1	0.07 (0.06)	0.04 (0.01)	0.04 (0.02)	1.18 (1.99)	0.22 (0.27)	0.05 (0.04)	0.67 (0.78)	0.30 (0.34)	0.06 (0.05)	0.04 (0.02)	0.04 (0.01)	0.04 (0.01)
Ethylene	2	0.07 (0.05)	0.04 (0.02)	0.02 (0.03)	0.83 (0.65)	0.14 (0.09)	0.04 (0.04)	0.90 (0.97)	0.24 (0.30)	0.02 (1.02)	0.05 (0.04)	0.04 (0.05)	0.14 (0.22)
glycol	3	0.04 (0.03)	0.02 (0.03)	0.02 (0.03)	0.87 (0.86)	0.15 (0.10)	0.15 (0.27)	1.18 (0.38)	0.52 (0.59)	0.32 (0.45)	0.33 (0.41)	0.12 (0.15)	0.20 (0.38)
Impel Rods +	1	0.15 (0.12)	0.05 (0.03)	0.06 (0.05)	0.61 (0.53)	0.07 (0.04)	0.08 (0.05)	0.79 (0.77)	1.47 (2.74)	0.16 (0.18)	0.66 (1.24)	0.08 (0.05)	0.1 (0.07)
Timbor®	2	0.15 (0.08)	0.06 (0.02)	0.03 (0.01)	0.60 (0.53)	0.41 (0.44)	0.05 (0.04)	0.64 (0.50)	0.32 (0.42)	0.08 (0.07)	0.39 (0.50)	0.09 (0.08)	0.03 (0.02)
	3	0.07 (0.05)	0.1 (0.08)	0.11 (0.13)	1.27 (1.07)	0.33 (0.30)	0.12 (0.12)	0.6 (0.64)	0.39 (0.44)	0.2 (0.17)	0.35 (0.43)	0.41 (0.54)	0.70 (0.54

a. Values are means of 5 replicates. Numbers in parentheses represent one standard deviation

Boron levels 300 mm above groundline; Wood moisture content 300 mm above groundline averaged 27% with no significant gradient from the outer to inner core segments (Figure I-2). The 300 mm sampling zone was close to the bottom of the highest treatment hole. Boron levels in this zone were below threshold with most treatments (Figure I-3). The Timbor® treatment resulted in the highest boron levels, near or above threshold in all three core segments by the third year. The Bora-Care® and Boracol 20® treatments resulted in fairly steady boron levels that, although mostly below the toxic threshold, may be sufficient to prevent infestation. Boron levels from the ethylene glycol treatment increased each year and may have provided some protection by the third year. The Boracol 40® treatment resulted in barely detectable levels of boron 300 mm above groundline.

The uniform moisture contents above the groundline do not seem to account for the large differences in boron retention 150 mm and 300 mm above groundline, but our single sample could not account for seasonal variations. The test site tends to experience very dry summers, which would like lead to low internal wood moisture contents for a major portion of the year. The relatively low levels of boron below ground may be due to diffusion from the pole into the surrounding soil. Boron from fused borate rods has been shown to be highly mobile at moisture contents above 40% (Morrell et. al. 1990). Boracol 40® was able to move more quickly through drier wood than the other formulations, resulting in early depletion from the higher sampling zones. The moisture content of these poles seems conducive to diffusion of boron from most treatments at and 150 mm above groundline.

All of the supplements tested enhanced boron movement through Douglas-fir heartwood. Boron diffused from the fused rods alone at levels high enough to protect wood at groundline and 150 mm above after 3 years, but levels diffusing from treatments with supplements were usually much greater. The Boracol 40® treatment appeared to increase the mobility of the boron to the point where it moved down the pole from the higher treatments even after one year. Boron movement at groundline tended to occur from the center of the pole outward. Further sampling will reveal whether boron is being lost from the pole to the surrounding soil. The Bora-Care®, Boracol 20®, ethylene glycol and Timbor® treatments all tended to produce more uniform levels of boron throughout the sampling zone. The Timbor® treatment does not contain any glycol, yet it improved boron diffusion and resulted in the most even distribution of boron throughout the sampling zone. The limited wood moisture content data available confirms that boron diffusion was highly dependant on moisture.

2. Performance of fluoride/boron rods in Douglas-fir poles

Fluoride/boron rods are used in Australia for controlling internal decay in eucalyptus poles. Although not currently registered in the U.S., at the time this test was installed, the manufacturer was pursuing a label. The boron/fluoride rods contain 24.3 % sodium fluoride and 58.2 % sodium octaborate tetrahydrate (Preschem Ltd., Australia). The rods have a chalk-like appearance. In theory, a boron/fluoride mixture should take advantage of the properties of both chemicals. Boron and fluoride both move through wood with moisture, but previous field tests suggest that fluoride interacts to a greater extent with the wood structure.

Pentachlorophenol treated Douglas-fir poles (250-300 in diameter by 3.6 m long) were set to a depth of 0.6 m and a series of three steeply sloping holes (19 mm in diameter by 300 mm long) were drilled 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/pole)was equally distributed among the three holes, which were plugged with tight-fitting wood dowels. Each treatment was replicated on five poles.

Chemical movement was assessed 1, 2, 3, and 5 years after treatment by removing increment cores from three equidistant sites around each pole 300 mm below groundline (GL), 300 mm above GL and 800 mm above GL. The outer, treated shell from each core was discarded, then the inner and outer 25 mm of each core were retained. Core segments from a given zone for the same sampling height were combined for the five poles in each treatment. The cores were then ground to pass a 20 mesh screen and the resulting dust was thoroughly mixed before being divided into 2 equal portions. One portion was extracted in hot water, then analyzed for boron using the Azomethine H/Carminic Acid method. The other portion was extracted in hot water, then fluoride levels in the extracts were quantified using a specific ion electrode. Although the latter method differs from the American Wood Preservers' Association Standard, previous laboratory studies have shown that this method produces results that are similar to those found with the standard ashing/distillation method.

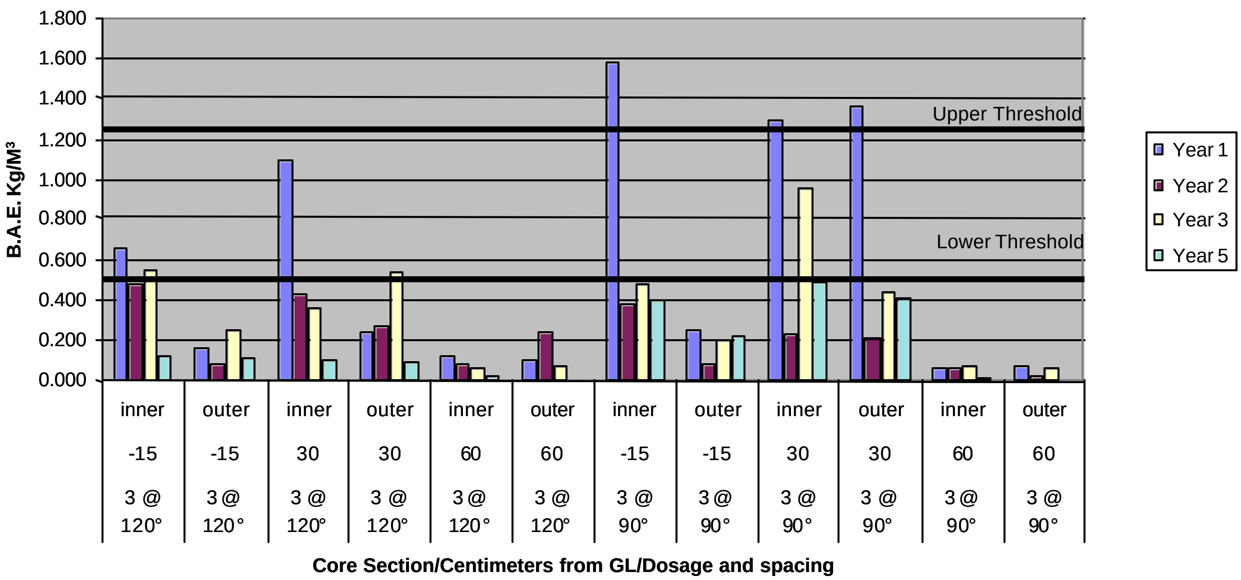
The boron levels believed to be protective against fungal attack vary somewhat depending upon exposure. For example, soil block tests suggested that the threshold ranged from 1.12 to 2.24 kg boric acid equivalent (BAE)/m^3, however, soil blocks tests represent a leaching exposure and boron is especially sensitive to leaching. As a result, soil block tests may poorly represent the actual activity of this chemical. Laboratory trials with boron treated blocks exposed above ground in a non-leaching exposures suggested that the thresholds were closer to 0.5 to 0.6 kg BAE/m^3.

Boron levels in poles receiving three boron fluoride rods per pole were generally below the accepted threshold for protection (1.12 kg) for poles treated using a 120 degree hole spacing, but were above this level for poles treated using a 90 degree spacing (Figure I-4). In most instances, boron levels declined sharply after one year in these poles. Boron levels 600 mm above the groundline were well below the levels required for fungal protection. Boron levels in poles receiving six rods per pole were slightly higher below groundline in poles with the 120 degree spacing, but declined sharply 2 years after treatment. While many of the samples contained boron at levels above the 0.6 kg threshold found in our tests for above ground decay, chemical levels had generally declined below even this threshold 5 years after treatment.

The threshold for fungal attack of fluoride treated wood has been reported to be between 0.3 and 0.5 percent, although laboratory trials described elsewhere in this report suggest that these levels are somewhat higher than are really needed for non-leaching exposures. Fluoride levels in the poles were all uniformly below the reported threshold and none approached the laboratory derived threshold (Figure I-5). The lower levels of fluoride, in part, reflect the smaller proportion of this chemical in the original rod; however, the lower levels of fluoride in the rods do not entirely account for the resulting wood levels.

Figure I-4. Residual boron levels at selected distances above or below the groundline in Douglas-fir poles 1 to 5 years after treatment with (a) 3 or (b) 6 boron/fluoride rods.

a.



b.

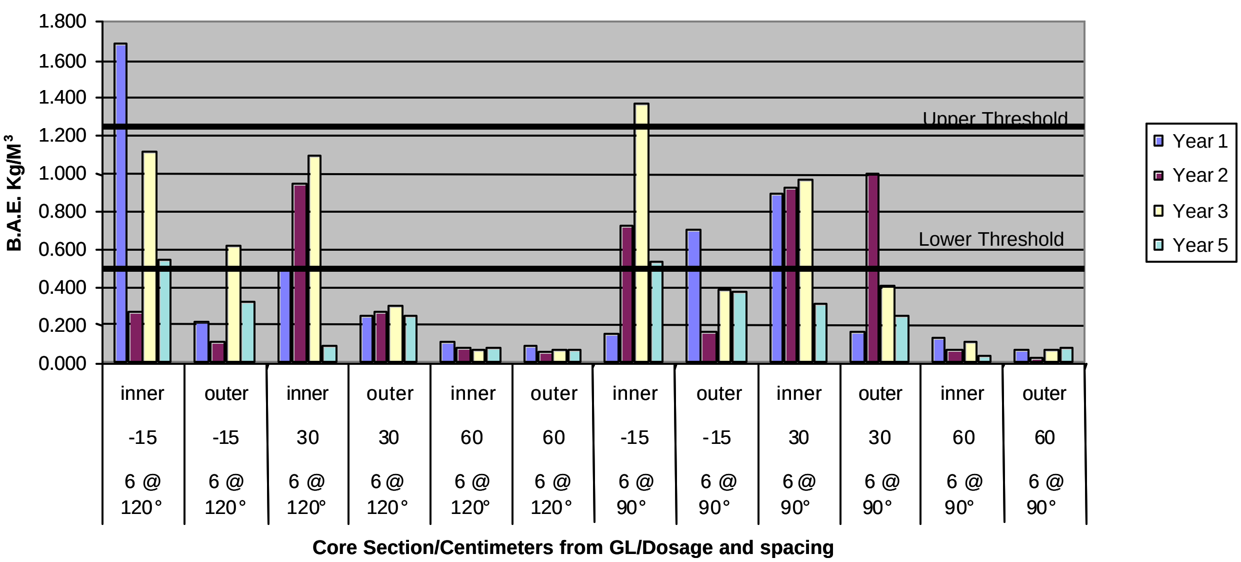
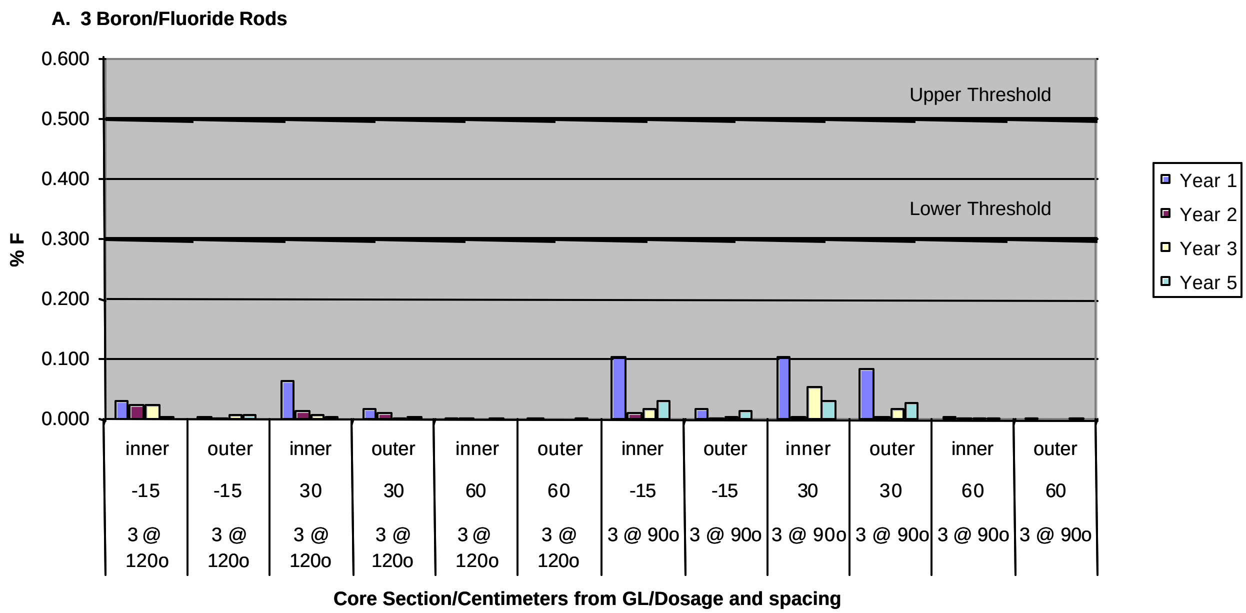
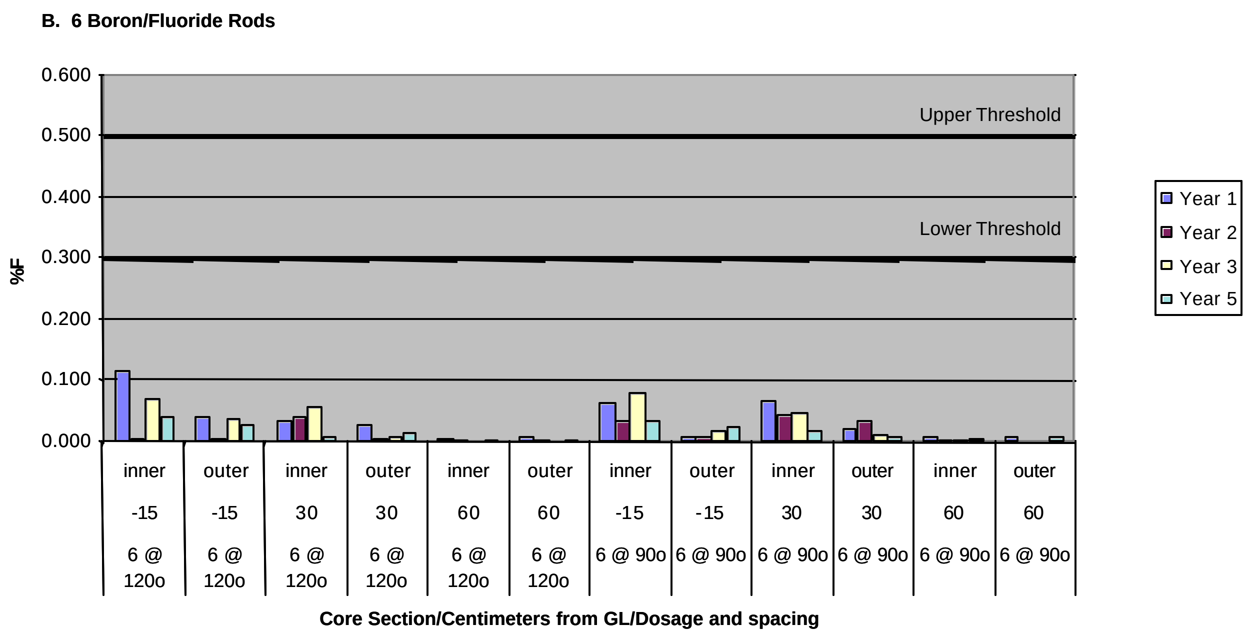


Figure I-5 Residual fluoride levels at selected distances above or below the groundline in Douglas-fir poles 1 to 5 years after treatment with (a) 3 or (b) 6 boron/fluoride rods.





The reasons for the lower levels of boron and fluoride in the poles over the test period in comparison with previous reports from Australia are unclear. We have noted that Douglas-fir represents a very difficult diffusion medium for water-soluble materials such as boron. For example, our boron rod results differ markedly from those found in other species, especially more permeable pines. We suspect that the same factors have influenced the movement of both boron and fluoride from these rods.

3. Performance of sodium fluoride rods in Douglas-fir poles

Fluoride has a long history of use for controlling internal decay below the tie plates in railroad ties and was a key component of fluor-chrome-arsenic-phenol (FCAP), an early waterborne preservative used for pressure treatment of wood. As mentioned above, fluoride has fungal thresholds that are similar to those reported for boron and has the ability to move through wood with moisture. There is, however, little data on the performance of this chemical in rod form as a remedial treatment for Douglas-fir poles.

Pentachlorophenol treated Douglas-fir poles (250-300 mm in diameter by 2.4 m long) were set to a depth of 0.6 m and three 19 mm diameter by 200 mm long steeply angled holes were drilled in the poles beginning at groundline and moving upward at 150 mm increments and around the pole 120 degrees. Each hole received 1 or 2 sodium fluoride rods (Fluor-Rods, Osmose Wood Preserving Inc., Buffalo, NY), then the holes were plugged with tight-fitting wooden dowels.

Chemical movement was assessed 1, 2, and 3 years after treatment by removing increment cores from three equidistant sites around each pole 150 mm below groundline as well as 225, and 450 mm above groundline. The outer preservative treated shell was discarded, then the remaining core was divided into inner and outer halves. The cores were ground to pass a 20 mesh screen. The samples were ashed and analyzed using a specific ion electrode as described in AWPA Standard A2 on a blind sample basis by Osmose Wood Preserving, Inc. In addition, two or three poles per treatment were destructively sampled three years after chemical application. The poles were cut into a series of 150 mm thick sections and the surface of each section was sprayed with a solution of sodium alizarin sulfonate followed by a mixture of zirconyl chloride and hydrochloric acid. The appearance of a yellow color following the second chemical indicated that presence of fluoride. The sections were then photographed to record the degree of fluoride penetration. Following spraying, a series of 10 mm cubes were removed at 25 mm intervals inward from the wood surface on each disc. These samples were ground to pass a 20 mesh screen and analyzed for fluoride as described above. The results from these assays were presented last year, but are included in this report along with the 3 year data for discussion purposes.

Fluoride levels were generally well below the threshold for most of the sites over the 3 year course of this study (Figure I-6). The exception was the outer zone of below ground samples in poles receiving two rods per hole, where fluoride levels were above the threshold 1 year after treatment. These levels, however, declined rapidly after the second year, suggesting that the one year sample may have inadvertently been taken too close to the original rod application site. Fluoride levels were also above the minimum threshold 2 and 3 years after treatment 230 mm above the groundline in the 2 rod treatments, suggesting that some fluoride movement upward was possible. Fluoride levels in the remaining cores were all well below the protective level.

Dissection of poles 3.5 years after treatment revealed similar patterns (Figure I-7). Fluoride was generally below the detectable limit of the indicator above the groundline. Fluoride distribution improved markedly below the groundline. Fluoride was present inside the treated shell 150 mm below ground in many sections, indicating that the elevated moisture levels in this zone had encouraged diffusion. Chemical assays of sections cut from these zones, however, showed that fluoride levels still remained below the accepted threshold levels. Cross sections cut 300 mm below the groundline showed little evidence of fluoride diffusion and chemical assays closely paralleled these results (Table I-5). The absence of substantial fluoride movement in the center of the poles above the groundline was disappointing since previous tests at this field site had indicated that the interior of the poles attained moisture contents well above the fiber saturation point during the rainy season.

The results continue to show that fluoride movement from the rods is limited and is highly dependent on moisture content. Like boron rods, fluoride may be an alternative for utilities who cannot accept any risk associated with chemical application and who are willing to accept a reduced level of protection.

Figure I-6. Residual fluoride at selected distances above or below the groundline in Douglas-fir pole sections 1 to 3 years after application of 3 or 6 fluoride rods per pole.

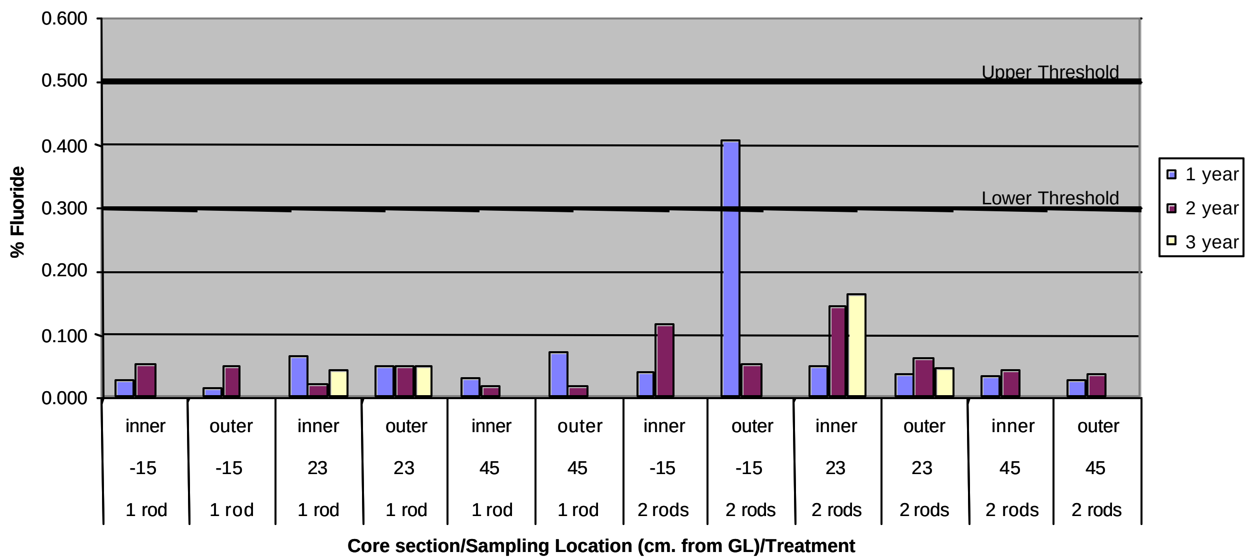


Figure I-7 Fluoride distribution at selected distances above or below the groundline in Douglas-fir pole sections 3 years after application of 3 or 6 fluoride rods per pole as shown using a fluoride indicator.

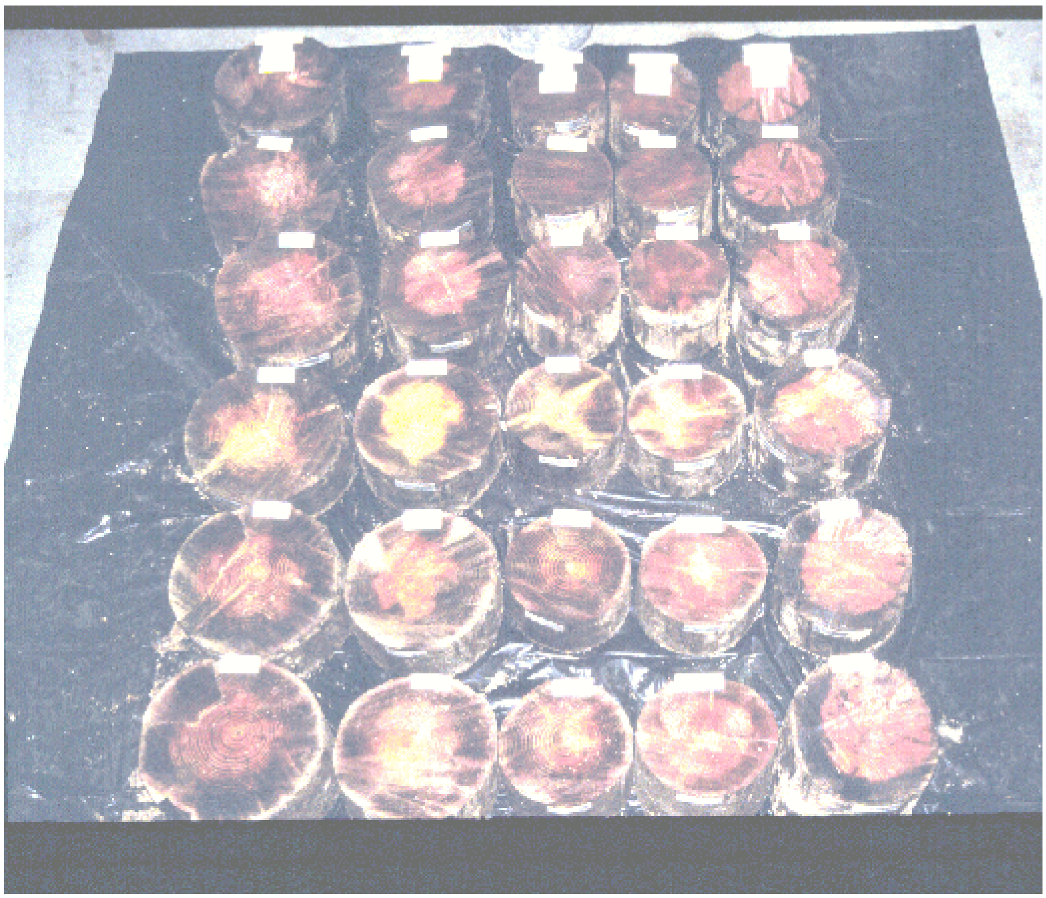


Table I-5. Residual sodium fluoride below ground at selected distances from the surfaces of Douglas-fir poles 3 years after treatment with 66 or 132 g of fluoride rod.

Fluoride Rod Dosage (g)	Distance Above Ground (mm)	Fluoride content (% wt/wt)[a]				
		0-25 mm	25-50 mm	51-75 mm	75-100 mm	> 100 mm
66	-300	0.009 (0.005)	0.009 (0.004)	0.007 (0.002)	0.013 (0.006)	0.031 (0.013)
	-150	0.025 (0.024)	0.017 (0.015)	0.084 (0.122)	0.091 (0.114)	0.071 (0.091)
132	-300	0.009 (0.009)	00.003 (0.006)	0.018 (0.014)	0.009 (0.013)	0.030 (0.033)
	-150	0.035 (0.039)	0.032 (0.021)	0.078 (0.093)	0.084 (0.098)	0.114 (0.058)

[a] Values represent means of 2 to 4 analyses per position. Figures in parentheses represent one standard deviation.

4. Develop reliable thresholds for boron and fluoride in above ground, non-leaching exposures

Over the past 7 years, we have developed a wealth of data on the ability of boron and fluoride to move through Douglas-fir heartwood under a variety of field conditions. While this data is useful, an important aspect of assessing performance is establishing how much chemical is needed to prevent or arrest fungal attack. As mentioned previously, a number of studies have established thresholds for boron and fluoride against various decay fungi using either soil or agar block methodologies. While these systems are useful laboratory tools, they do not accurately represent the interior of a utility pole. In previous reports, we have described results of tests to establish thresholds for boron against selected wood decay fungi using a modified non-soil contact exposure method. These results suggested that the thresholds for boron were far lower than the generally accepted levels (1.12 to 2.24 kg/m^3). Last year, we reported on similar tests to establish threshold values for fluoride; however, we were concerned that the weight losses on untreated controls were too low for comparison. This past year, we repeated the original experiment.

A single 0.5 mm diameter by 2 mm long hole was drilled into one wide face of each of 320 Douglas-fir sapwood and heartwood wafers (5 by 10 by 30 mm long). The wafers were oven dried at 54 C and weighed. The wafers were then divided into 8 groups of 40 and each group was treated to one of seven target retentions of sodium fluoride (0.02 , 0.05 , 0.1 , 0.2 , 0.3, 0.4, or 0.5 %). The wafers were immersed in the respective treatment solution, and an 80 kPa vacuum was drawn over the solution for 15 minutes, then released. Pressure was increased to 800 kPa and held for 1 hour. The pressure was released, then each sample was removed, wiped clean of excess solution and weighed to determine net solution absorption. Four blocks from each treatment were removed and retained for later analysis. The remainder of the blocks were placed into sealable plastic bags and subjected to 2.5 mrad of ionizing radiation from a cobalt 60 source. The sterile wafers were then placed on glass rods on top of moistened filter paper in glass petri dishes. The glass rods, petri dishes and filter paper assemblies had previously been sterilized by heating at 121 C for 60 minutes.

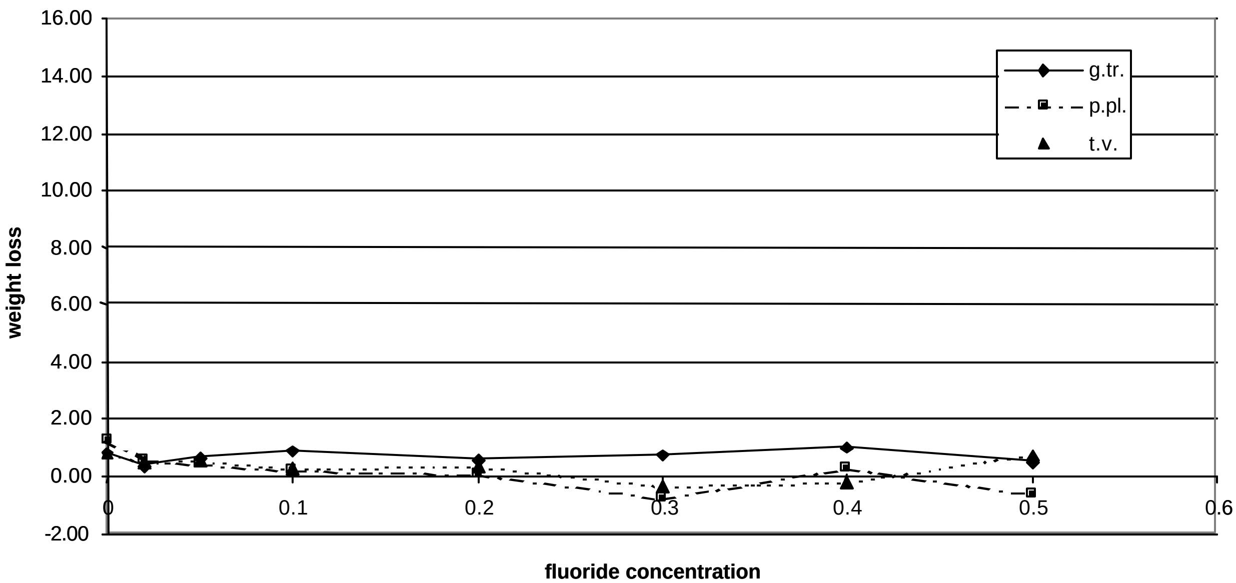
The wafers were inoculated with one of two brown rot fungi, *Gloeophyllum trabeum* (Pers.:Fr) Murr (Isolate MAD 617) or *Postia placenta* (Fries.) M. Larsen et Lombard (Isolate Mad 698), or the white rot fungus, *Trametes versicolor* (L.:Fr.) Pilat (Isolate R-105). Agar discs of the test fungus were inoculated into flasks containing 1.5 % malt extract which were incubated for 7 to 10 days at room temperature (23 to 25 C). The resulting mycelium was collected by filtration and washed with sterile distilled water. The filtrate was resuspended in distilled water and blended for 10 seconds to fragment the mycelium. Each wafer received 50 ul of this mixture through the small hole drilled into the wide face. The plates were sealed with wax film and incubated at 28 C for 16 to 20 weeks. The longer incubation period was used for the white rot fungus.

The procedures permitted the moist fluoride treated wafers to be exposed to the fungus with little risk of leaching. At the end of the incubation period, the wafers were removed, scraped clean of any adhering mycelium, and oven-dried (54 C) prior to being weighed. Weight loss served as the primary measure of chemical effectiveness.

Weight losses of nontreated blocks exposed to all the fungi were generally low in heartwood blocks, reflecting the moderate durability of the heartwood of this wood species. Weight losses of fluoride treated heartwood blocks were also low. Untreated sapwood blocks experienced 12 to 13 % weight loss when exposed to *G. trabeum* or *P. placenta*, while blocks exposed to *T. versicolor* experienced only 4 % weight loss. Despite these relatively low weight losses, the results can be used to assess the ability of fluoride to protect sapwood against fungal attack. Weight losses were negligible for blocks treated to 0.02 % fluoride and exposed to *G. trabeum*. Weight losses for similarly treated blocks exposed to *P. placenta* were approximately half of the levels found with untreated controls, but declined to background levels in blocks treated to 0.05 % fluoride. The results suggest that fluoride was exceptionally effective at protecting Douglas-fir sapwood against fungal attack, even at relatively low levels of treatment. The low levels of weight loss in Douglas-fir heartwood preclude any conclusions concerning the levels of fluoride required to protect this material. The exceptional effectiveness of fluoride on sapwood, however, implies that this chemical should protect heartwood at fairly low levels in the absence of soil contact.

Figure I-8. Wood weight losses of control and sodium fluoride treated Douglas-fir heartwood (a) and sapwood (b) wafers following exposure to one of three decay fungi in a simulated above ground decay test.

a.



b.

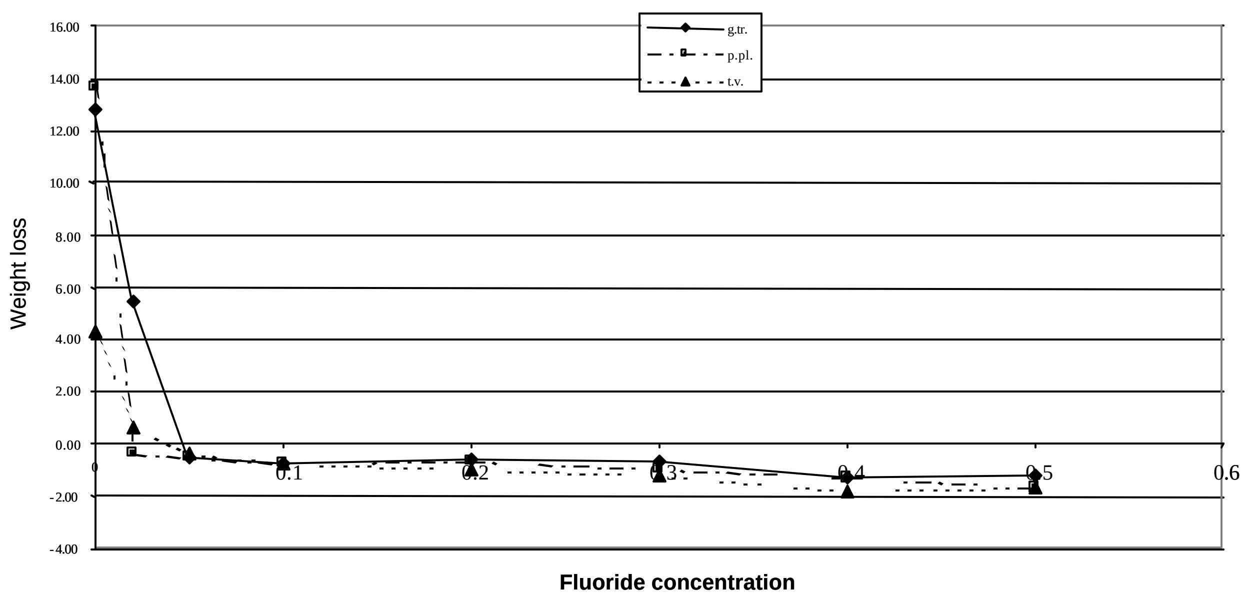


Table I-6 Wood weight losses of control and sodium fluoride treated Douglas-fir sapwood (a) and heartwood (b) wafers following exposure to one of three decay fungi in a simulated above ground decay test.

Target Fluoride Retention (% wt/wt)	Wood Weight Loss (%)[a]					
	Douglas-fir heartwood			Douglas-fir sapwood		
	G. trabeum	*P. placenta*	*T. versicolor*	*G. trabeum*	*P. placenta*	*T. versicolor*
0	0.83 (0.42)	1.28 (0.46)	0.83 (0.41)	12.84 (2.97)	13.72 (2.44)	4.31 (1.18)
0.02	0.38 (0.42)	0.52 (0.22)	0.48 (0.21)	5.47 (0.68)	-0.34 (0.25)	0.62 (0.22)
0.05	0.63 (0.28)	0.40 (0.33)	0.58 (0.24)	-0.51 (0.11)	-0.50 (0.20)	-0.41 (0.29)
0.10	0.88 (0.73)	0.21 (0.33)	0.28 (0.37)	-0.74 (0.24)	-0.74 (0.16)	-0.74 (0.36)
0.20	0.56 (0.69)	0.11 (0.43)	0.37 (0.29)	-0.62 (0.25)	-0.72 (0.41)	-1.00 (0.40)
0.30	0.78 (0.38)	-0.73 (0.63)	-0.29 (0.30)	-0.67 (0.18)	-0.97 (0.39)	-1.24 (0.42)
0.40	1.02 (0.35)	0.31 (0.24)	-0.19 (0.31)	-1.30 (0.19)	-1.26 (0.18)	-1.80 (0.36)
0.50	0.48 (0.24)	-0.57 (0.48)	0.76 (0.46)	-1.19 (0.18)	-1.67 (0.34)	-1.67 (0.12)

[a] Values represent means of 6 replicates per treatment. Figures in parentheses represent one standard deviation.

5. Performance of a copper naphthenate/boron paste for internal treatment of Douglas-fir

Although traditionally viewed as an external treatment, a copper naphthenate/boron paste (ISK Biosciences, Memphis, TN) is labeled for internal application to poles. The potential efficacy of this system was assessed on pentachlorophenol treated Douglas-fir pole stubs (250-300 mm in diameter by 2.0 m long). The poles were set to a depth of 0.6 m and then three 21 mm diameter by 200 mm long steeply angled holes were drilled beginning at groundline and moving upward 150 mm and around the pole 120 degrees. Ten poles each received 150 or 300 g of a paste containing 18.16 % amine-based copper naphthenate and 40 % sodium tetraborate decahydrate. The chemical was applied using a grease gun. The holes were then plugged with tight-fitting wooden dowels

Chemical movement was assessed 3, 5, 8 and 10 years after treatment by removing increment cores from three equidistant sites around each pole at groundline as well as 75, 150, 225, and 300 mm above groundline. The outer, treated shell from each core was discarded, then the remaining core was divided into inner and outer halves. Cores from a given height and treatment were combined before being ground to pass a 20 mesh screen. The resulting dust was first analyzed for copper by x-ray fluorescence using an ASOMA 8620 x-ray fluorescence analyzer, then the wood was hot-water extracted and the extract was analyzed for boron using the Azomethine H method. As discussed earlier, the threshold for boron has been estimated to be between 1.12 and 2.24 kg/m^3.

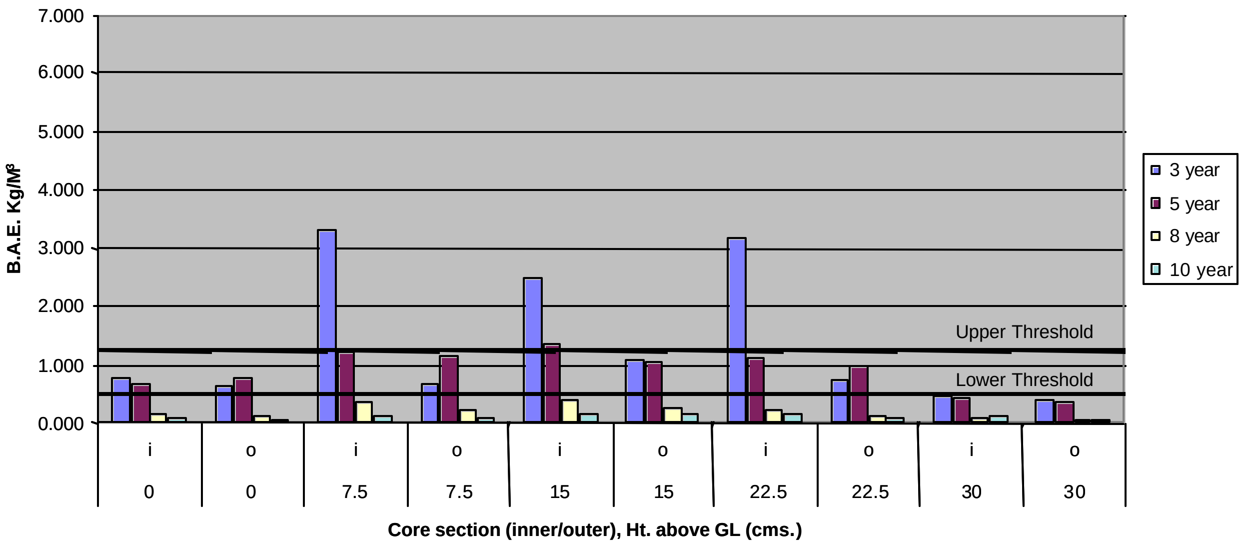
Boron levels in the nontreated control poles were initially quite high, approaching those found in the treated poles after the first year (Figure I-9). Boron levels in the nontreated controls were generally far lower in subsequent tests and we suspect that our first year samples were contaminated during processing. Boron levels in poles receiving 150 g of paste were initially above the threshold in the inner zones 75, 150, and 225 mm above groundline, but these levels declined to well below the threshold level 8 years after treatment. Boron levels failed to achieve the threshold levels at groundline or 300 mm above that zone. The former low levels probably reflect the severe leaching environment near groundline, while the latter reflects the difficult of obtaining substantial upward boron movement in Douglas-fir. Boron levels were all uniformly low 10 years after treatment suggesting that the paste had either leached from the wood or had diffused so completely that the resulting levels of boron were too low to be of biological significance. Boron levels in poles receiving the higher dosages followed trends similar to those found with the 150 g dosage, but the levels of boron found in the inner zones 3 years after treatment were extremely high. Boron levels then declined to near the threshold level after 5 years. While boron levels were all generally below the threshold for fungal attack 10 years after treatment, the levels remained much higher than those found with the lower dosage, suggesting that further increasing the paste dosage could enhance performance.

Copper naphthenate levels tended to be well below the accepted threshold for this compound (0.64 kg/m^3) in the 150 g paste treatment (Figure I-10). Copper levels tended to remain fairly stable in the inner zone 75 mm above groundline but varied more above this zone. The 75 mm sampling location is near the center of the three application points and the presence of elevated levels probably reflects this close proximity to the original application point. Copper levels nearly doubled with a doubling of the paste dosage, again suggesting that the use of pastes to control internal decay might be more effective at higher dosages. Elevated copper levels were present in the inner zones at both 75 and 150 mm above groundline and these levels appeared to remain relatively stable over the 10 year test period. Copper levels declined sharply above or below this sampling zone and there was little evidence of copper at groundline or 300 mm above that zone.

The boron/copper naphthenate paste appeared to be capable of substantial movement within a narrow zone of the pole sections. While the resulting chemical levels in the wood were generally below those required for arresting fungal attack, the results indicate that this formulation could work at higher dosages.

Figure I-9. Residual boron levels in Douglas-fir poles 3 to 10 years after internal application of (a) 150 g or (b) 300 g of a copper naphthenate/boron paste.

a.



b.

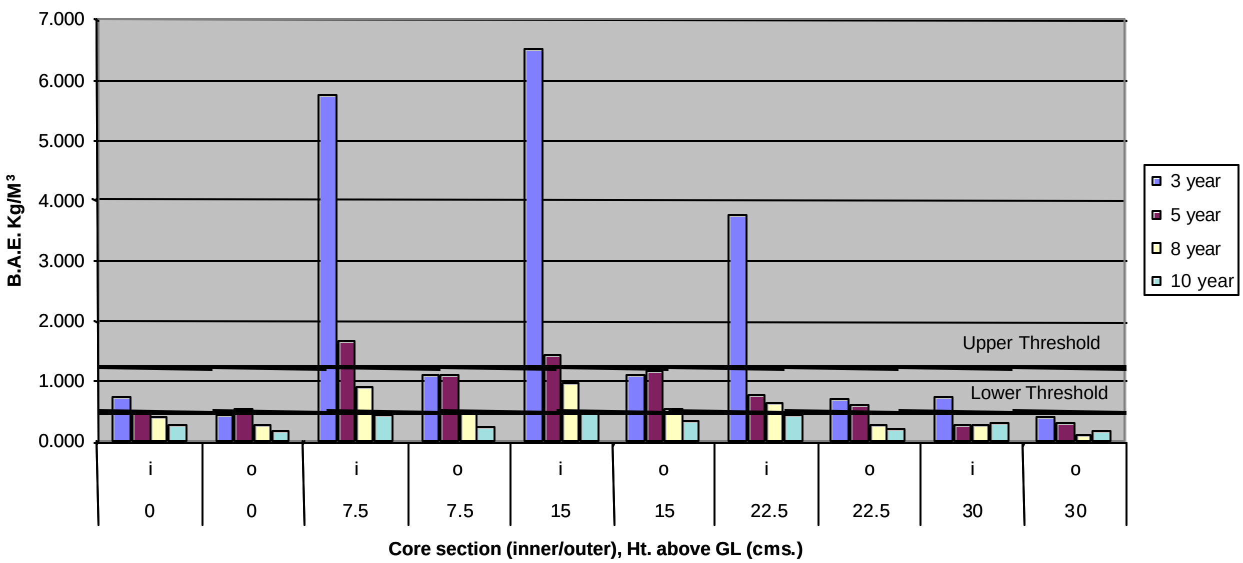
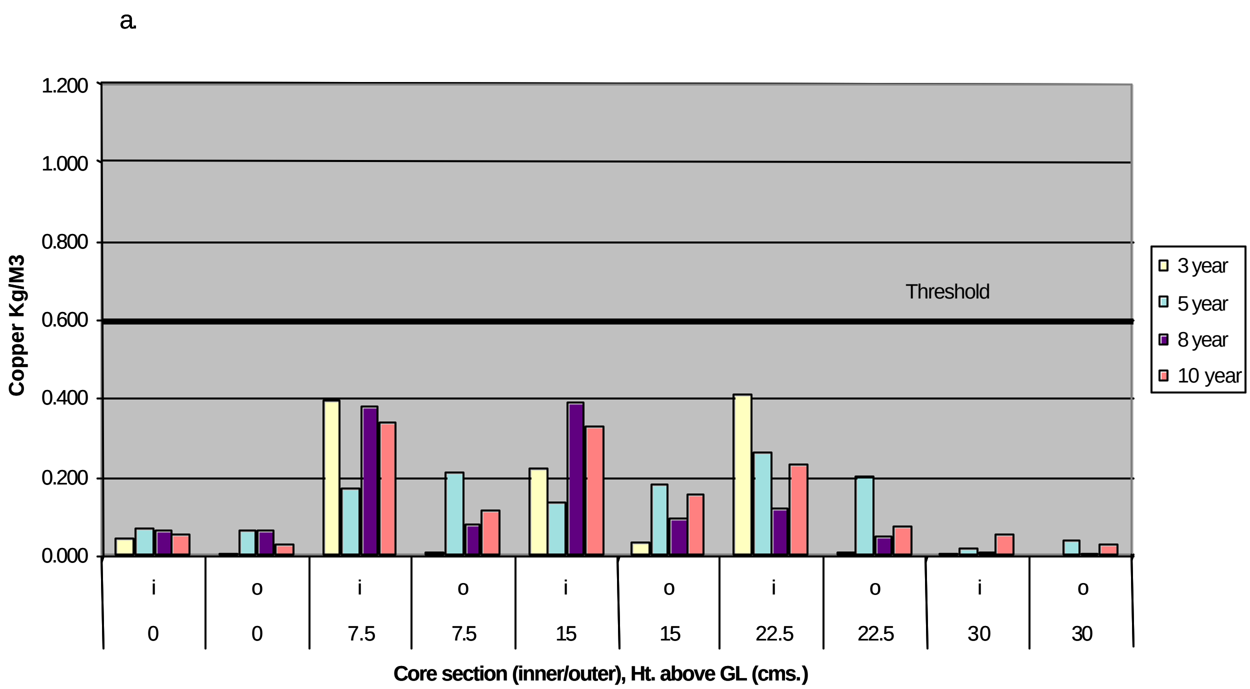
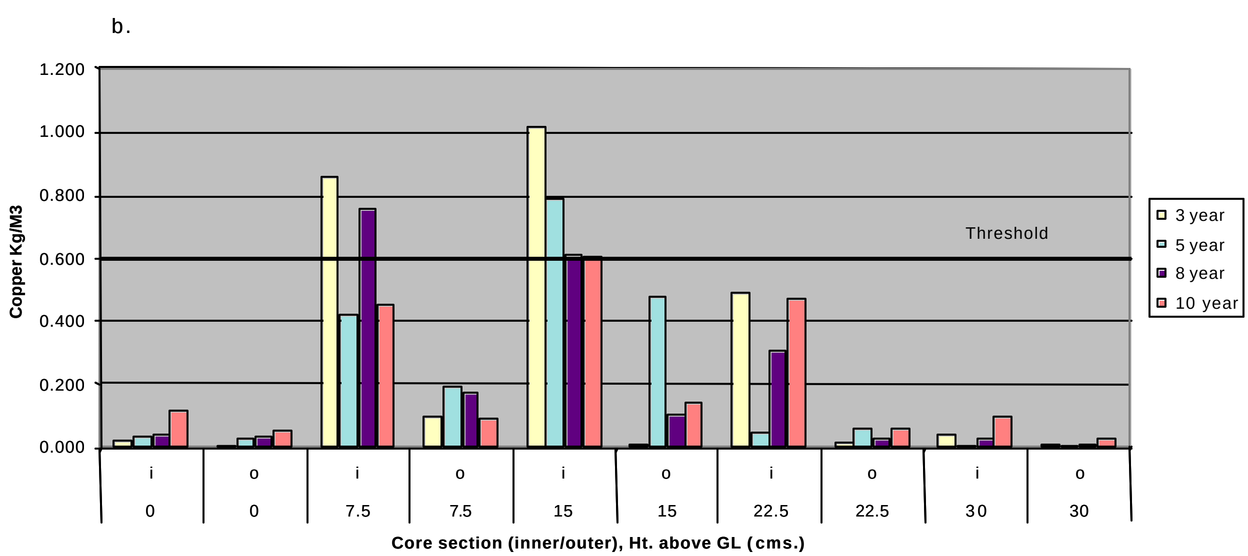


Figure I-10. Residual copper levels in Douglas-fir poles 3 to 10 years after internal application of (a) 150 g or (b) 300 g of a copper naphthenate/boron paste.





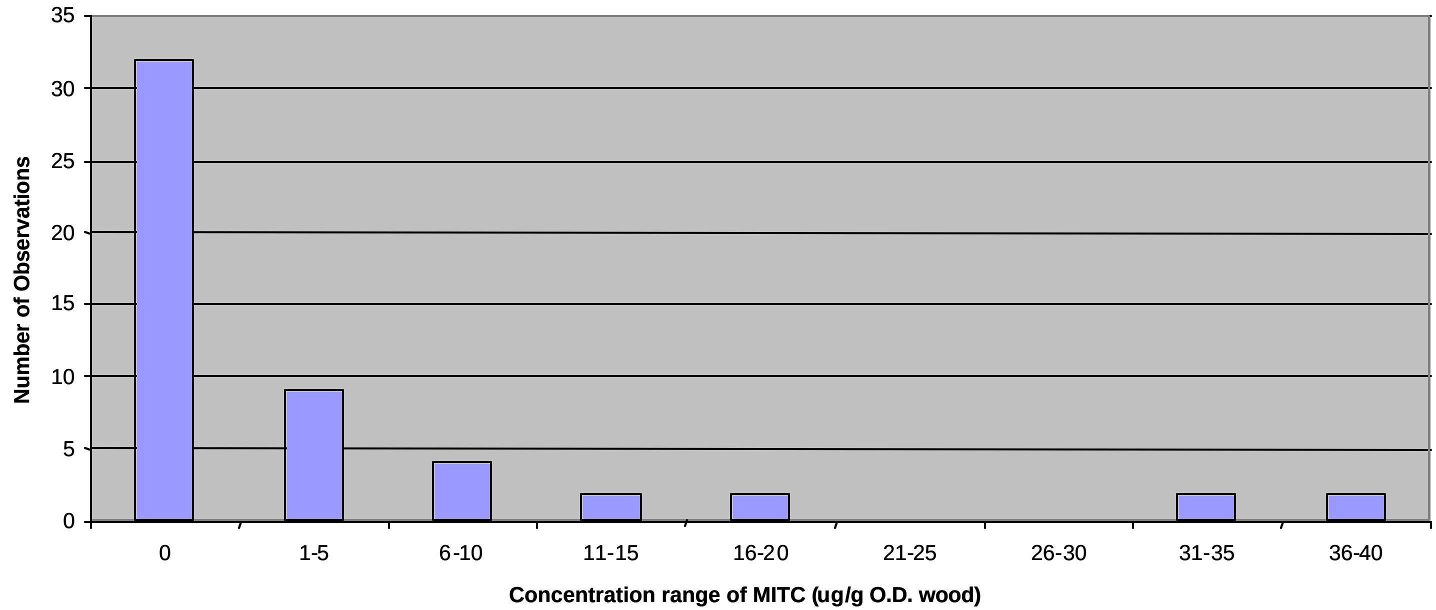
C. Develop Estimated Thresholds for Fumigants

While fumigants have been used for over 3 decades to arrest internal decay in utility poles, we still lack information on the actual levels required to prevent fungal colonization. Laboratory studies suggest that low concentrations of either MITC or chloropicrin (< 20 ug/cc air) can rapidly arrest fungal growth in Douglas-fir heartwood, but these studies are complicated by the tendency of both of these chemicals to selectively sorb to wood. As a result, concentrations in wood can far exceed those present in the air, producing apparent control at artificially low air concentrations. While elevated concentrations can also develop in large timbers, the presence of an excess of wood away from the application point should provide a continuing reservoir to which excess MITC can migrate. In addition, there is little doubt that elevated levels of fumigant are toxic, but a more important question is, at what point does the chemical level decline to the point where retreatment is necessary?

This past year, data from previous field tests were re-examined in an attempt to determine if there was any relationship between fungal isolation and residual chemical level. The field trial of MITC-FUME provides an ideal test for this purpose since it includes multiple dosages of MITC and was sampled over a 10 year period using both culturing and chemical analysis. In these tests, increment cores were removed from the poles at various heights above and below the treatment zone, then the outer treated zone was discarded. The inner and outer 25 mm of the remaining core were then placed into ethyl acetate and extracted for 48 hours at room temperature. The resulting extract was analyzed for MITC by gas chromatography. The remainder of each core was then cultured for decay fungi on 1.5 % malt extract agar. In the initial analysis, the cultural data was compared with MITC levels in the inner zone of the corresponding core.

Although the comparisons are crude, since residual fumigant levels change over time, decay fungi were consistently isolated when MITC concentrations were below 5 ug/oven dried gram of wood (Figure I-11). Isolations declined sharply between 6 and 10 ug, and few fungi were isolated above 20 ug. While these observations are preliminary, they clearly suggest that MITC levels above 20 ug sharply diminish the potential for fungal attack. We intend to examine other field data to determine if this relationship holds.

Figure (I-11). Relationship between fungal isolations and residual MITC in Douglas-fir and southern pine poles at various times after application 60 to 240 g of MITC-FUME.



OBJECTIVE II
IDENTIFY CHEMICALS FOR PROTECTING EXPOSED WOOD SURFACES IN POLES

Preservative treatment creates an excellent barrier against fungal, insect, and even marine borer attack. This barrier, however, only remains effective when it is intact. Deep checks that form after treatment, damage from rough handling, and drilling or cutting during installation can all compromise the barrier, allowing both moisture and agents of decay to enter. For decades, the standards of the American Wood Preservers' Association recommended that any damage to treated wood be protected by applying solutions containing creosote, pentachlorophenol or chromated copper arsenate (depending on the original treatment) to the damaged area. These treatments provided a thin layer of supplemental protection, that, while not as effective as the initial treatment, at least provided some protection to the exposed wood.

Many line personnel avoided the use of these treatments because of their oily nature. In addition, the decision by the Environmental Protection Agency to list creosote, pentachlorophenol and CCA as restricted use pesticides further discouraged utilities from using these topical remedial treatments. While copper naphthenate emerged as an alternative for remedial treatments, the oily nature of this system continued to discourage its use.

In 1980, the Coop initiated a series of tests to identify alternative treatments for protecting field drilled bolt holes. In addition, we have surveyed poles to determine incidence of decay and found that about 15 to 20 % of poles in service in the Pacific Northwest have some decay fungi associated with the bolt hole region. This elevated level of fungal colonization implies that a huge number of poles are at risk of failure during high wind or ice loadings. In this Objective, we summarize progress on efforts to identify alternative treatments for field damage to treated utility poles.

A. Evaluation of Treatments for Protecting Field Drilled Bolt Holes

The study of treatments for field drilled bolt holes was not sampled in 1999, but will be sampled in the summer of 2001, 20 years after its inception. The results to date show that boron and fluoride based treatments provided the best long term protection against fungal attack, while pentachlorophenol in oil (the treatment recommended for field damage at the time this test was initiated) provided minimal protection.

B. Evaluation of Topical Treatments on Large, Untreated Douglas-fir Timbers

Although this project was not initiated under the coop, the study has provided excellent evidence of the benefits of topical treatments and kerfing on performance of large timbers. In 1979, five simulated piers were constructed using Douglas-fir timbers in an open field at the Peavy Arboretum test site. Each structure was supported by 9 creosoted piles that were equally spaced in a 3.6 m square area. Each pier was constructed with eight pairs of abutting caps measuring 250 mm by 250 mm by 2.1 m long, ten pairs of abutting stringers measuring 100 mm by 25 mm by 2.1 m long, and eight sets of three abutting deck planks measuring 100 mm by 250 mm by 1.6 m long (Figure II-1).

Figure II-1. Schematic of simulated piers used to assess topical treatments for protecting untreated

Douglas-fir timbers from decay.

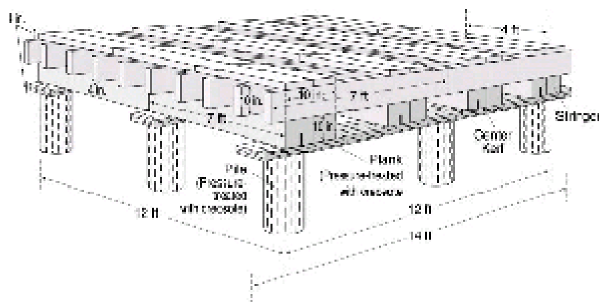


Table II-1. Treatments applied to the upper surfaces of Douglas- fir caps, stringers, and decking planks in a simulated wood pier.		
Treatment	Carrier	Concentration (%)
Pentachlorophenol (penta)	oil	10.0
Copper-8-quinolinolate (Cu-8)	oil	1.0 (as Cu)
Fluor-chrome-arsenic-phenol (FCAP)	water	12.0
Ammonium bifluoride (ABF)	water	20.0
Sodium octaborate tetrahydrate (boron)	water	9.0
FCAP in roofing felt	water	2.0
ABF in roofing felt	water	20.0
Boron in roofing felt	water	9.0
Roofing felt alone	-	-
[a] Felt was applied beneath stringers and decking planks.		

Eight of the caps were center kerfed to minimize check development and oriented downward to limit collection of water in the kerf. The structures were built to enable protective measures to be assessed as well as to create combinations that exposed end-grain and untreated butt joints that could trap moisture.

At the time of installation, nine different treatments were applied to the caps, stringers and decking planks in the structures (Table II-1). Each treatment was applied to one half of five structures and one half of one pier was left untreated to serve as a control. The same preservative was applied to each underlying stringer cap as well as to the four sets of three abutting deck planks in that half of the structure. A supplemental treatment of FCAP, ammonium bifluoride or sodium octaborate tetrahydrate was applied 2 years after installation to decking laid over roofing felt. A total of 3.5 l of the given preservative was sprayed onto the upper surface, into seasoning checks and into the butt joints of the decking planks.

Chemical performance was assessed annually for the first eight years then at 10, 13, 18, and 20 years by removing increment cores from various locations and placing those onto malt extract agar in petri dishes. The cores were observed for fungal growth and any growth was examined for characteristics typical of basidiomycetes, a class of fungi containing many important wood decayers. Two cores were removed from the underside of each cap adjacent to the support planks. Four cores were removed from every fourth stringer on a rotating basis so that each stringer was evaluated every fourth sampling year. Two cores were removed from the stringer directly under the overlaying decking plank and from the stringer/cap junction.

In addition, decking planks were sampled at the junction of abutting deck planks, at the decking stringer junction, and at mid-span between two stringers. One core was removed from one of these locations in each decking plank each sampling year so that a site was sampled every third time on each plank.

The incidence of decay fungi in decking timbers was relatively low in timbers receiving FCAP or ABF in roofing felt or in ABF treatments alone (Figure II-2). Fungal isolation levels in the remaining treatments varied over time, but most of the timbers in these treatments experienced infestation levels of 30 % or greater at some point in the exposure suggesting that the treatment had failed to protect the wood from fungal attack.

While the levels of fungal infestation approached 90 % in decking, fungal isolation levels were far lower in the deck stringers, approaching 50 % in penta treated samples 20 years after treatment (Figure II-3). Isolation levels were generally low for the diffusible chemicals (boron and fluoride) although there were some variations in performance. ABF with roofing felt appeared to provide the greatest protection followed by FCAP plus roofing felt and FCAP alone. Once again, penta provided poor protection against fungal infestation. Copper-8 provided good protection for the first 13 years of the test, but has apparently lost its activity in the two recent samplings. The strong performance of copper-8 mirrors similar results found in laboratory simulated bolt hole tests. Copper-8 is an oil soluble material and its ability to protect the wood against fungal attack in fairly severe exposure should be of tremendous interest for those seeking long term protection of exposed, untreated wood.

Figure II-2. Incidence of decay fungi in increment cores removed from Douglas-fir decking timbers 1 to 20 years after application of various surface treatments.

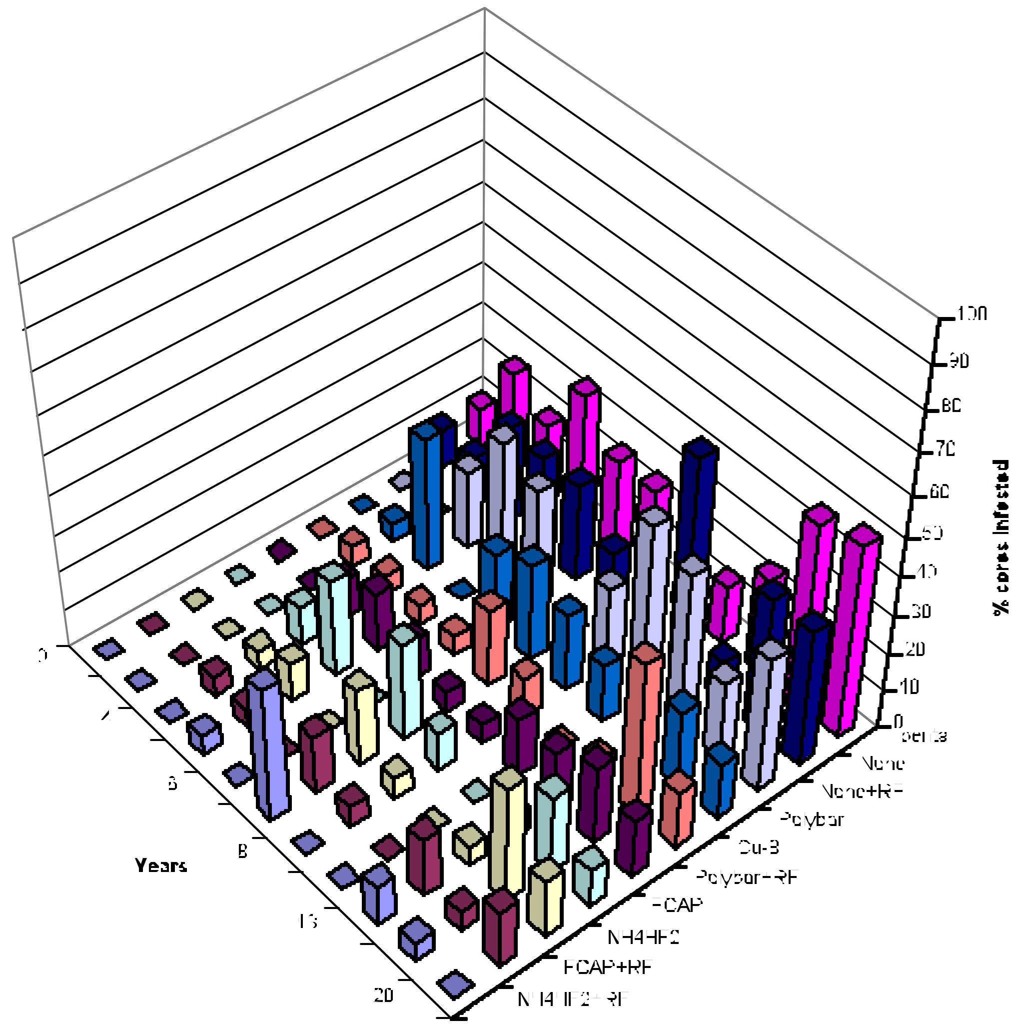
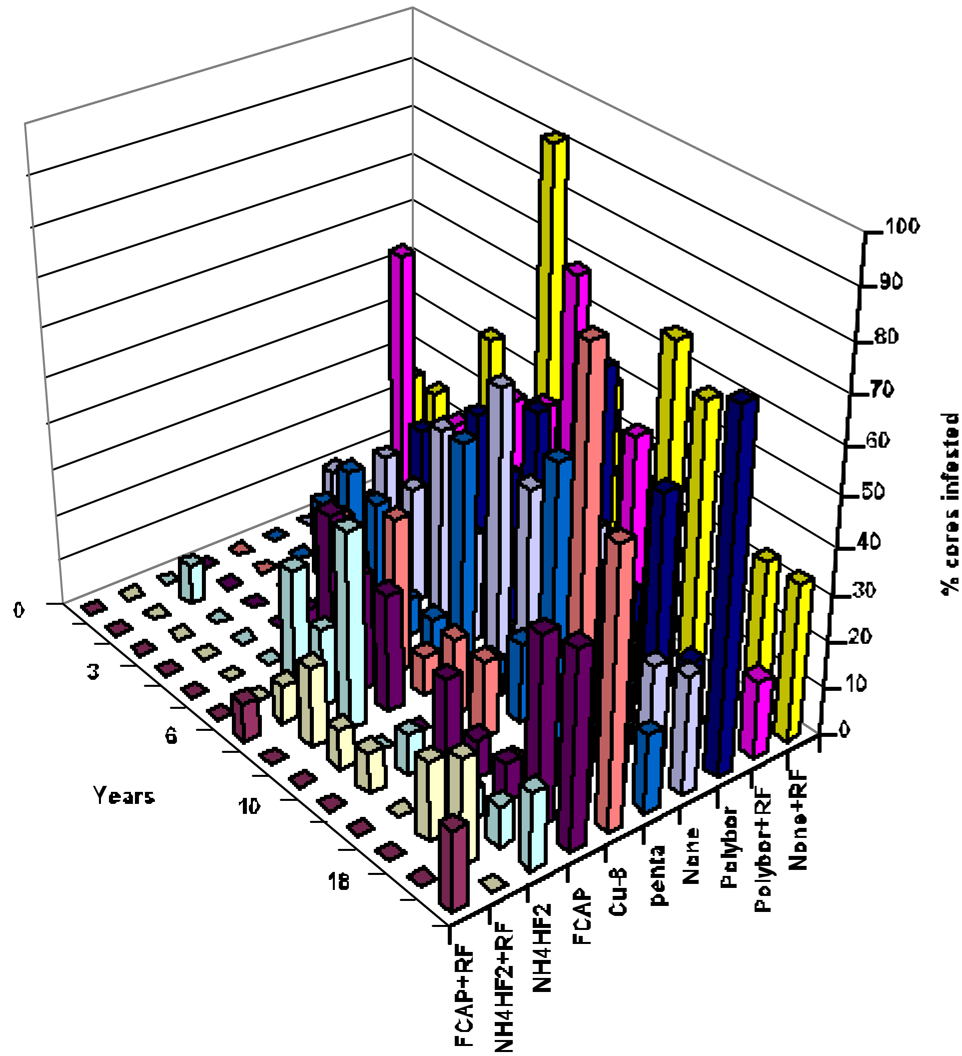


Figure II-3. Incidence of decay fungi in increment cores removed from Douglas-fir stringers 1 to 20 years after application of various surface treatments.

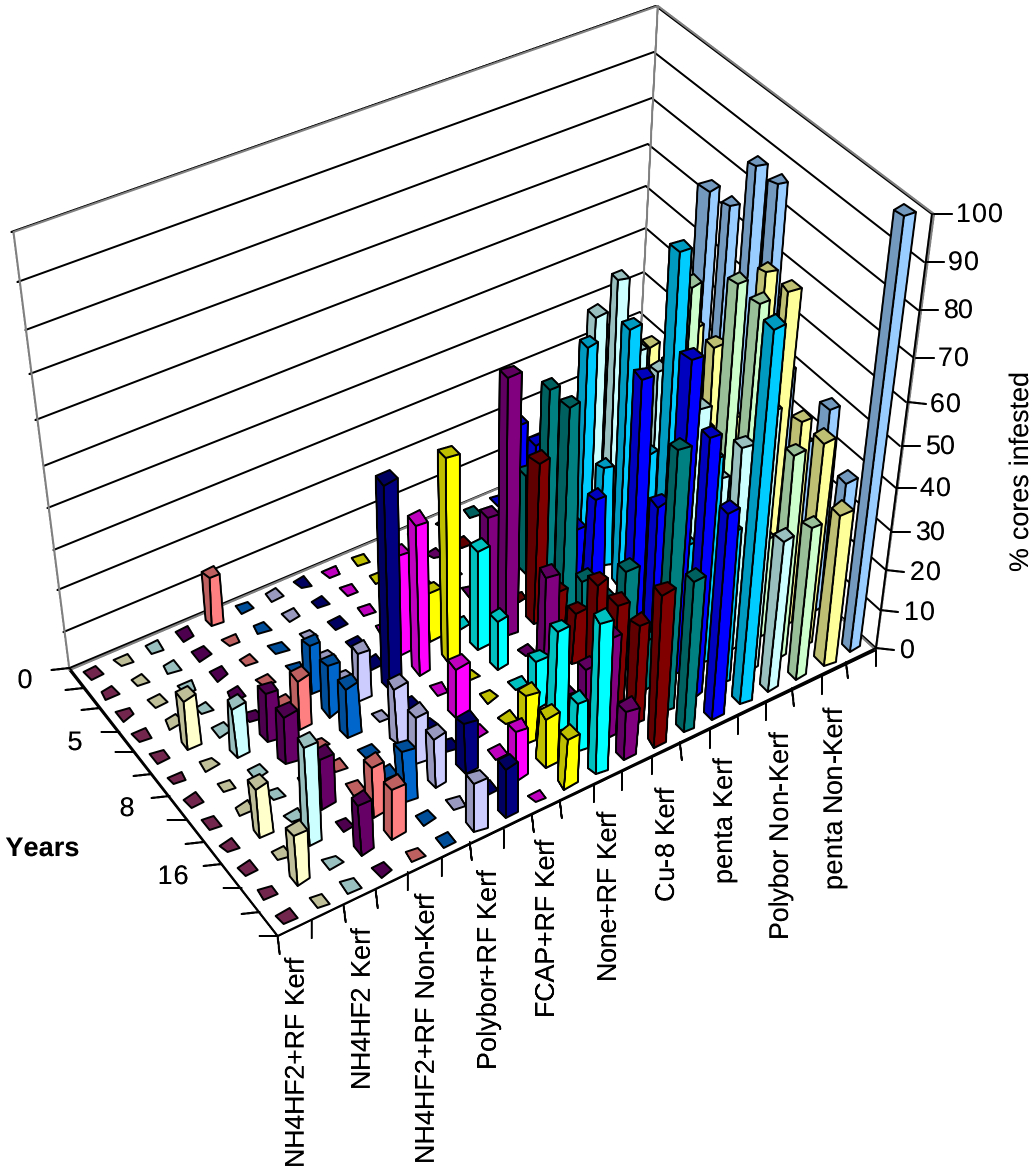


Protecting decking and stringers is primarily a function of protecting the small checks that form in the upper surfaces of the timbers. Protecting larger timbers used for the caps poses a far greater challenge since deep checks can open far beyond the depth of the original treatment. Kerfing had a dramatic effect on the incidence of decay fungi in caps over the course of the tests (Figure II-4). Fungi were generally less prevalent in kerfed caps, regardless of the chemical treatment applied. Application of a water diffusible chemical to the kerfed caps markedly improved performance. ABF with or without roofing felt provided the best protection over the 20 year tests, No decay fungi were isolated from any kerfed caps that received ABF in roofing felt. Isolation frequencies were also far lower in kerfed caps when FCAP or boron were applied

The results illustrate the benefits of topical diffusible treatments for protecting wood, but they also illustrate the limits of protection as the size of the member being treated increases. These limitations reflect the inability to deliver an adequate amount of chemical to the wood surface for subsequent diffusion into the wood at a level that confers protection against decay fungi. Roofing felt improved performance of the diffusibles because it improved surface retention of chemical and provided a reservoir of chemical for later movement into the wood.

Kerfing had a dramatic effect on the incidence of decay fungi. This effect highlights the importance of deep check development in fungal colonization. Deep checks that penetrate beyond the treated shell provide an ideal environment for germination and growth of fungal spores. Fungal spores landing on wood surfaces lacking deep checks must germinate and grow on an exposed wood surface where temperature and moisture conditions can fluctuate widely. These conditions sharply reduce the likelihood of successful colonization. Kerfs relieve the stresses associated with drying. Previous tests have shown that the kerf opens and closes seasonally with moisture changes in the poles, but continues to limit check development many years after installation. Kerfing appeared to slow fungal colonization of otherwise untreated timbers to a slight extent, but its primary benefit was when it was used in conjunction with a preservative. Kerfing is infrequently used in the U.S., but these results illustrate the benefits of relatively simple procedures for protecting wood against fungal attack.

Figure II-4. Incidence of decay fungi in increment cores removed from kerfed and non-kerfed Douglas-fir deck caps 1 to 20 years after application of various surface treatments.



OBJECTIVE III
EVALUATE PROPERTIES AND DEVELOP IMPROVED SPECIFICATIONS FOR WOOD POLES

A. Survey Utility Specification, Inspection, and Maintenance Practices

Wood poles have a long history of providing excellent service for supporting overhead electrical and telecommunication lines. These lines represent up to 40% of the net value of some utilities. More importantly, failures of these lines can interrupt service, reduce sales and result in costly emergency repairs.

In recognition of these risks, the National Electric Safety Code (NESC) requires that utilities regularly inspect and maintain the poles in their system and that they replace structures whose strength has declined below 66% of their original design value. Most utilities meet NESC requirements through regular inspection and remedial treatment programs, but there are no standards for these programs.

A 1983 survey showed that most utilities had some type of inspection program, although the frequency of inspections, the procedures employed and the treatments applied to arrest decay varied widely (Goodell and Graham 1983). This survey was performed in an era when utilities were more tightly regulated. Recent moves to deregulate utilities, coupled with substantial down-sizing and a trend toward consolidation have sharply altered the environment in which utilities operate. Despite these major changes, utilities must still reliably deliver power to their customers using overhead lines that are primarily supported by wood poles. Thus, the conflict between the need to be more profitable while maintaining reliability may cause utilities to alter their inspection program. In order to explore whether these changes had affected utility inspection and maintenance programs, the following study was undertaken.

<u>Survey Instrument</u>: The survey instrument developed by Goodell and Graham (1983) formed the basis for our survey, but was expanded to gain additional insight concerning pole material trends and chemical preferences.

The survey was initially mailed to 1100 utility engineers, purchasing agents and specifiers across the U.S. In this phase, 173 usable surveys were returned while another 70 surveys were undeliverable. A subsequent mailing to non-respondents produced an additional 87 responses (25.2% response rate).

The results were tabulated on an overall basis as well as on the basis of utility ownership (investor or public), region of the country and number of poles in the system to determine if their characteristics affected their pole inspection and maintenance practices or their attitudes concerning materials or chemicals.

Utility Sizes: The majority of respondents maintained 10,000 to 50,000 poles within their system. This level partially reflected the large number of public utilities among the respondents. Wood poles tended to be an important component of most utility systems. While 82 of 260 respondents limited wood pole usage to lines with voltages below 70kv, 72 used wood up to 230kv and an additional 65 employed wood for lines above this level. No utility reported using wood poles to support lines above 345kv, which is typically considered the upper limit for wood.

Almost half of the respondents would be broadly classified as public utilities, reflecting the large number of rural utility systems located across the United States Public utilities represented 120 of the 259 respondents, followed by Cooperatives (58), investor owned (57) and government (5) (Figure III-1). Most of the responding utilities were located in regions where the risk of decay was somewhat low (Figure III-2). Fully, 116 of 261 respondents to this question had some or all of their service territory in zones 1 or 2 (where Zone 1 represents low rainfall/cooler temperatures and 5 represents moist/warm temperatures) as listed in American Wood Preservers Association C4 (1999). Only 63 utilities were in Zone 4 and 26 were the most severe Zone 5. Utility location can clearly influence pole service life as well as the performance of many initial and remedial chemical treatments.

The majority of the 43 million poles in the 244 responding utility systems were southern pine (69.05%) followed by Douglas-fir (15.1%) and Western red cedar (12.66%) (Figure III-3). Limited numbers of ponderosa and lodgepole pine were also reported. Nearly 63% of these poles were treated with oilborne pentachlorophenol, reflecting a long standing utility preference for this treatment (Figure III-4). The remaining poles were treated with CCA (16.4%), creosote (15.7%), copper naphthenate (2.85%) and ACA/ACZA (1.09%). Oilborne chemicals continue to dominate utility systems, although CCA treated southern pine poles are an increasingly frequent part of utility systems in the southern part of the U.S.

New Pole Purchases: Most utilities purchased fewer than 500 poles per year, a finding that reinforces several western surveys showing that pole replacement rates at many utilities hover between 0.5 and 0.7% per year (Morrell and James, 1997, Morrell et al, 1999).

A majority of respondents were also interested in confirming pole quality as evidenced by the nearly 200 respondents that used either an in-house program or third party agent to inspect new poles. This suggests that utilities remain concerned about the quality of in-house inspection programs at treatment plants. These practices are in sharp contrast to other material purchases where the manufacturer is expected to provide quality materials without significant oversight.

Figure III-1. Types of utility ownership by respondents. A total of 261 utilities responded to this question.

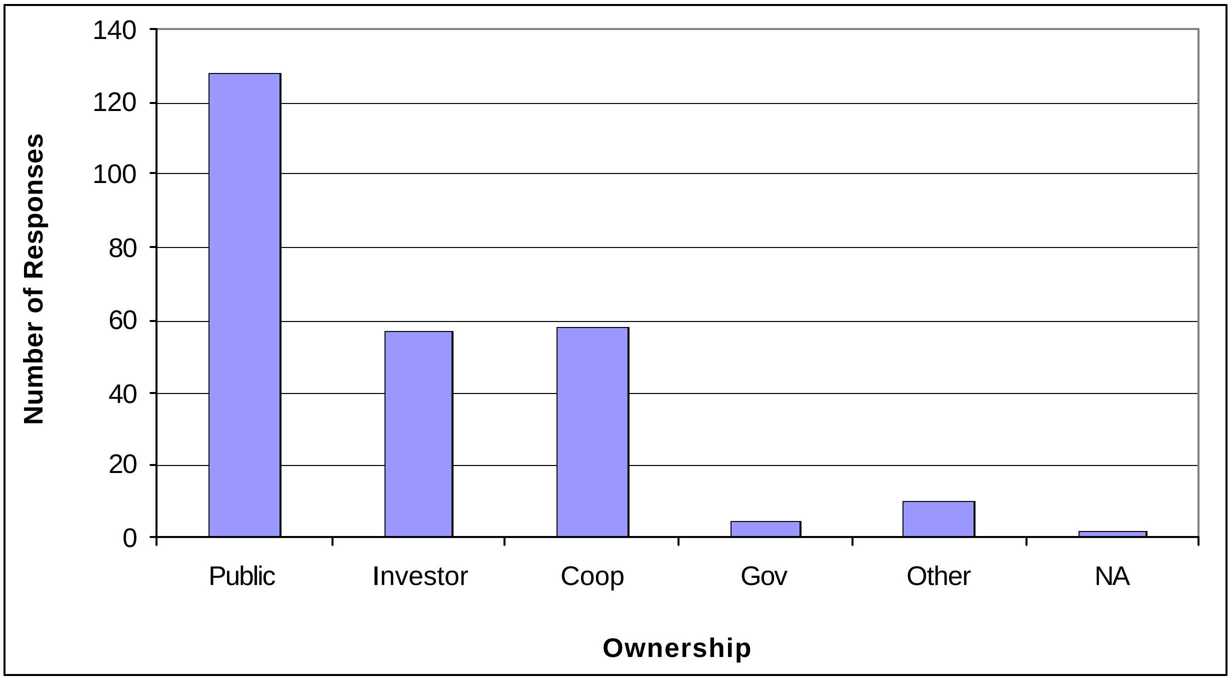


Figure III-2. Decay hazard zones in which responding utilities were located. A total of 261 utilities responded to this question.

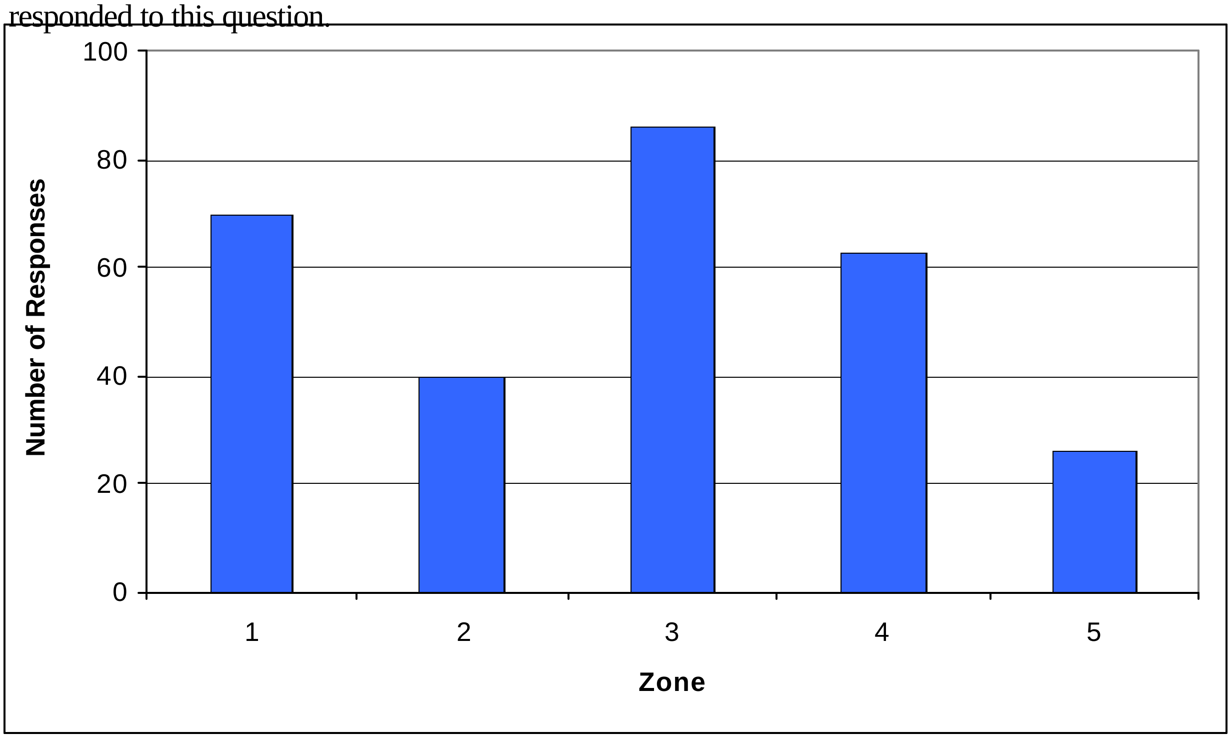


Figure III-3. Wood species composition of the responding utility systems. A total of 245 utilities responded to this question.

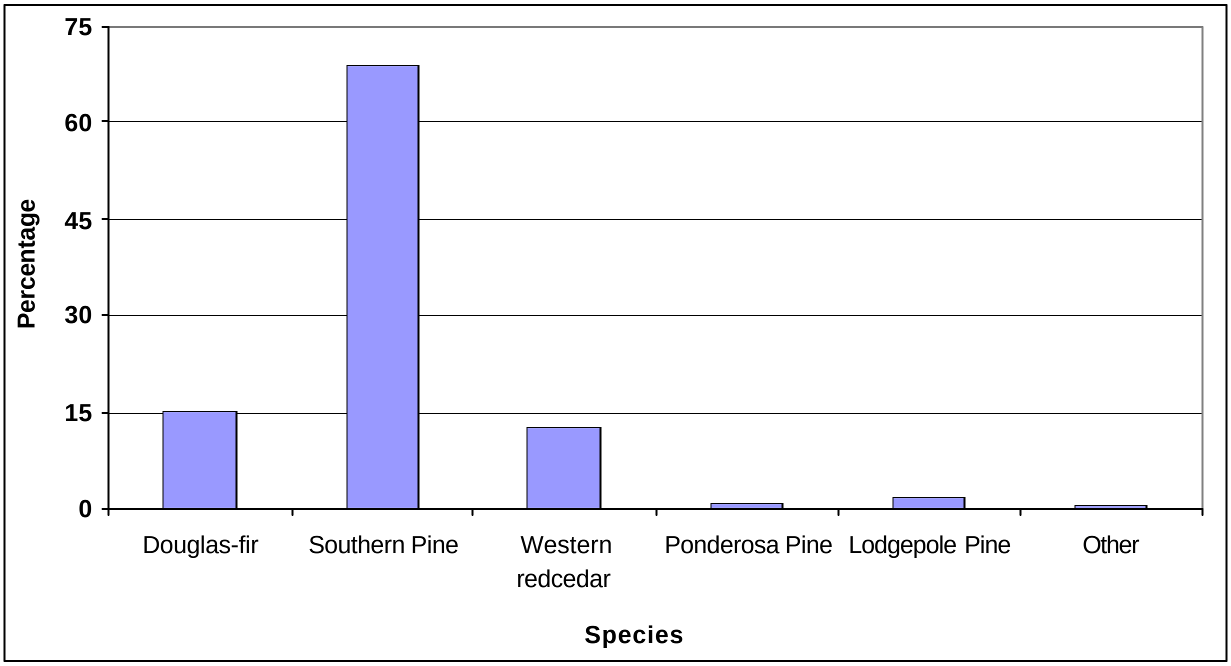
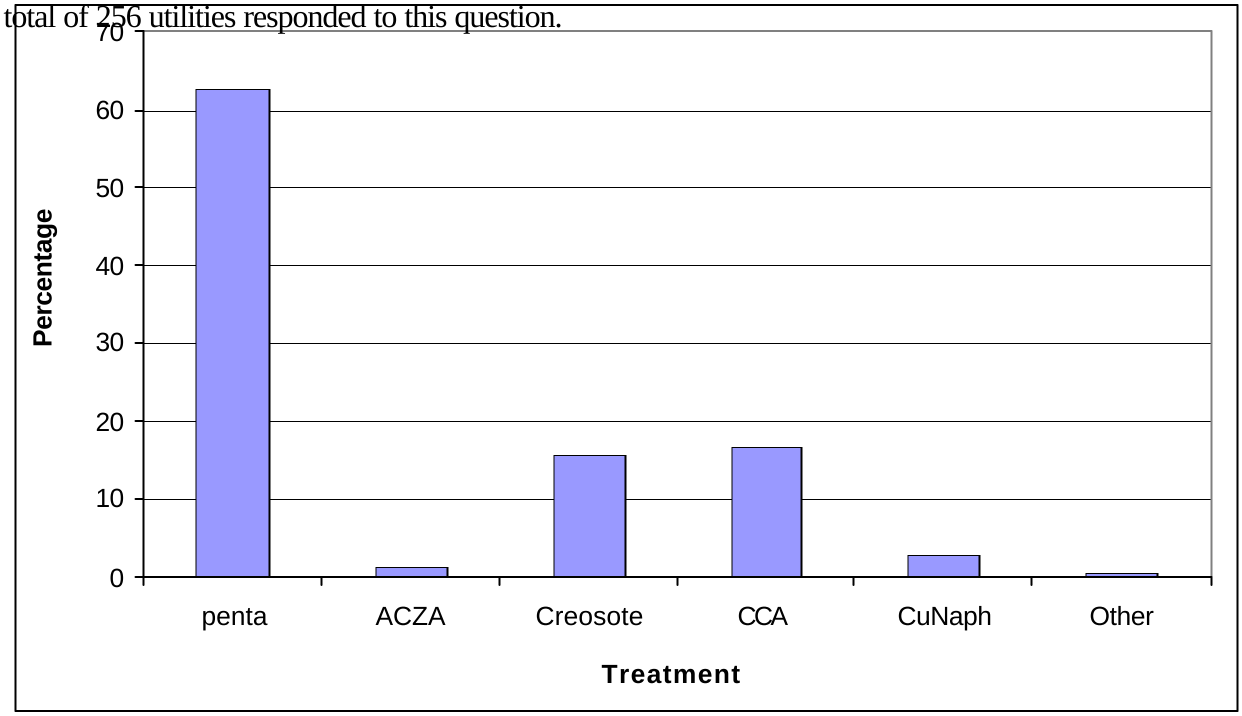


Figure III-4. Frequency of initial preservative treatments in poles in the responding utility systems. A total of 256 utilities responded to this question.



A final question under the new pole purchase section concerned pre-treatment procedures to improve the depth of initial treatment. These practices included radial drilling, through boring and deep incising that are primarily applied to Douglas-fir, a species with a thin sapwood band surrounding a difficult to treat heartwood core (Graham, 1983). A majority of respondents (140 utilities) did not use Douglas-fir in their systems, reflecting the abundance of smaller public utilities east of the Rocky Mountains. These utilities typically do not have large numbers of transmission lines where Douglas-fir would be used. Of the remaining 120 respondents, 110 employed one of the three groundline pretreatment practices on their Douglas-fir poles. Most utilities claimed to use deep incising on their poles, a some what surprising finding given the limited number of treaters that can apply this method. We suspect that some respondents confused conventional incising, which uses 12 to 19mm long teeth on rollers to improve sapwood penetration with deep incising that drives 60 to 75 mm long teeth into the wood. As a result, the incising response must be viewed cautiously. The 60 utilities that incorporated radial drilling or through-boring into their specifications reflect a growing trend among Douglas-fir users to improve treatment in the critical groundline zone. These trends should markedly improve pole service life and alter the manner in which these utilities inspect their poles.

<u>Expected Service Life</u>: Utility consolidations and increasing drives for higher investment returns have encouraged many utilities to evaluate the service lives they obtain from a variety of materials, including wood. At the same time, alternative materials have made service life claims that are, at best, difficult to confirm. For many years, most utilities have used 30 to 40 years as the estimated service life for wood poles. The survey responses reflected these figures for southern pine, ponderosa pine, lodgepole pine and Douglas-fir (Figure III-5). However, a majority of western redcedar users estimated service life of this species to be between 51 and 70 years for this species. Numerous lower voltage cedar transmission lines across North America that were installed in the 1930's clearly attest to the excellent performance of this species. The tendency for utilities to continue to perceive lower services lives for other species is perplexing in light of advances in inspection and maintenance practices over the past 3 decades. Western surveys suggesting replacement rates of 0.5 to 0.7% /year would place average service life at 70 to 100 years. A recent report on several mid-western utilities supports these estimates (Stewart, 1996). While these results are promising, it is clear that utilities continue to use out-dated information when comparing wood pole service life with that of other materials.

This misconception may also influence future utility purchasing decisions. Of the respondents, 48 had used laminated poles, 116 steel poles, 57 fiberglass and 62 concrete within their systems within the last five years (Figure III-6). While the survey did not ask what percentage of total purchases were alternative materials, results imply a diversification of pole usage patterns as utility engineers explore the performance properties of wood alternatives.

Maintenance Practices

Inspection Cycles: As expected, there was a wide disparity in inspection frequency among respondents. This disparity was greatest in the distribution systems, where many utilities reported that they had no inspection program for these poles. Transmission poles were inspected on a 7.2 year cycle while distribution poles were inspected every 8.1 years. It is important to remember that an inspection could range from a cursory visual inspection to a complete excavation, sound and boring.

The vast majority of utilities reported using combinations of visual inspection, sounding with a hammer and boring with a drill (Figure III-7, 8, 9). A majority of utilities bored both above and below groundline, although the number that inspected below ground was somewhat lower, possibly reflecting the decay risk in many locations. It is common knowledge among utilities in many areas of Zone 1 that decay tends to occur 300 to 450 mm below ground where moisture conditions are more suitable for fungal growth. Excavation is essential for detecting decay in poles in these regions.

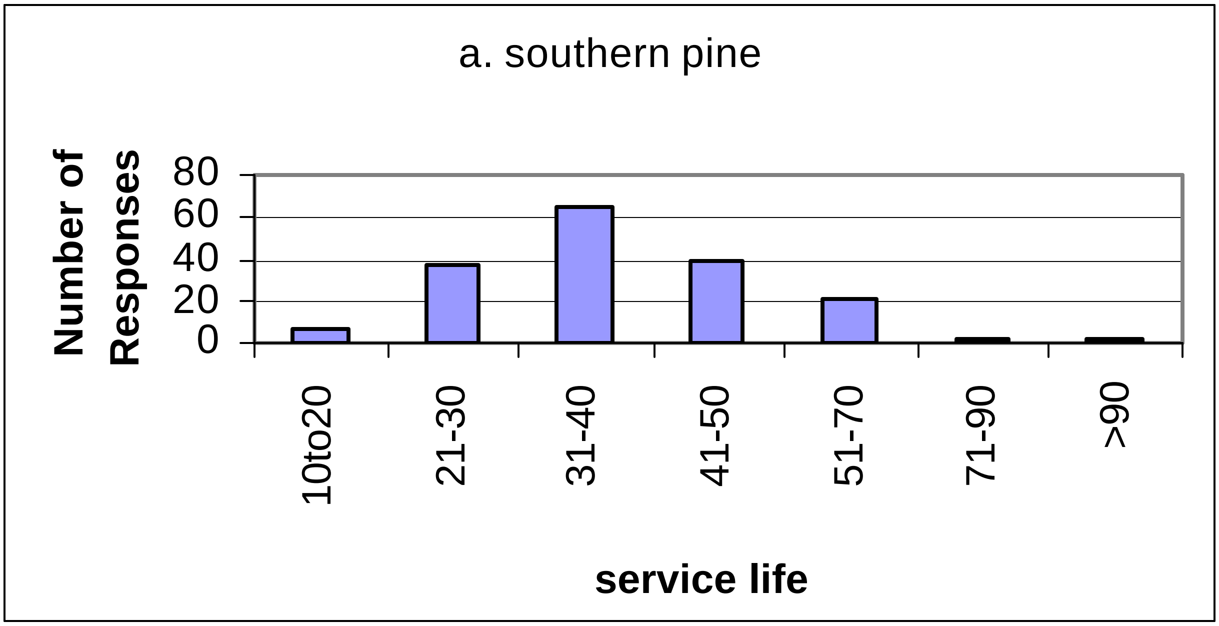
While sounding and boring formed the basis for most pole inspection, some respondents used alternative inspection devices. Seven respondents reported using a moisture meter for pole inspection (Figure III-10). While this device will detect wet wood that could be at risk of decay, it does not detect decay. It is possible that the respondents used the moisture meter to assess conformance to post-treatment moisture levels in newly purchased poles. Seven utilities reportedly used the Shigometer for pole inspection. This device measures resistance drops as a twisted wire probe is inserted into a predrilled hole in the pole. Resistance drops signify areas of possible decay. The Shigometer was originally developed for detecting decay in living trees, and has seen only limited application to wood products. A number of evaluations have concluded that this device is best operated by trained inspectors who can interpret the resulting output.

Twenty-one respondents report using the sonic device Poletest in their inspection process, with a majority (15/21) using the device on Douglas-fir or Western redcedar (Figure III-10). While sonic devices have attracted considerable utility interest, it appears that only a small proportion of respondents have incorporated this technology into their systems. A number of respondents reportedly used other inspection tools in their programs (21 respondents) but did not specify the nature of these devices.

The past decade has witnessed the introduction of a number of microdrilling or sonic devices that seek to provide supplemental information to the inspector. Despite these efforts, however, it appears that most utilities are unwilling to change their inspection procedures to incorporate such devices. It is unclear whether the delayed adoption of new technology represents the conservative nature of the industry or dissatisfaction with the results these new devices provide.

Carpenter Ants: Carpenter ants can be an important problem in some regions of the U.S., particularly where utility right-of-ways pass through forested areas. Unlike termites, which can usually be controlled by void treatments into their galleries, carpenter ants are more mobile and therefore capable of moving out of the treated zone to attack other portions of the pole.

Figure III-5. Expected service life of a) southern pine, b) Douglas-fir, c) western redcedar, d) ponderosa pine, e) lodge pole pine and f) other. A total of 260 utilities responded to this question.



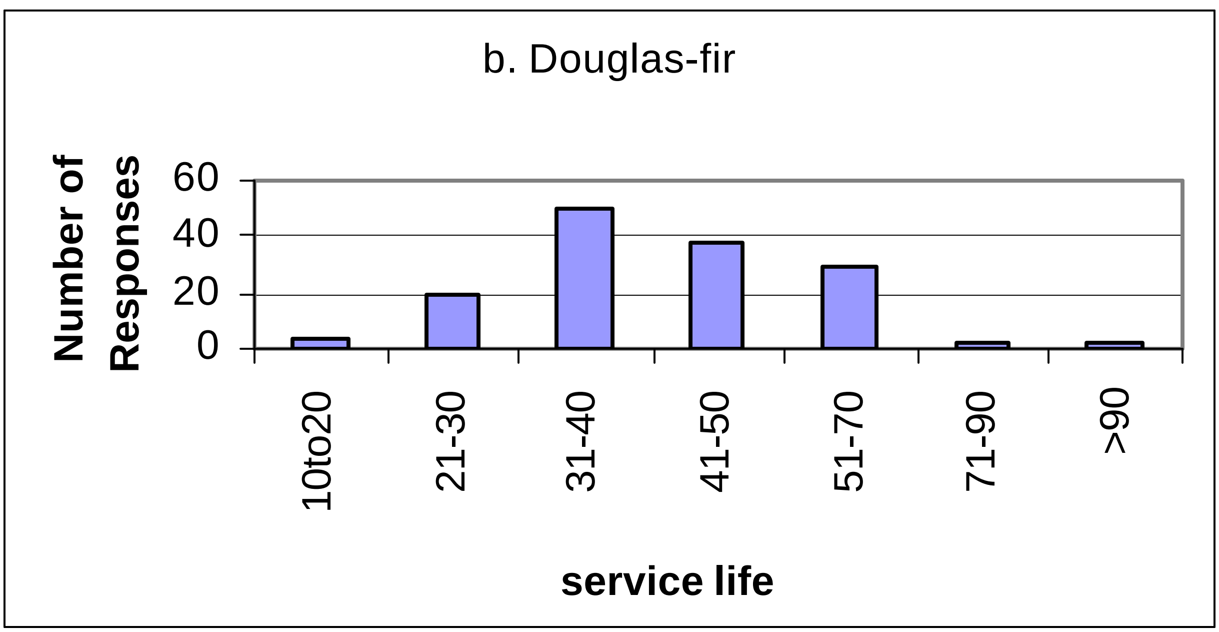
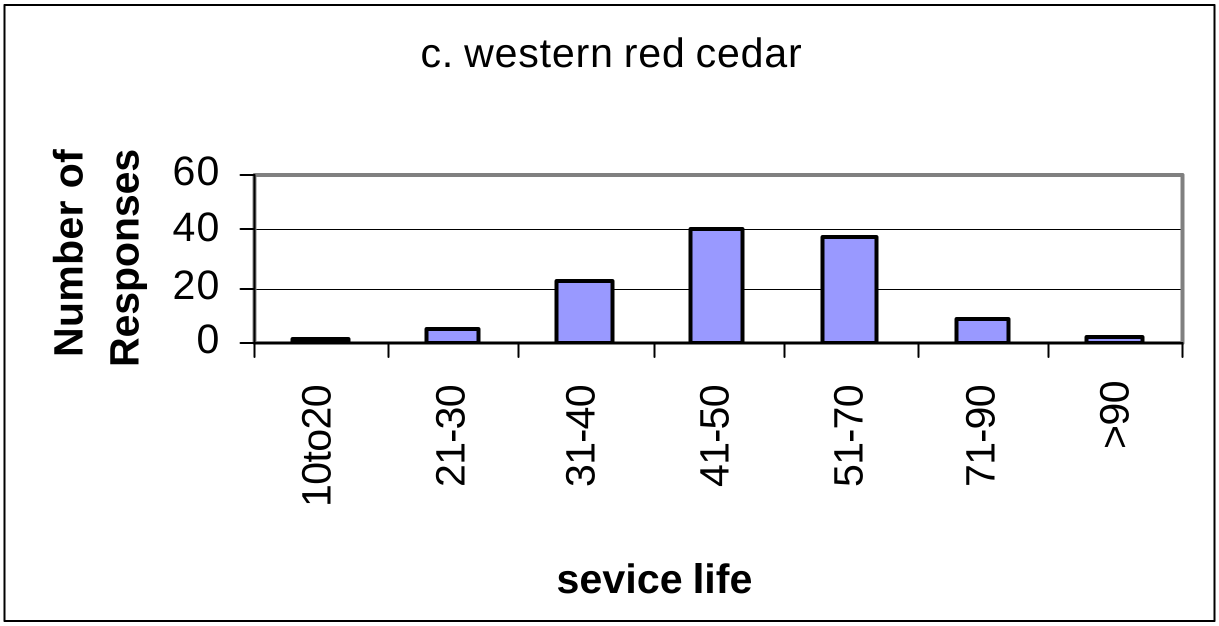


Figure III-5. Continued



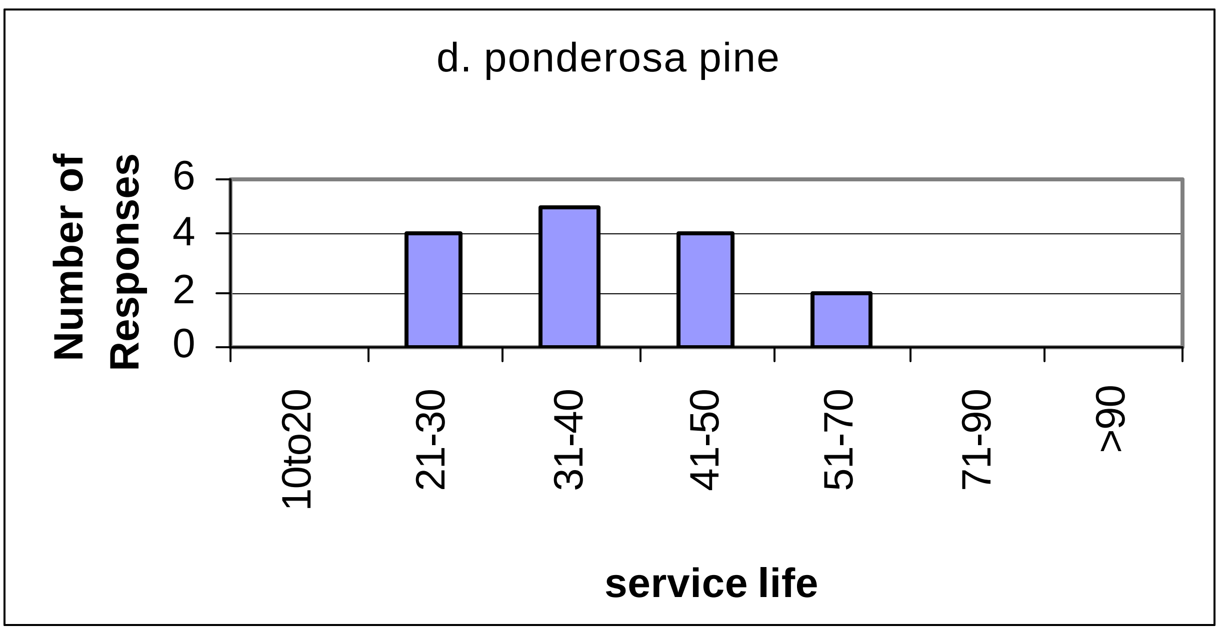
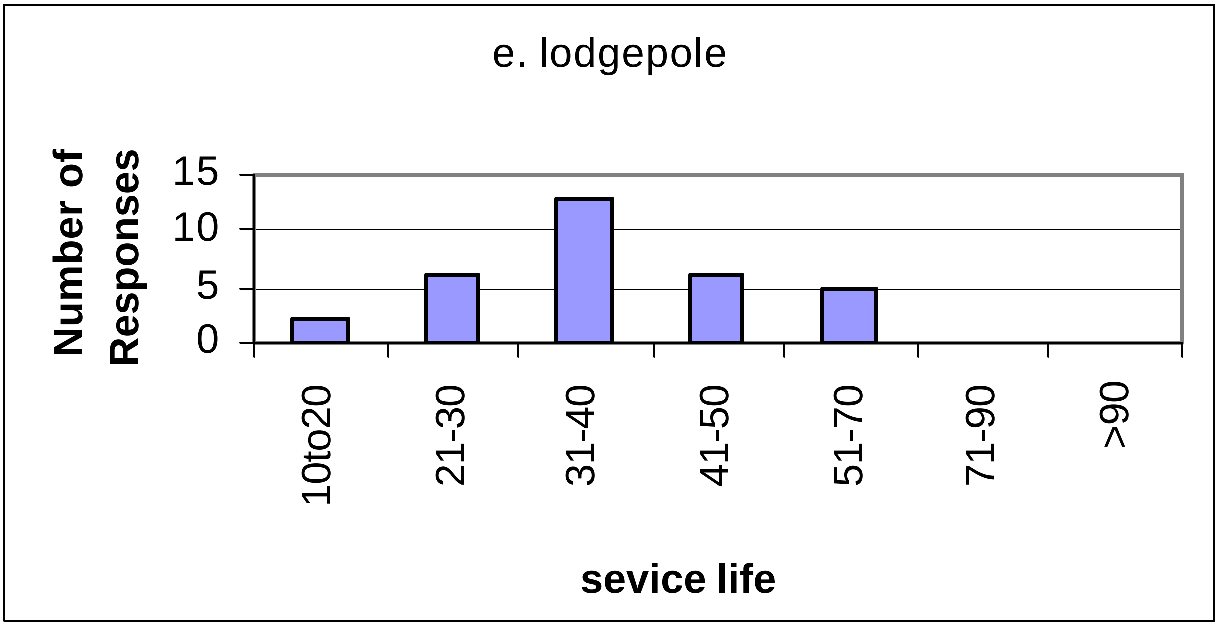


Figure III-5. Continued



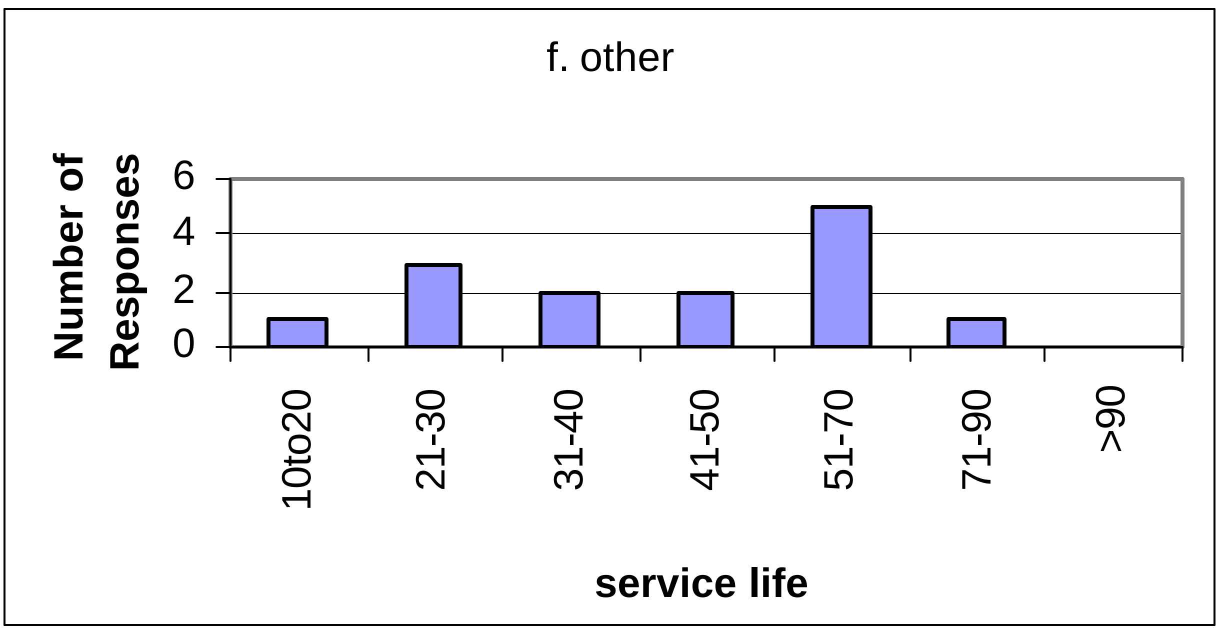


Figure III-6. Frequency that responding utilities purchased wood substitutes in the last 5 years. A total of 261 utilities responded to this question.

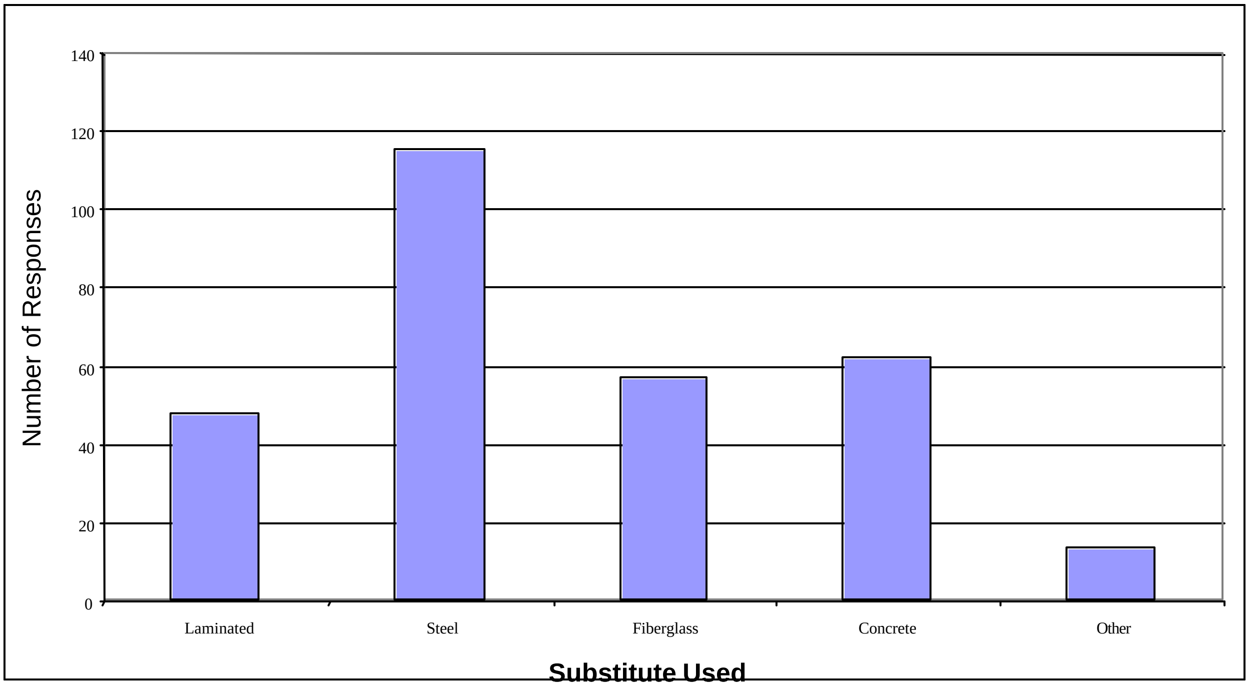


Figure III-7. Frequency that utilities used visual inspection for various pole species. A total of 231 utilities responded to this question.

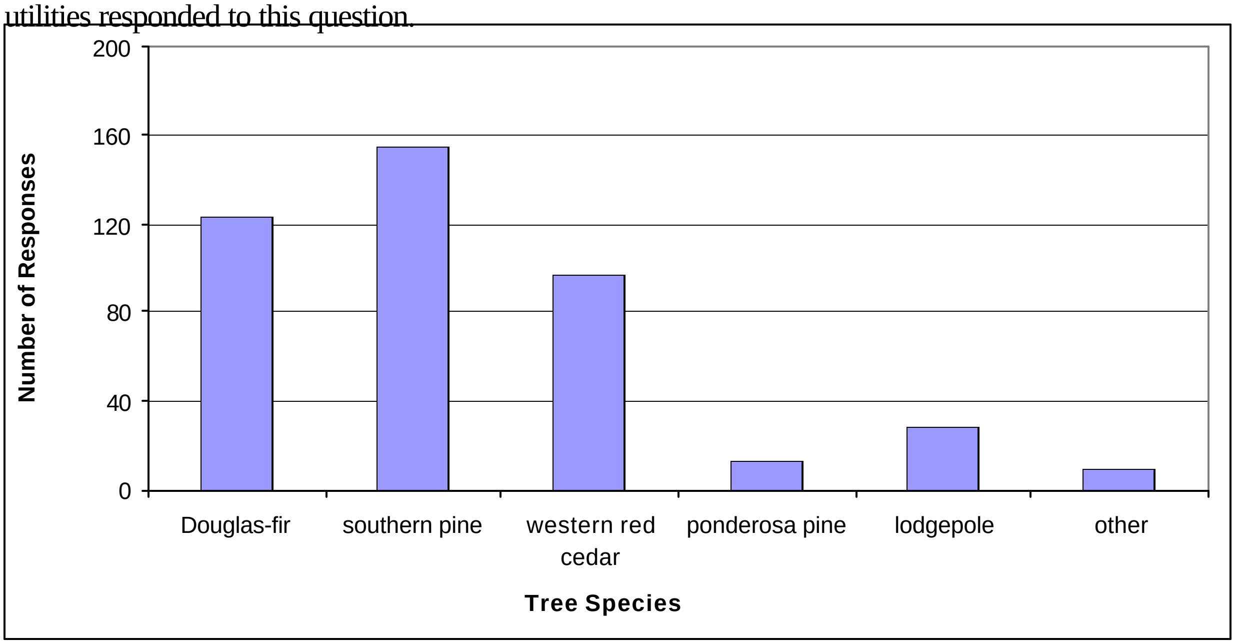


Figure III-8. Frequency that utilities used sounding with a hammer as part of the inspection process for various pole species. A total of 231 utilities responded to this question.

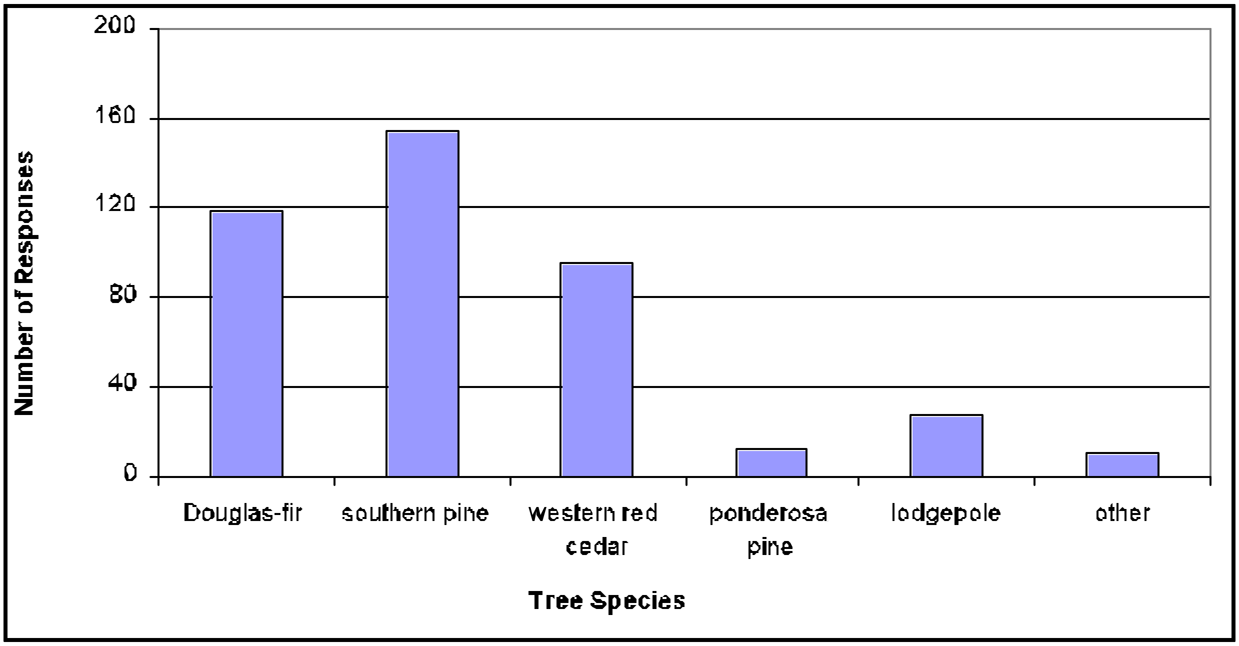


Figure III-9. Frequency that utilities used boring/drilling (a) at or (b) below the groundline as part of their routine inspection procedures. A total of 231 utilities responded to this question.

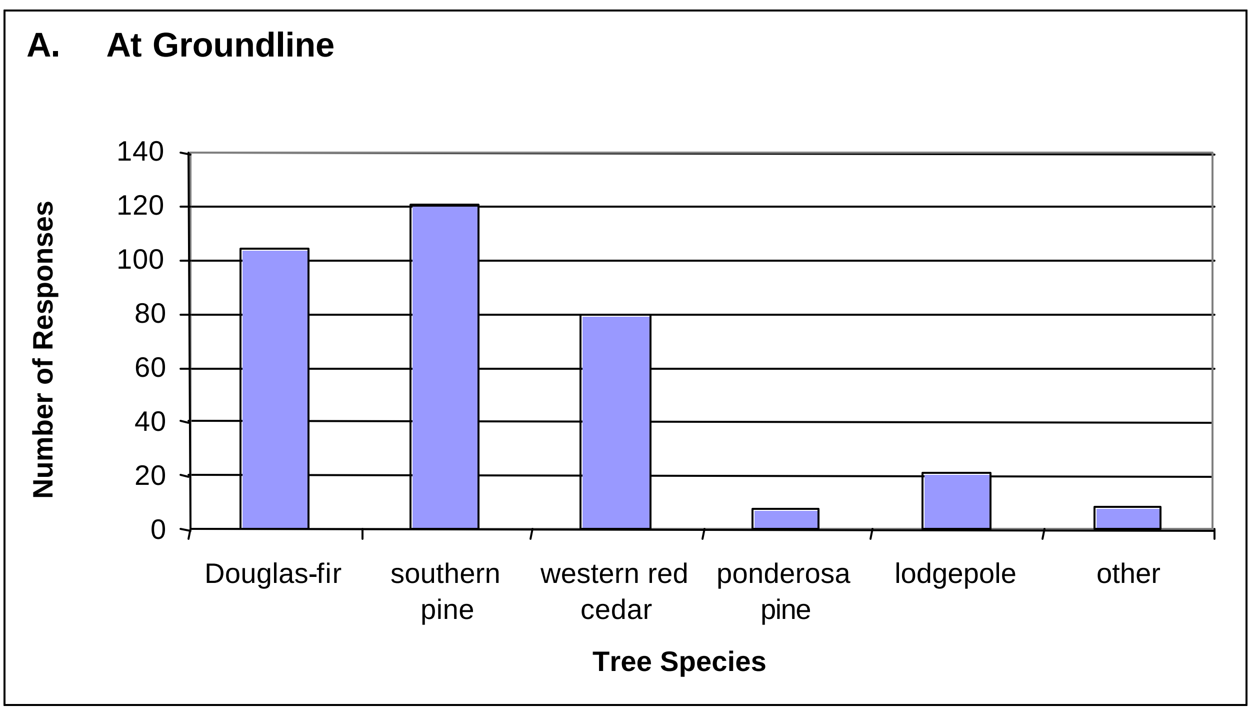


Figure III-9. Continued

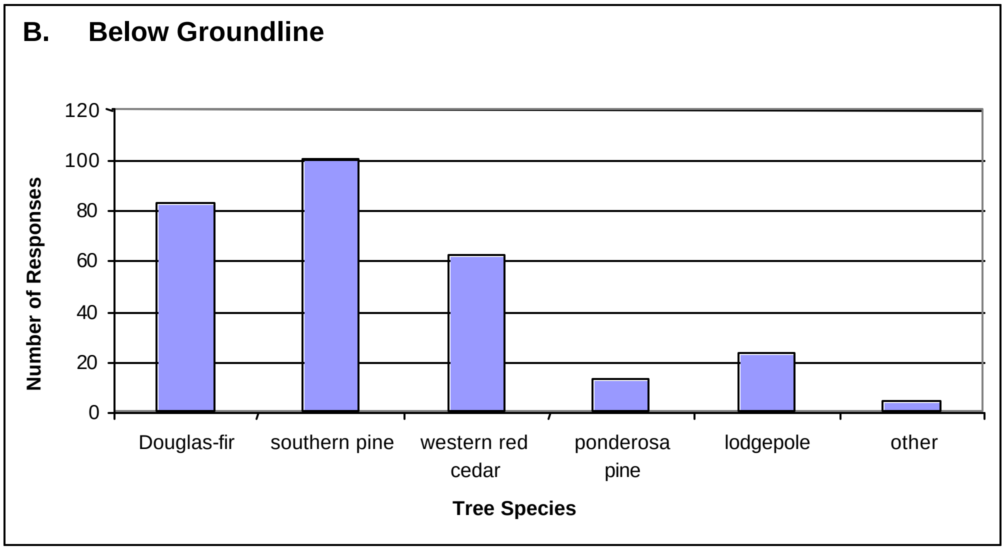


Figure III-10. Frequency of utilities employing (a) moisture meters, (b) the Shigometer, or (c) PoleTest as a part of their pole inspection procedures. A total of 231 utilities responded to this question.

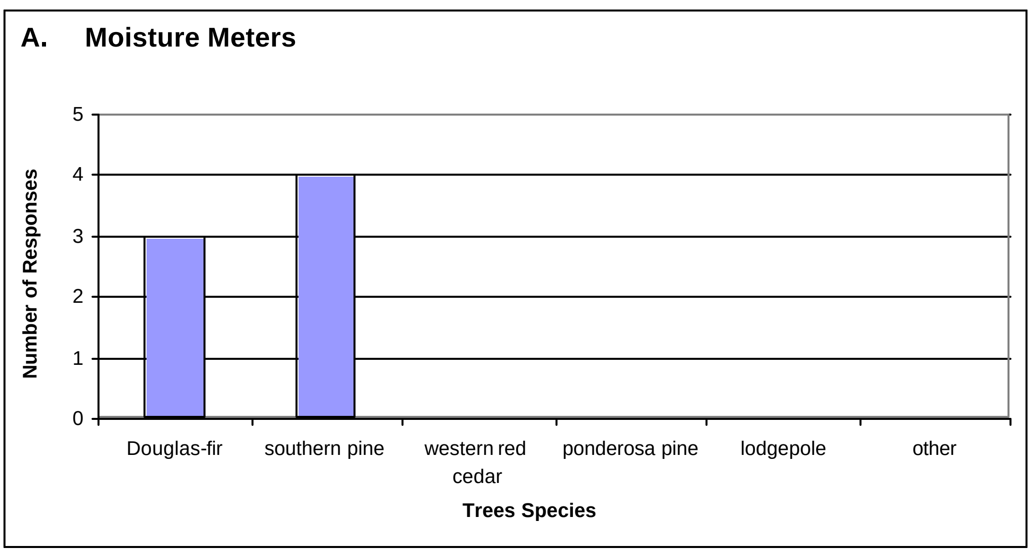
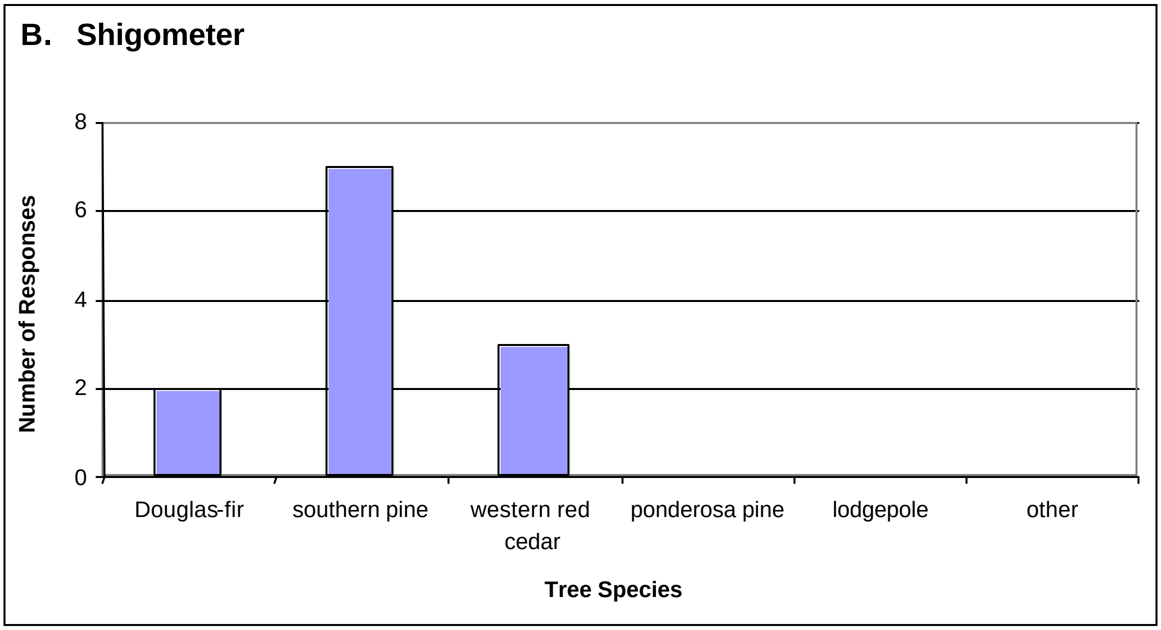
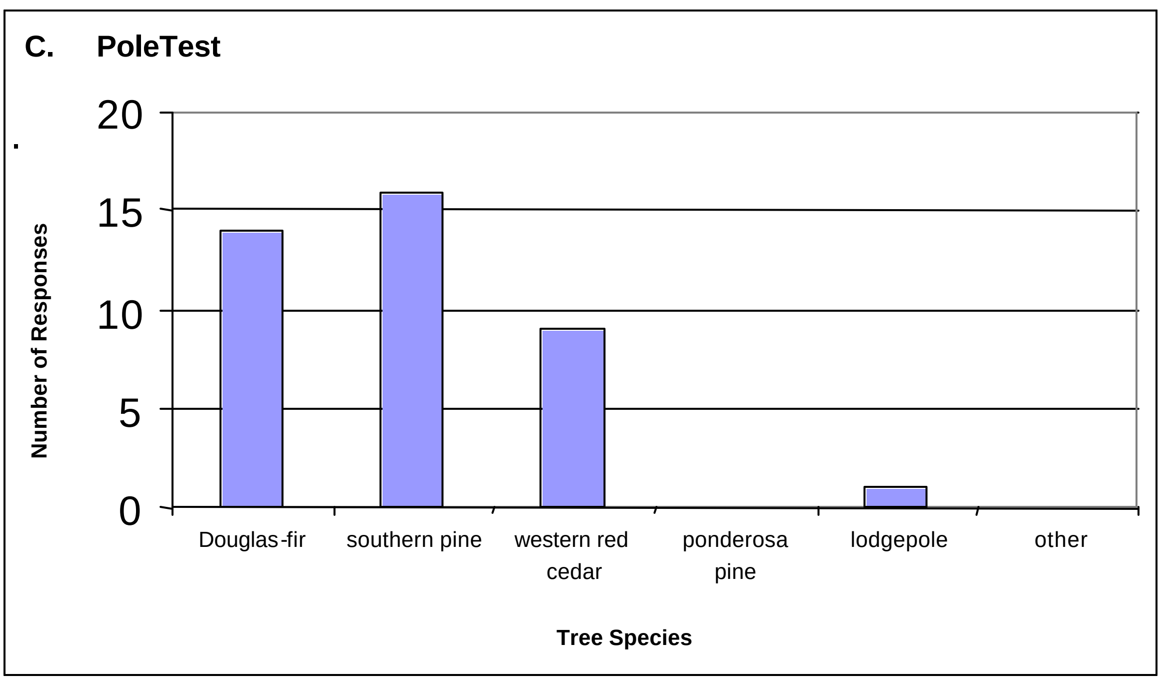


Figure III-10. Continued





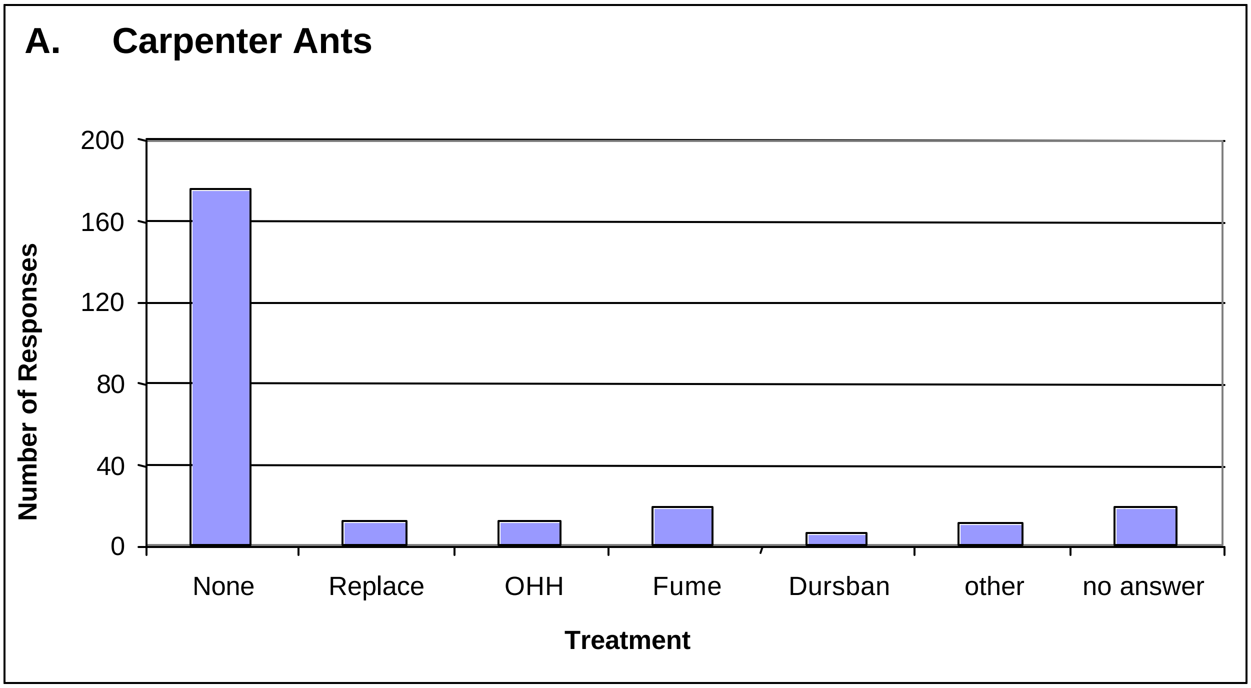
Approximately 1.4% of poles in the responding utilities experienced carpenter ant attack. The damage, however, was often concentrated among utilities that had extensive territories in more heavily forested areas. Most utilities (261 respondents) reported that they had no treatment in their specifications for carpenter ant control. Presumably, utilities in this group that experience attack replace poles once the damage exceed the utility's replacement criteria. The remaining respondents used a variety of treatments including Hollowheart, "Fume", Dursban, sodium fluoride rods, copper naphthenate and Patox (Figure III-11). While carpenter ants do not appear to be a nationwide utility issue, it is clear that they are locally important. It is unclear, however, if the level of damage is sufficient to support specialized products for controlling these insects.

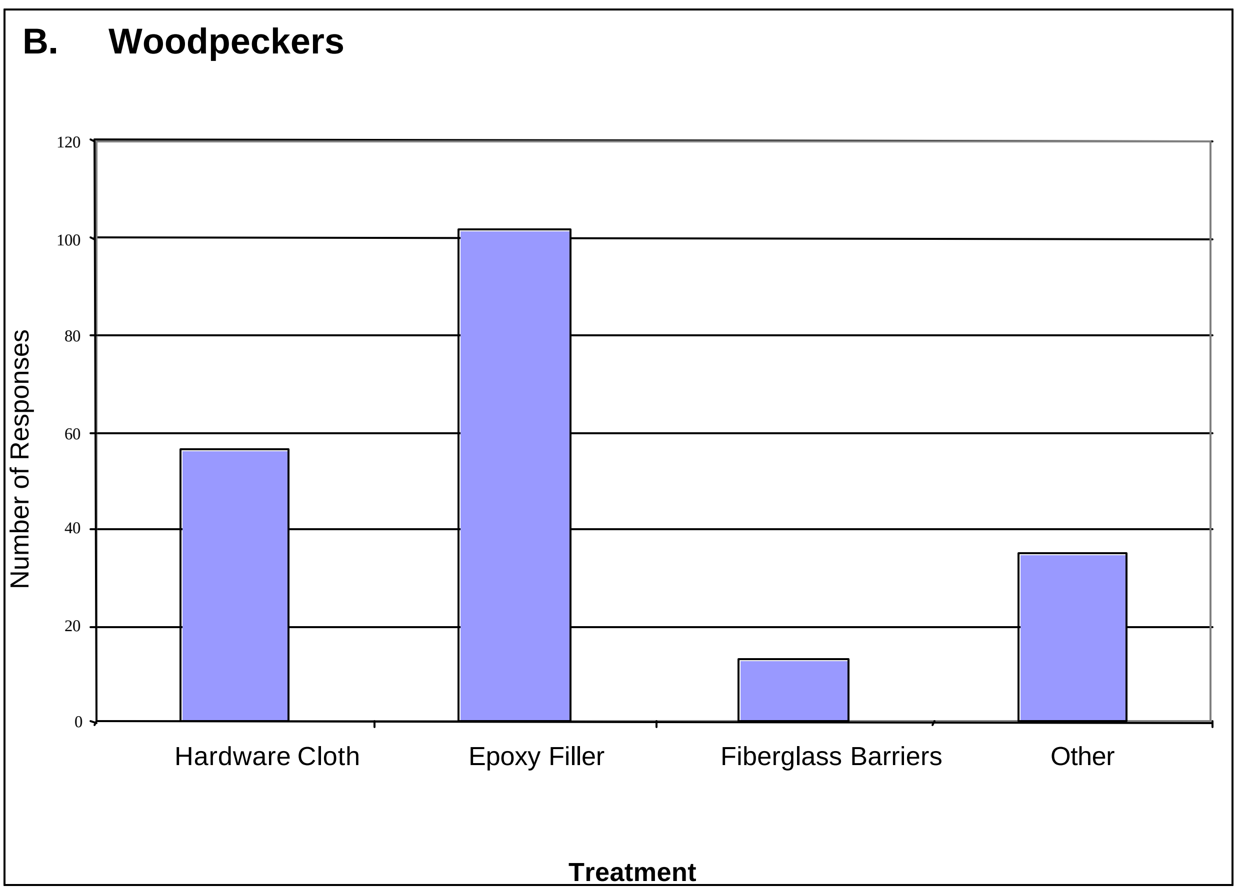
<u>Woodpeckers</u>: Like carpenter ants, most woodpecker damage appears to be closely related to the proximity of a line to a forested area. However, even a small grove of trees can serve as a potential source of attack. Woodpeckers attack wood poles for a variety of reasons including resting, feeding, and nesting, and not all species attack poles. Woodpeckers damaged an estimated 5.75% of poles in the responding systems, a figure suggesting that the estimated cost of this damage ($5,272,200/year) seems relatively low. A majority of respondents (102/206 responses) used epoxy fillers to control woodpecker attack, while 56/206 used hardware cloth to prevent damage (Figure III-11). A limited number of utilities used fiberglass wraps (13/206) while 35 respondents used "other" methods, but did not identify their methods.

<u>Remedial Treatments</u>: Respondents were asked to identify all of the remedial treatments used in their systems and then assess their level of satisfaction with each chemical (Figure III-12). These treatments can be divided into external systems for controlling soft rot attack and internal systems for controlling internal decay. Over 40% of the respondents used Osmoplastic for external decay control, while nearly 30% used one of three copper naphthenate-based formulations (Figure III-13). Nearly 20% of respondents used Patox, which we presumed to be Patox II, a sodium fluoride-based system. The results indicated that most utilities have shifted using from penta and creosote-based external treatments.

While chemical usage patterns have changed, it is also clear that the respondents were generally satisfied with the performance of these systems (Figure III-13). Most utilities perceived the performance of the current specified systems to be acceptable or better. Osmoplastic received the most excellent responses of any chemical evaluated (nearly 30% rated this chemical as an excellent performer). Similarly, utility perceptions about safety mirrored performance perceptions. Most importantly, few respondents viewed the chemicals as being unsafe.

Figure III-11. Frequency of utilities using various systems for (a) carpenter ant infestation or (b) woodpecker attack of wood poles. A total of 242 utilities responded to this question.





III-12. Frequency of usage of various remedial treatments among responding utilities. A total of 260 utilities responded to this question.

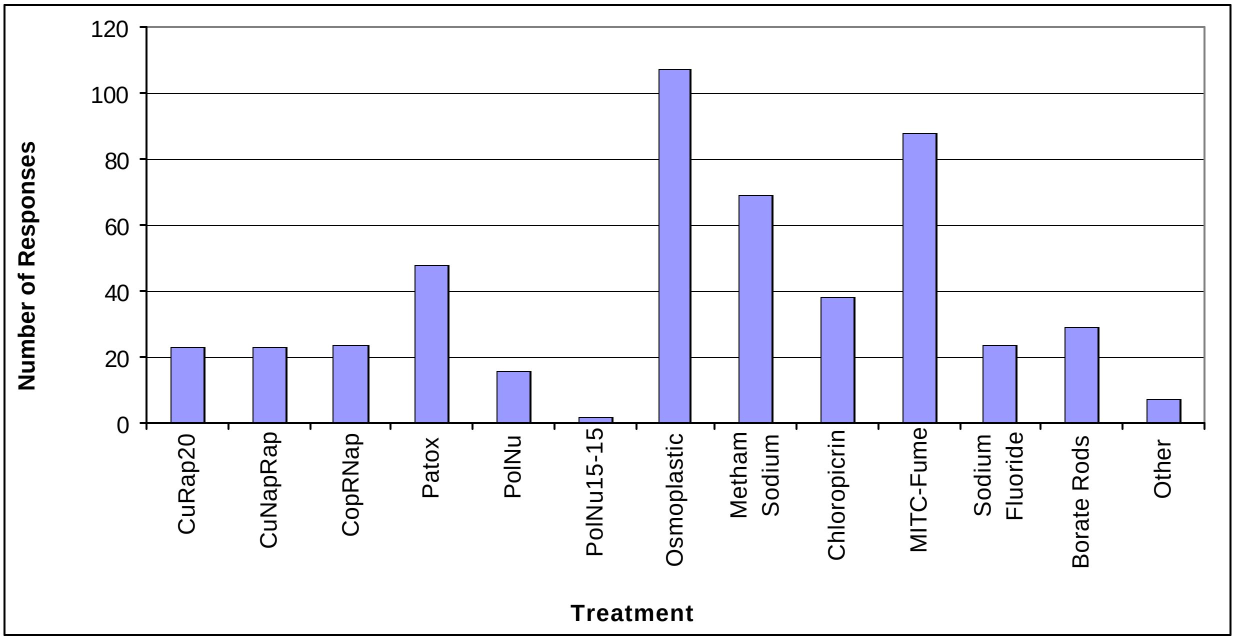


Figure III-13. Utility perceptions concerning (a) performance and (b) safety of various internal remedial treatments for arresting decay in wood poles (where 1 = dissatisfied or unsafe and 5 = very satisfied or safe). A total of 260 utilities responded to this question.

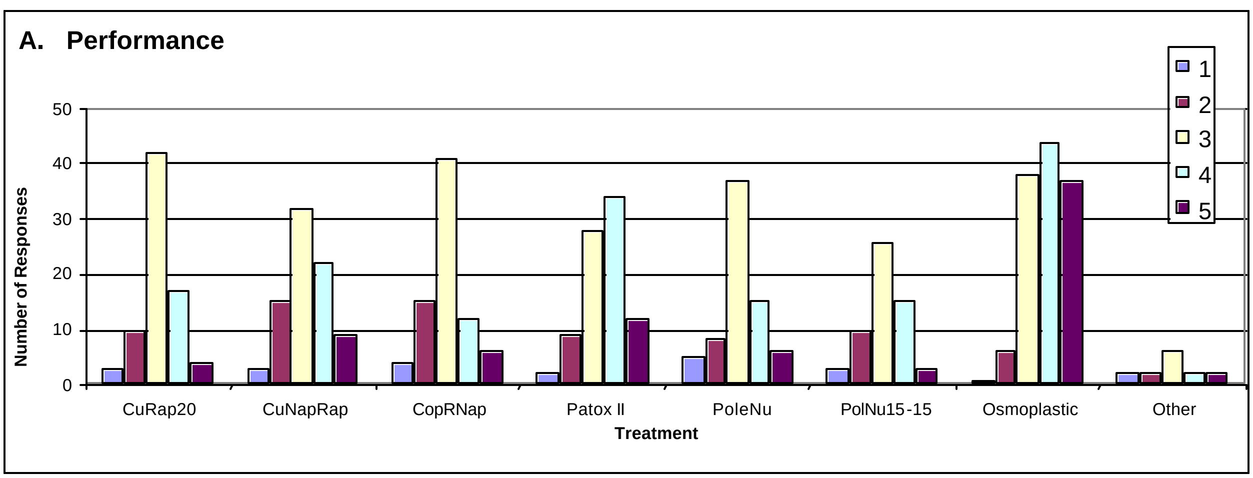
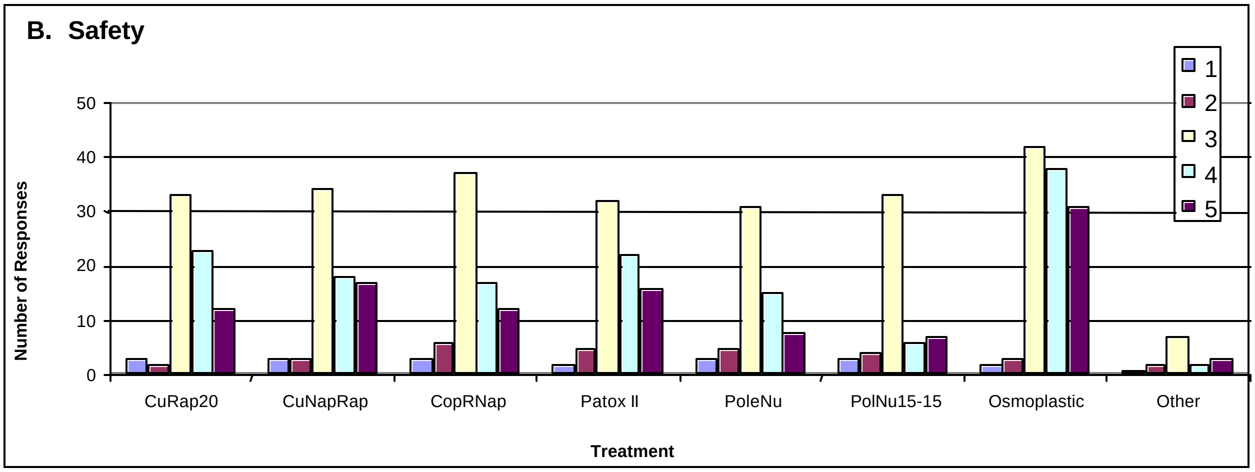
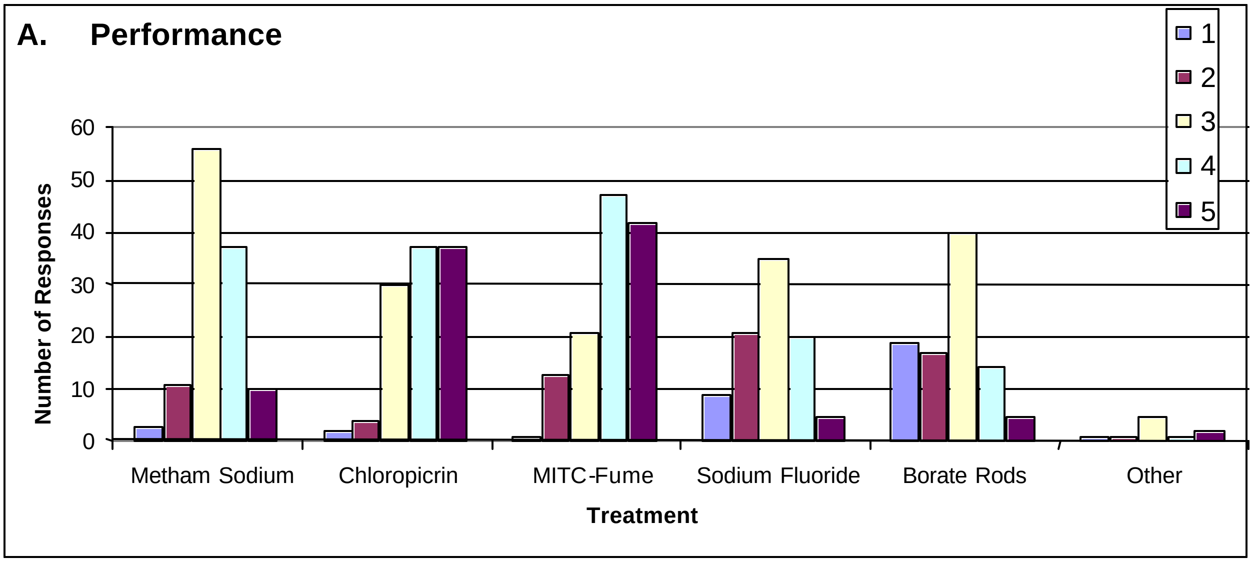


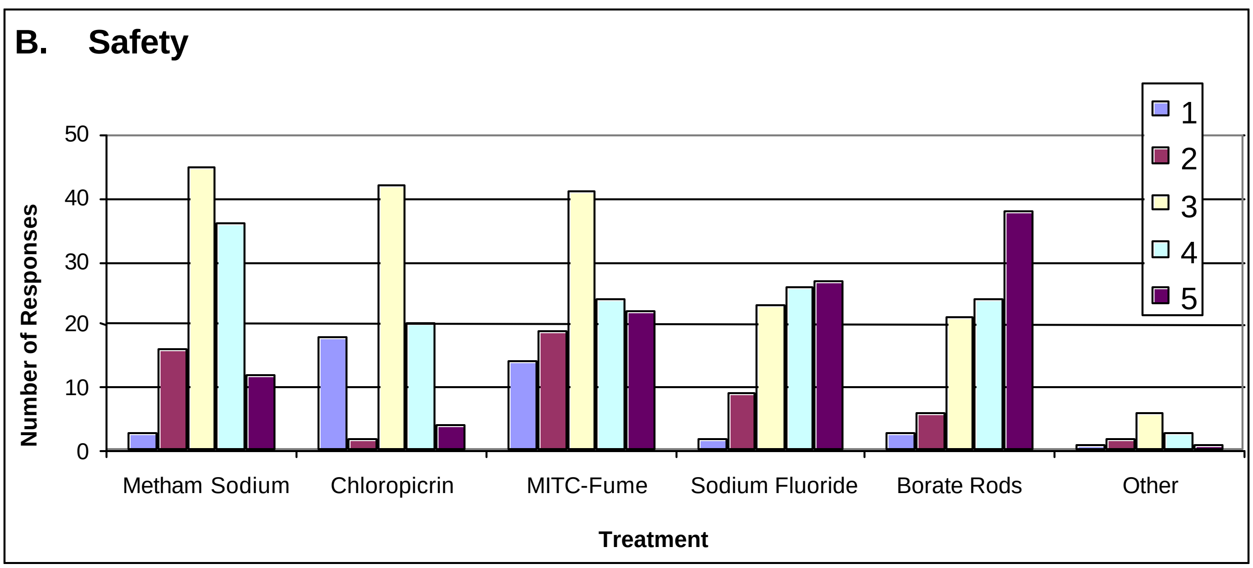
Figure 13 Continued



Utilities rated their perceptions on 5 internal remedial treatments, metham sodium, chloropicrin, MITC-Fume, sodium fluoride rods and fused boron rods (Figure III-14). A majority of respondents used one of the three fumigants. MITC-Fume was the most commonly used internal treatment followed by metham sodium and chloropicrin. Until the introduction of MITC-Fume in the early 90's, metham sodium was the dominant fumigant used for internal decay control. Chloropicrin was traditionally used in overland transmission lines away from inhabited areas for safety reasons. It would appear that MITC-Fume, which is a solid at room temperature and is encapsulated in aluminum tubes for safe handling, has taken market share from both metham sodium and chloropicrin. Boron and fluoride rods are both relatively recent entries into the U.S. utility market although both have been commercially used in other countries. Both systems are water soluble and easily handled. They have relatively mild labels that do not require that the applicator have an applicators license for installation. These chemicals, however, work more slowly than fumigants. It would appear that utilities are incorporating diffusable rods into their systems, but the pace of adoption is relatively slow. The slow rates of adoption may reflect perceptions about performance and safety. Most utilities felt that MITC-FUME, metham sodium and chloropicrin provided good to excellent performance and a huge percentage of these respondents felt that MITC-FUME and chloropicrin provided excellent protection. Conversely, few respondents felt that either boron or fluoride rods provided excellent performance. These perceptions nearly reversed when safety was the primary concern. Most respondents rated the rods as excellent in terms of safety, while few perceived either metham sodium or chloropicrin in this category. It is interesting to note that MITC-FUME proved to be intermediate in these categories with many utilities rating both safety and performance favorably. This presumably accounts for the high number of utilities who currently specify this chemical.

Figure III-14. Utility perceptions concerning (a) performance and (b) safety of various external preservative pastes or bandages used to arrest external decay on wood poles (where 1 = dissatisfied or unsafe and 5 = very satisfied or safe). A total of 260 utilities responded to this question.

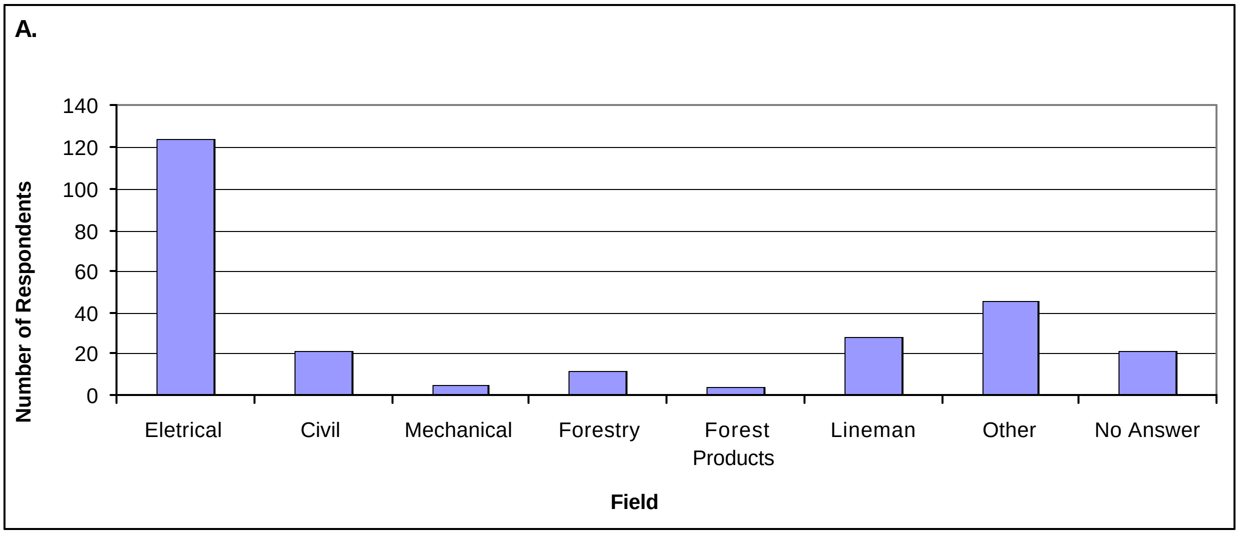


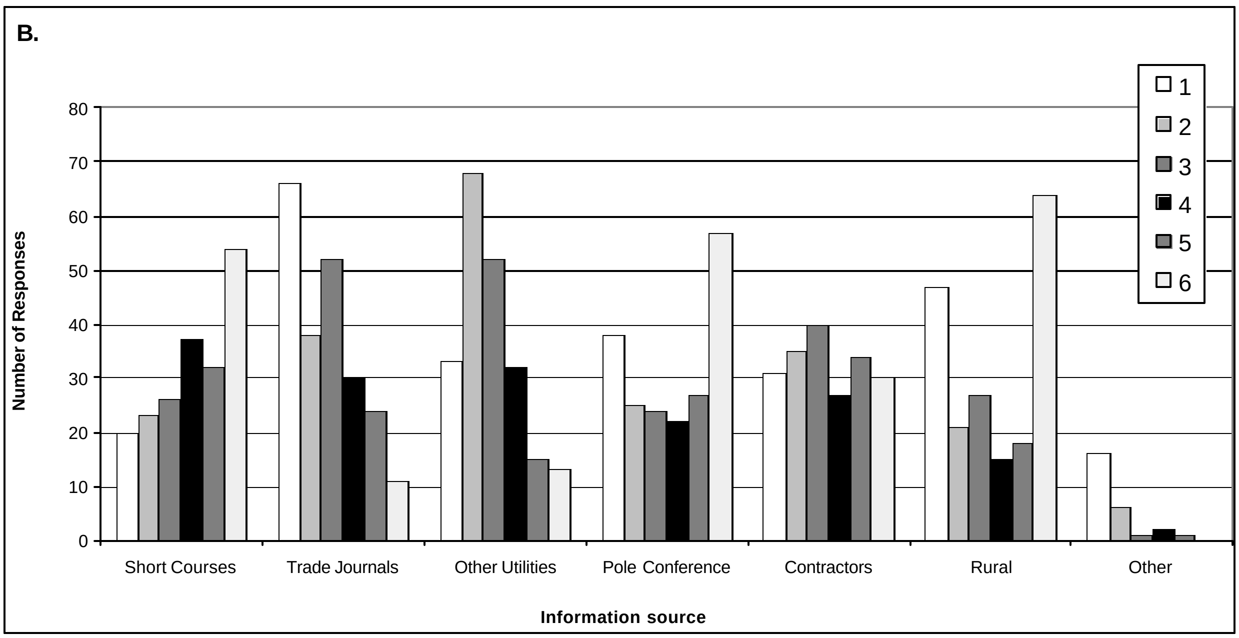


Training: An inspection and maintenance program is only as effective as the degree to which the personnel understand the nature of wood and the characteristics of the chemicals used to protect it. Almost half of the respondents listed electrical engineering as their primary field of training (124/260) suggesting that they came to their jobs with little in the way of formal training in wood as a material (Figure III-15). Only 16/260 respondents had forestry training and only 4 of these were trained in forest products, an astoundingly low level of initial training given the economic importance of wood in most utility systems. The low initial knowledge level that many utility personnel bring to the job implies a need for substantial training and information to educate personnel on wood related issues. Utilities were asked to rate the importance of short courses, conferences, trade journals, contractors, and the Rural Electrification Adm., and other utilities as sources of information. Trade journals appeared to be the most widely accepted information sources, while conferences and short courses appeared to be the least accepted source of information. The REA produced the most diverse response with high numbers of respondents rating this source extremely low or high. This spread may reflect the responses of the investor owned utilities which would have little need to interact with this group in comparison with public utilities who often must follow REA guidelines as a requirement for obtaining REA financing. It was interesting to note that contractors were evaluated more favorably than other utilities, a finding that may reflect an increasingly deregulated environment where utilities are unwilling or unable to share information with groups that may ultimately compete for their business. One major disadvantage of this trend is that fragmentation of information among many utilities may obscure major problems with specific materials or practices. This applies to all materials not just wood.

The results suggest that many utility practices remain relatively unchanged from those found 17 years ago. Utilities clearly see wood as an important component in their systems, although their perceptions on service life of wood need some reconsideration. Most utilities have regular inspection programs and appear to be satisfied with the chemicals they use to arrest decay. The survey also suggested a considerable need for training.

Figure III-15. Primary field of training for respondents (a) and (b) perceived value for various sources of information on the use of wood poles (where 1 = most frequently used and 6 = least frequently used). A total of 261 utilities responded to this question.





B. Ability of Selected Pole Inspection Devices to Detect Decay and Estimate Residual Pole Strength

Last year, we reported on a test to assess the ability of various inspection devices to predict residual pole strength. Briefly, the devices were used to evaluate a population of poles in the field, then the poles were removed, brought to the laboratory and tested to failure in cantilever loading. The results were presented in a series of diagrams showing estimated versus actual bending strength. The tools tested included the Resistograph, the Purl 1, PoleCalc, D-Calc, and PoleTest. In addition, increment cores were removed from along the length of the pole and examined for evidence of decay. These cores were then cultured for the presence of decay fungi.

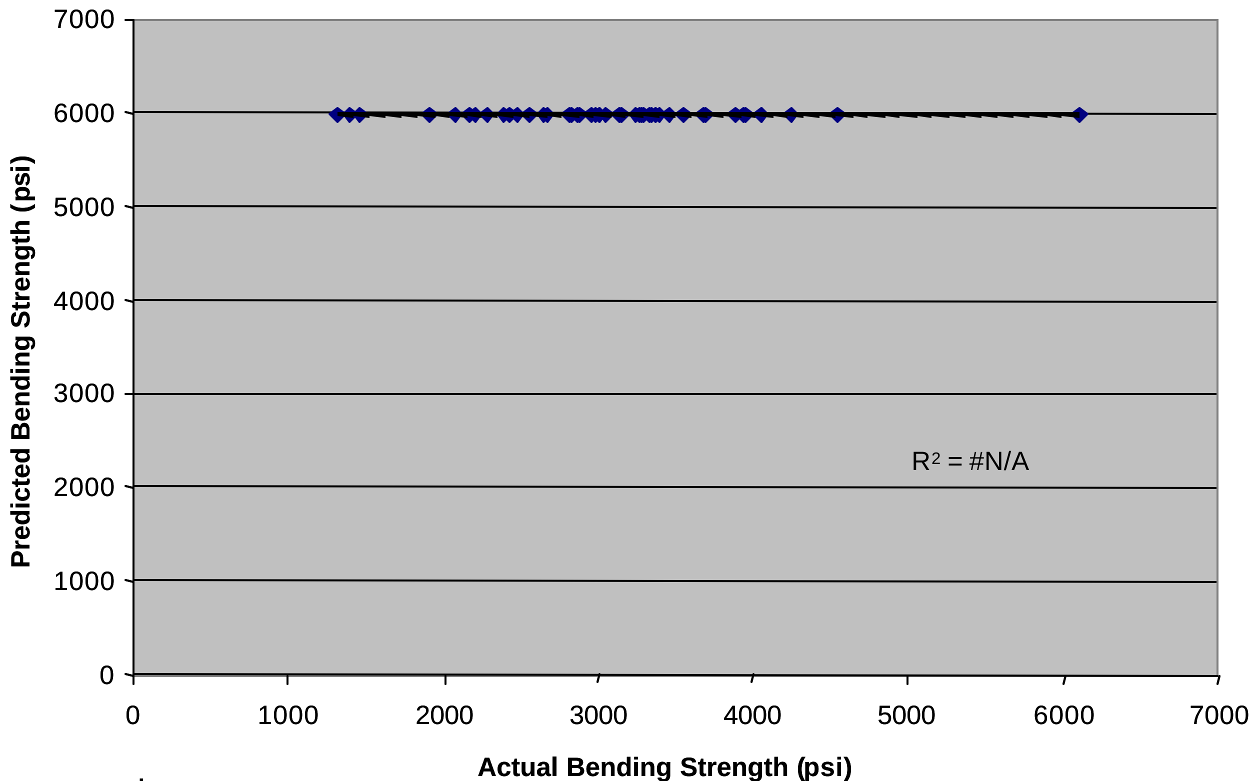
The results indicated that most of the devices were poor predictors of residual pole strength. In many instances, however, the manufacturers of these devices do not, themselves, recommend that their devices be used as stand-alone inspection tools. This past year, we re-analyzed the data obtained last year, along with additional test data on western redcedar transmission poles through the kind assistance of Bonneville Power Administration to determine if the predictive accuracy of the various systems could be improved by incorporating the results from multiple tools. Data from 16 Douglas-fir and 47 western redcedar poles were evaluated in these tests, although not all devices were evaluated on all poles.

Generally, the devices were poor predictors of residual bending strength in western redcedar poles, even when used in combination (Figures III-16, 17). In general, the western redcedar poles tested contained shell rot and were heavily checked. The devices evaluated were primarily designed for internal decay detection and may have lacked the ability to accurately assess the effects of surface softening on overall bending strength. Given the high contribution of the outer 50 mm of the pole shell to overall pole strength, it is not surprising that most of the devices tested provided poor predictions on this species. It is likely that vigorous scraping of decayed wood followed by careful measurement of the remaining sound wood would have yielded better results.

One device that surprisingly performed poorly on cedar was the Resistograph. This device drills into the wood, providing as its output the torque required to penetrate the material. This device should have been a good predictor of weakness in the outer shell, but associated software apparently failed to accurately assess this damage.

Figure III-16. Predicted vs actual bending strength of western redcedar poles using (a) the ANSI pole class values or (b) PoleTest output as the predictors.

a.



b.

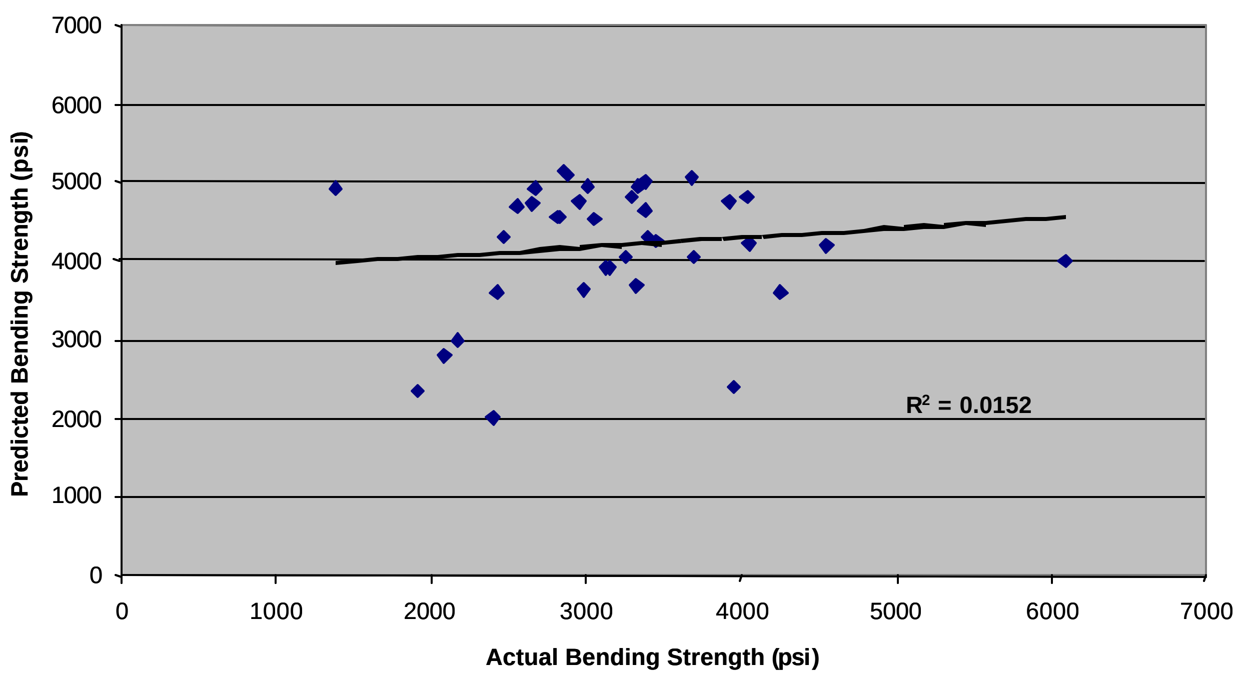


Figure III-17. Actual bending strength of western redcedar poles vs strength predicted using combination of PoleCalc, the Resistograph, PoleTest, drilling, and ANSI values.

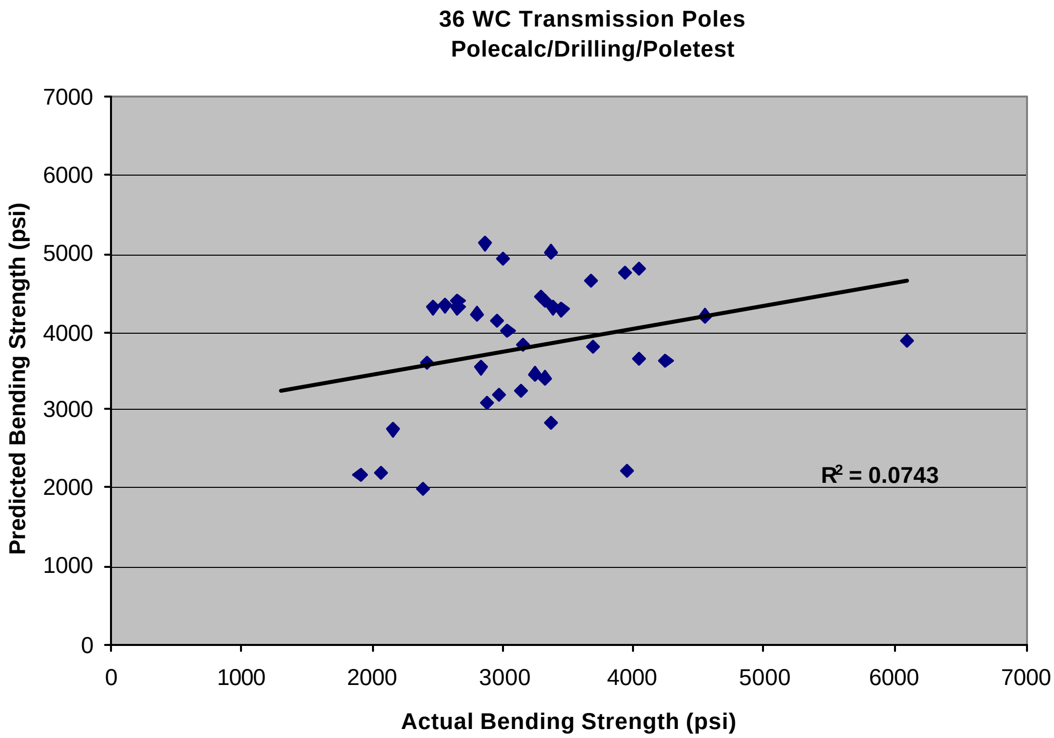
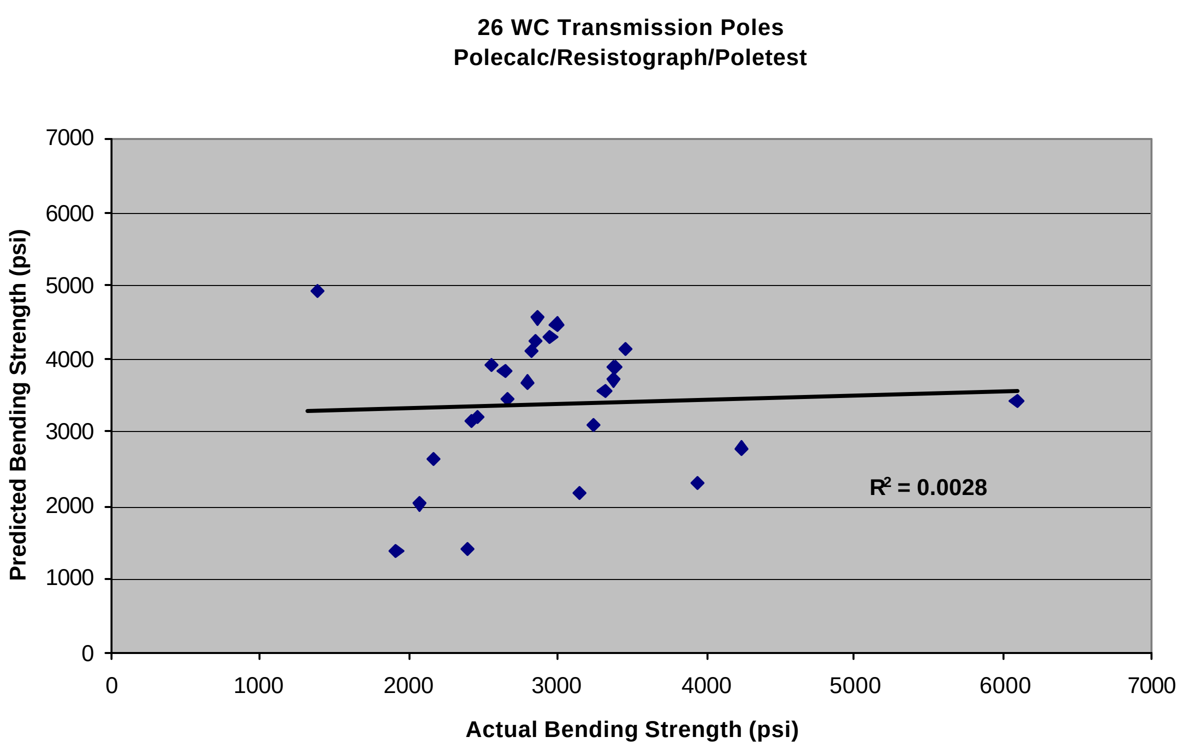
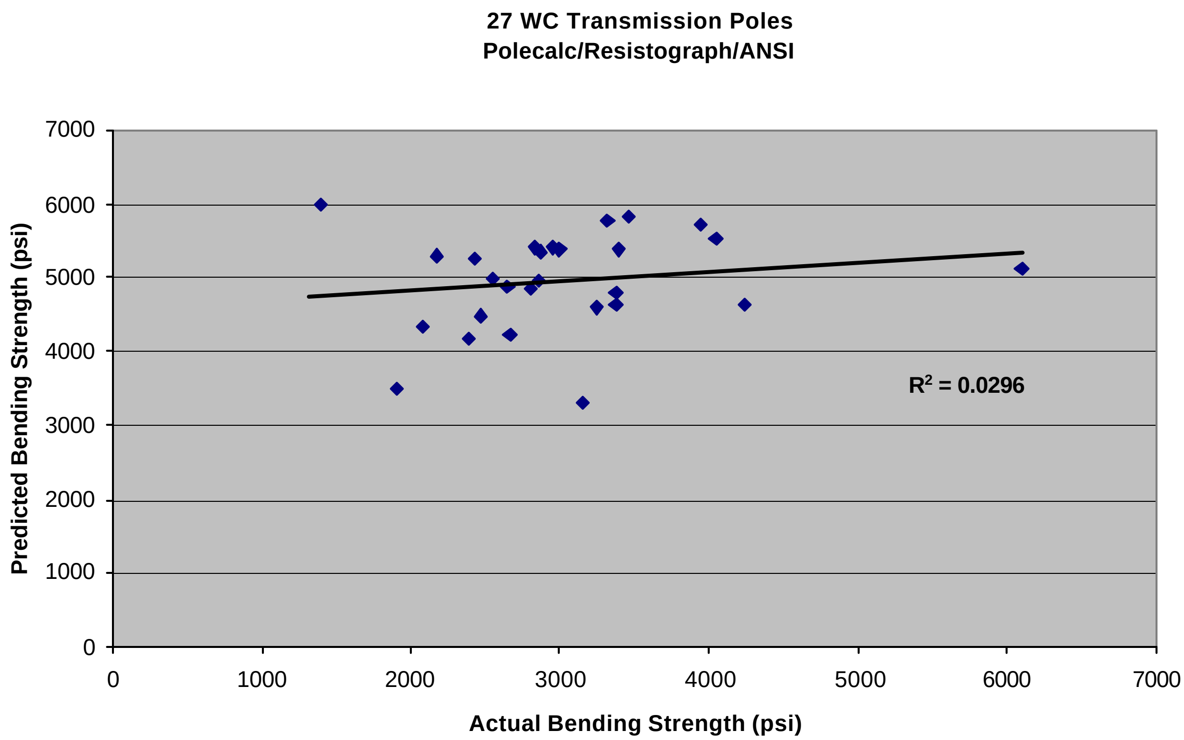


Figure III-17 Continued





As expected, the correlation between actual bending and the ANSI values for Douglas-fir pole was poor (Figure III-18). ANSI values are based upon a normal distribution of pole strengths surrounding a mean. The low number of poles in our sample sharply reduced the likelihood that our population would follow that of the entire population. Similarly, PoleTest alone was a poor predictor of pole strength (r^2= 0.1416) (Figure III-18).

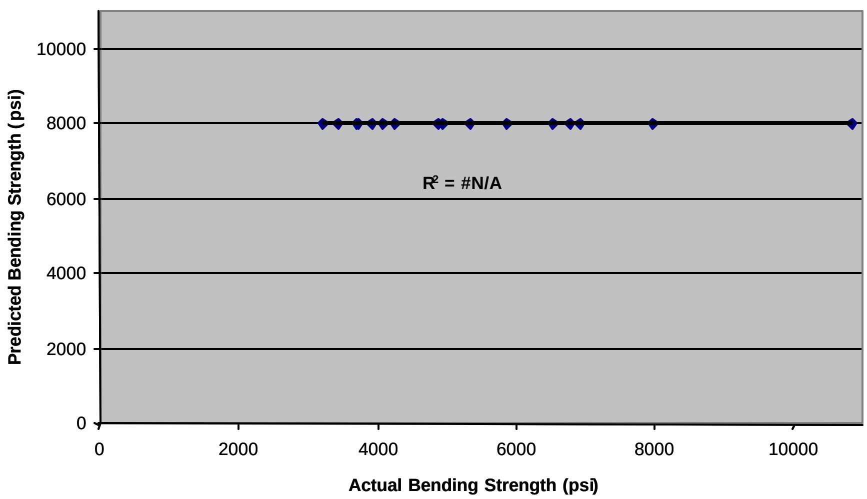
The use of multiple tools for predicting strength produced variable results. For example, combining the Purl 1 data with ANSI resulted in a relatively poor prediction of residual strength (Figure III-19). Combining Purl 1 with PoleTest data improved the prediction slightly, but the correlation was still relatively low (r^2= 0.3865). More importantly, the devices tended to over-predict residual strength.

In addition to physical inspection devices, two of the tools evaluated in our tests (DCalc and PoleCalc) were programs to calculate residual strength based upon physical measurement of shell thickness. We examined the ability of these tools to predict residual strength using output from drilling, ANSI, PoleTest, and the Resistograph (Figure III-20). The use of drilling and ANSI values with DCalc provided a relatively poor predictor of pole strength, while the use of drilling and PoleTest improved the correlation (r^2= 0.3224). Substitution of the Resistograph for drilling markedly improved the correlation between predicted and actual strength, although the correlations were still less than 0.56 (Figure III-21). Similarly, PoleCalc produced the poorest predictions when drilling and ANSI values were used (Figure III-21). Predictions improved slightly when drilling and the PoleTest or the Resistograph and ANSI values were used, but were more accurate when the Resistograph and PoleTest values were used. Once again, however, the correlations were relatively low (r^2=0.5638). In addition, more than half of the predictions using the Resistograph and PoleTest data exceeded the actual bending strength.

Ideally, an inspection program would accurately predict remaining pole properties with a minimum risk of calling a bad pole good or rejecting good poles. Our results suggest that there remains considerable room for improving the ability of the various inspection devices to predict pole strength. It also implies that users of these devices should employ the resulting numbers with some caution. For example, adding some form of safety factor to the resulting number to account for the tendency of the devices, alone or in combination, to over-estimate strength.

Figure III-18. Actual bending strength of Douglas-fir distribution poles vs strength predicted using (a) ANSI values or (b) the PoleTest.

a.



b.

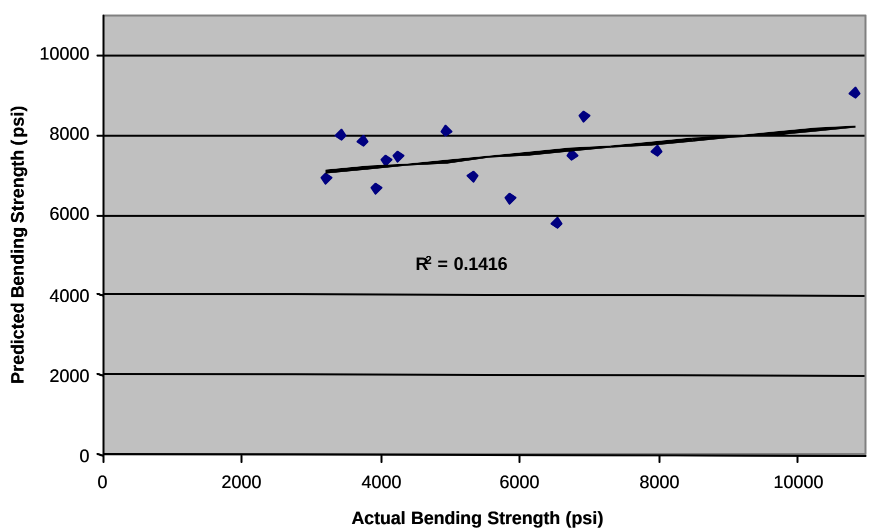
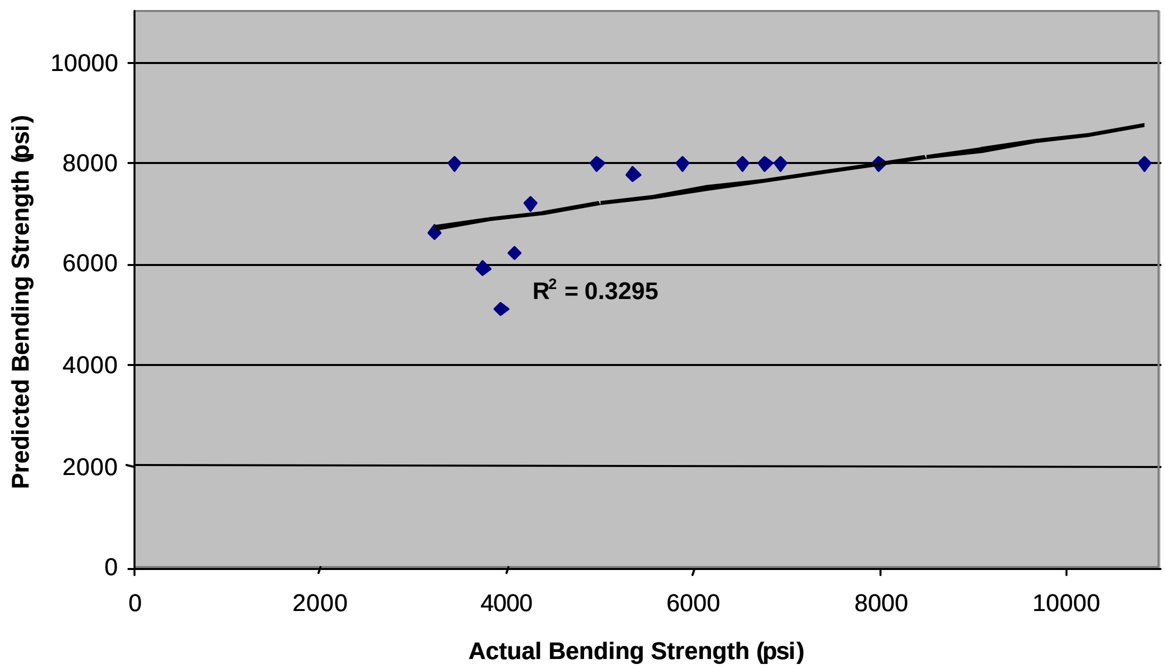


Figure III-19 Actual bending strength of Douglas-fir distribution poles vs strength predicted using the Purl 1 plus (a) ANSI values or (b) PoleTest output.

a.



b.

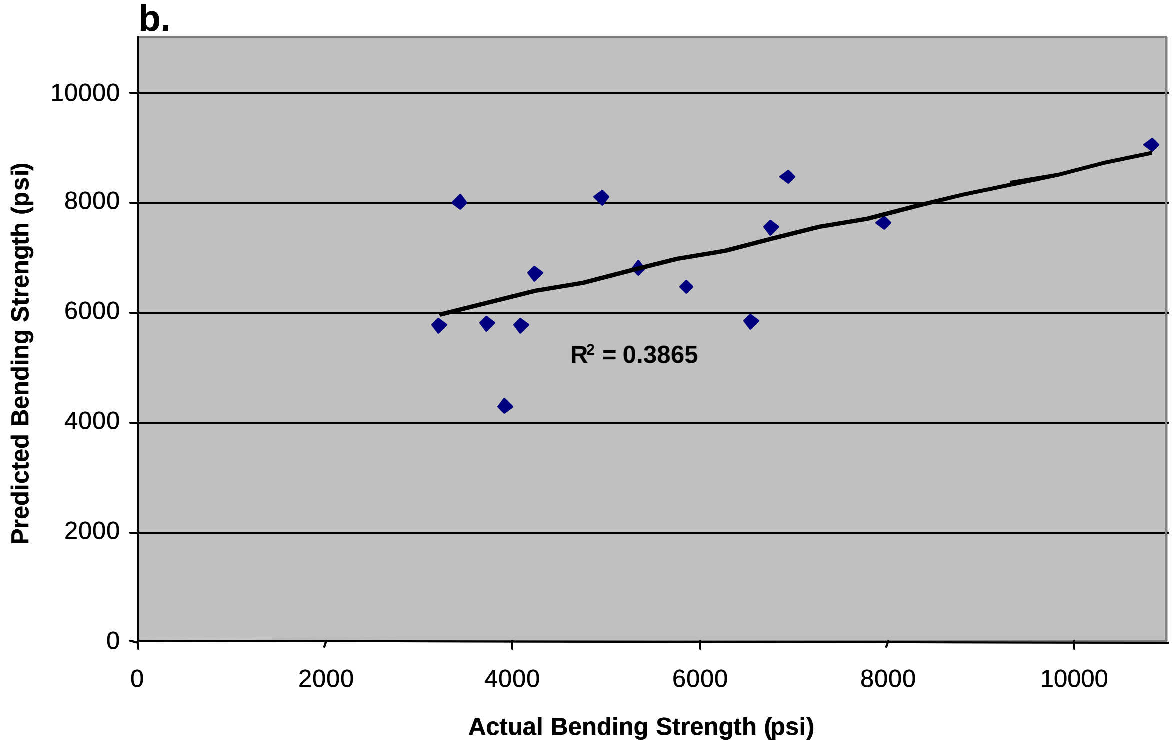
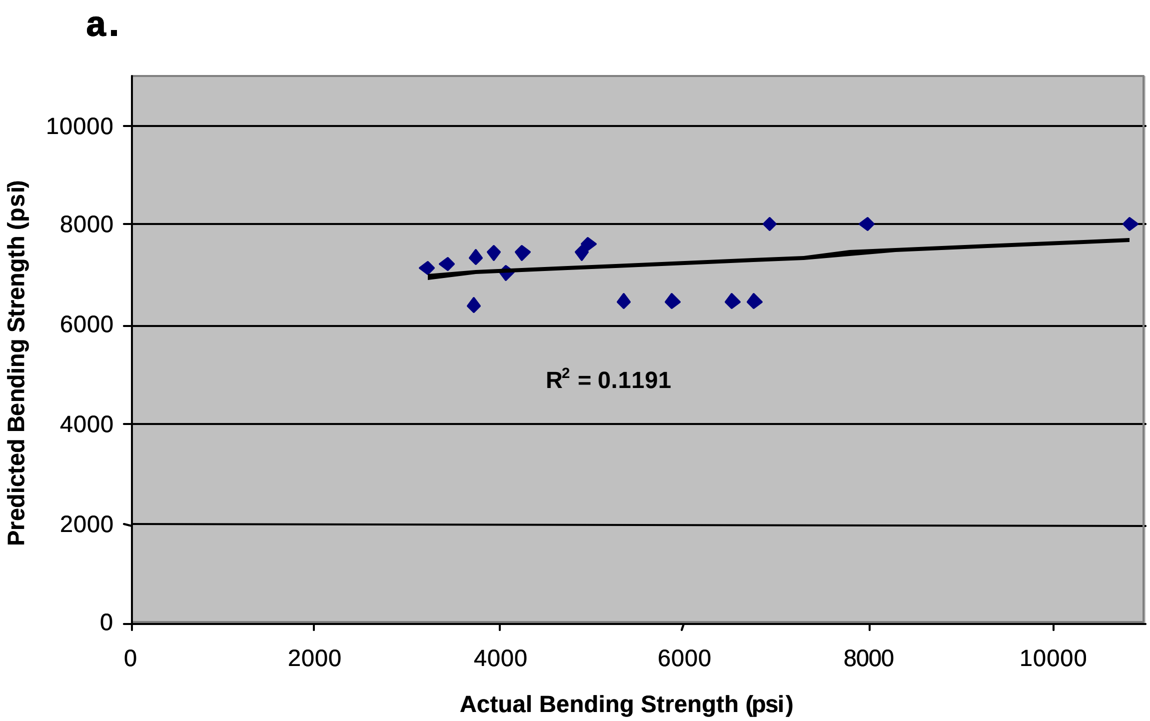


Figure III-20. Actual bending strength of Douglas-fir distribution poles vs strength predicted using DCalc plus output from (a) drilling and ANSI, (b) drilling and PoleTest, (c) the Resistograph and ANSI., or (d) the Resistograph and PoleTest.



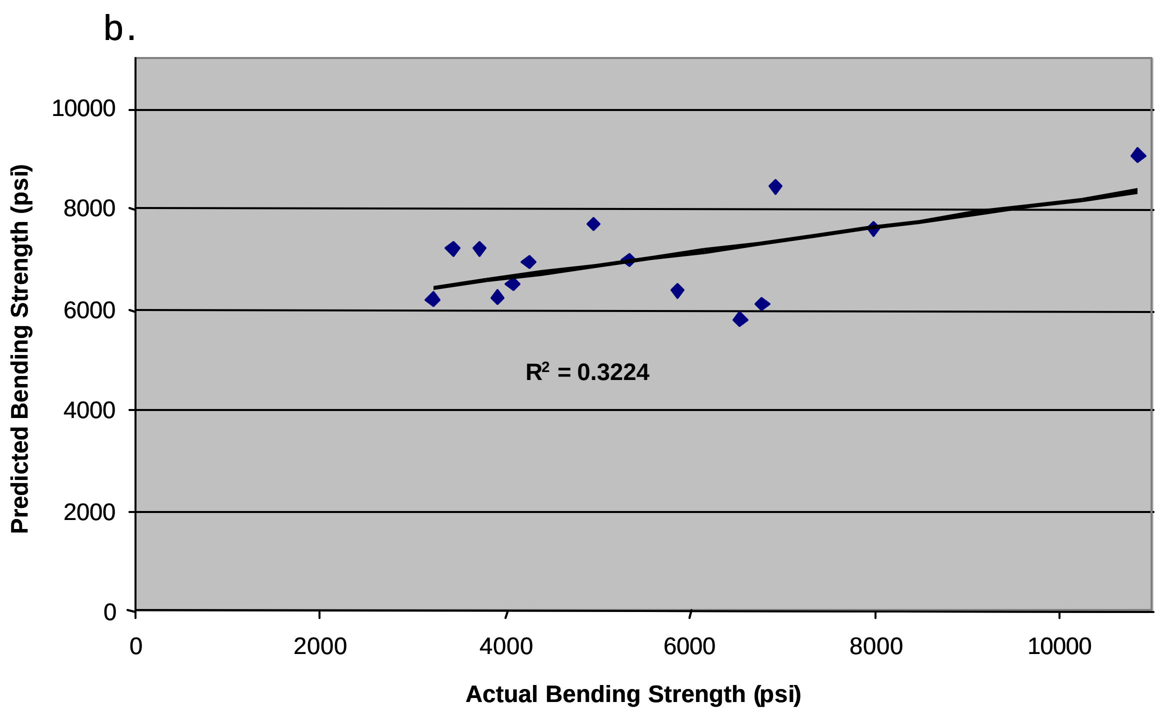
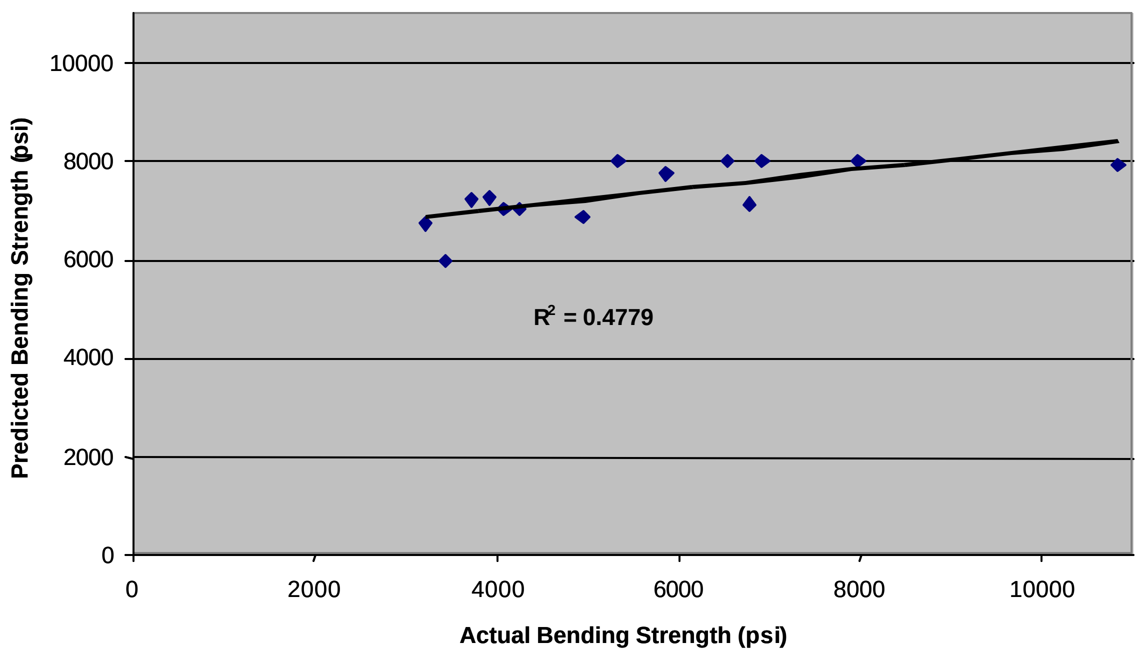


Figure III-20 Continued

c.



d.

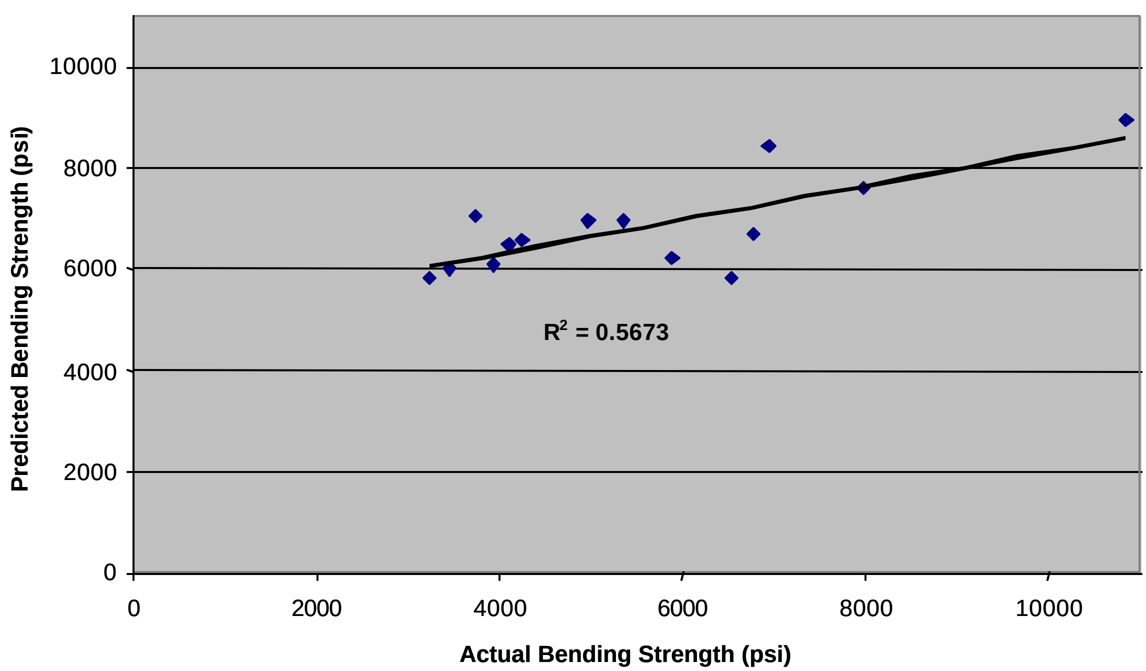
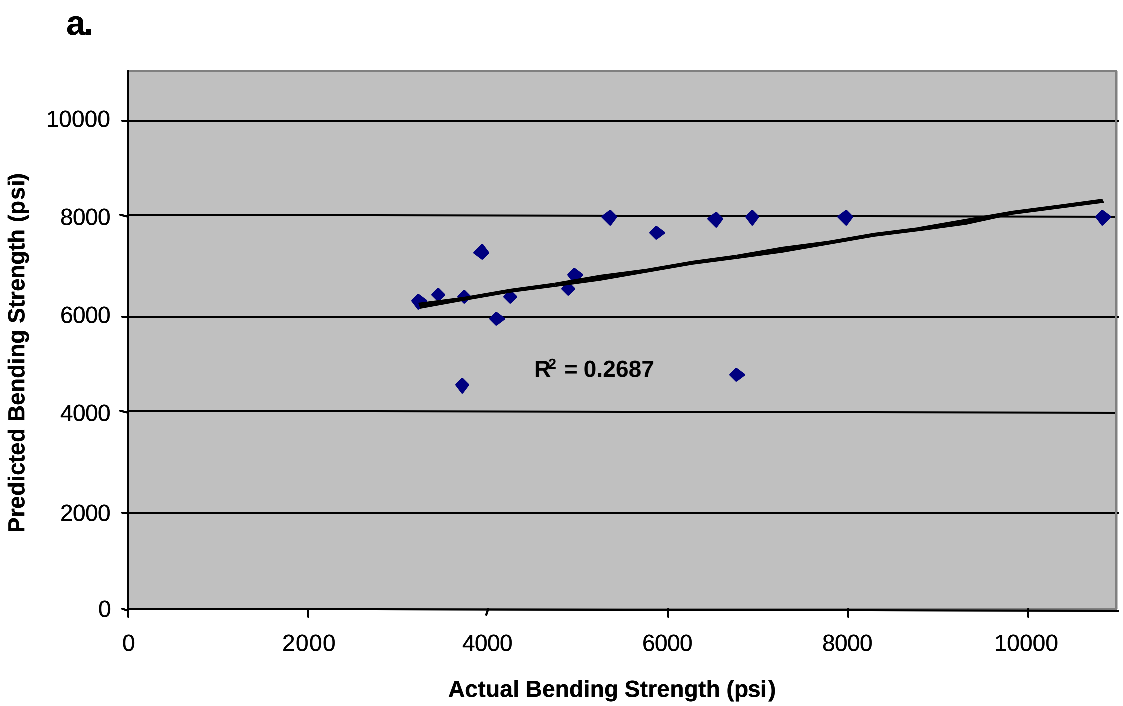


Figure III-21. Actual bending strength of Douglas-fir distribution poles vs strength predicted using PoleCalc plus output from (a) drilling and ANSI, (b) drilling and PoleTest, (c) the Resistograph and ANSI., or (d) the Resistograph and PoleTest.



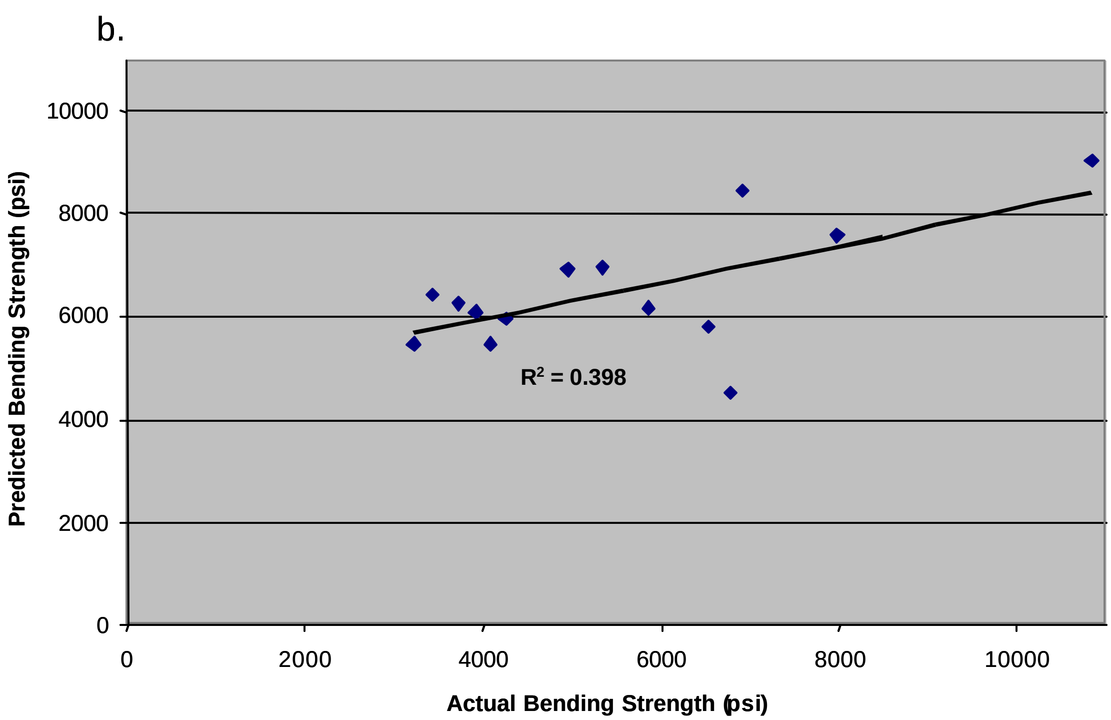
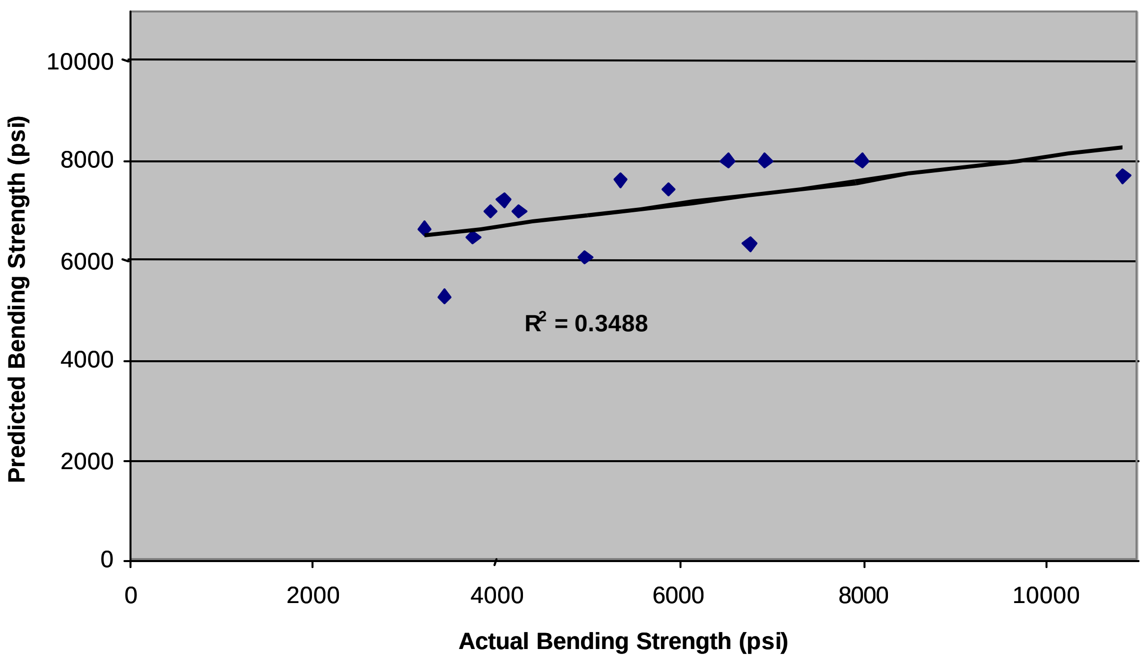
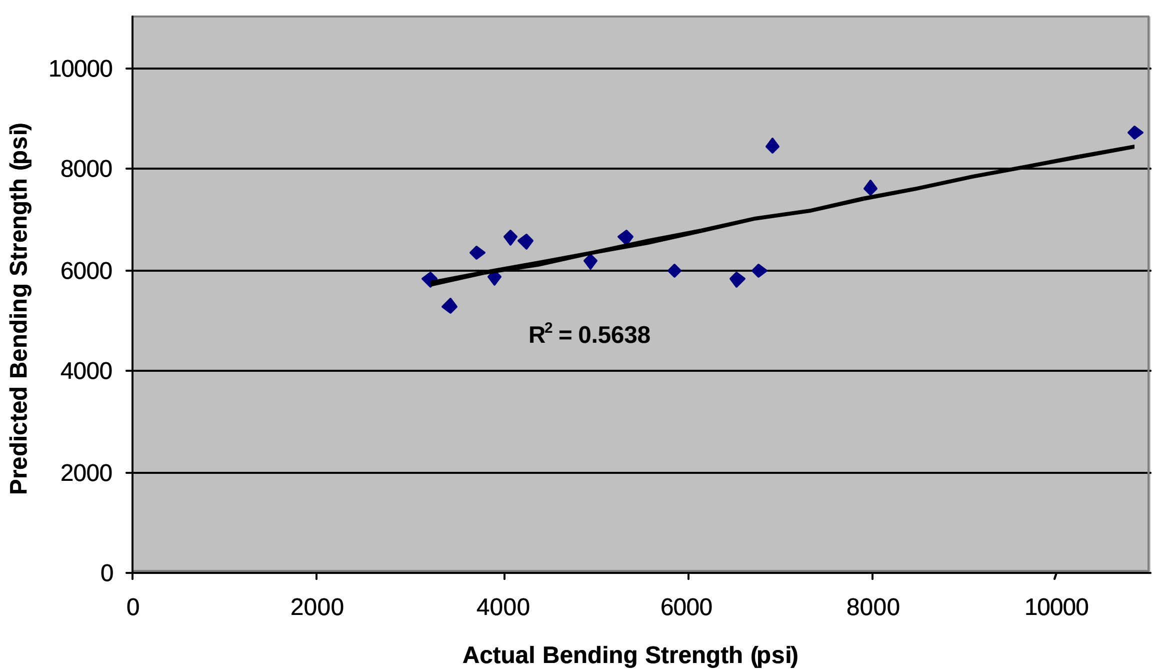


Figure III-21 Continued

c.



d.



C. **Effect of Through Boring and Preservative Treatment on Fire Resistance of Douglas-fir Poles**

Grass fires are a frequent occurrence in many regions where wood utility poles are employed. In most instances, the fires are short lived and the temperatures reached during these fires cause little or no damage to the poles, however, fires under high fuel conditions or on poles with copper or chromium based preservatives can cause considerable damage. In 1998, we initiated a field test to assess the fire resistance of pentachlorophenol (penta), ammoniacal copper zinc arsenate (ACZA), or ammoniacal copper arsenate (ACA) treated Douglas-fir poles.

These results showed that both ACZA and ACA poles slowly charred through and failed as a result of copper combustion. The penta poles experienced charring, particularly near wide checks, but were generally sound following exposure. While these results were promising, we wondered if the fire had affected the efficacy of the initial treatment. To answer this question, we cut two sets of 10 mm cubes from the outer 10 mm, 10-20 mm, and 20 to 30 mm from the wood surface in the groundline section of each of the five non-through bored penta poles as well as the four remaining through bored poles treated with this chemical .

One set of cubes was ground to pass a 20 mesh screen and then sent to Vulcan Chemical Inc. (Wichita, Kansas) for penta analysis on a blind sample basis. The other samples were exposed to *Postia placenta* in a modified soil block test.

Chemical analysis showed that penta levels in the blocks were well above the presumed threshold for pentachlorophenol against wood decay fungi (2.4 to 4.0 kg/m^3) at all three depths measured (Table III-1), and all were above the retention specified in the American Wood Preservers' Association Standard C4 for wood poles (9.6 kg/m^3). The analysis clearly implied that the levels present would still protect against fungal attack.

Soil block tests indicated that weight losses ranged from 12.9 to 21.4 % in blocks from various depths. While this suggests that the fire exposed wood was more sensitive to fungal attack, an examination of the blocks revealed little or no evidence of fungal attack. In many instances, the test fungus failed to grow from the feeder strip onto the test block. These results imply that the weight losses observed primarily resulted from loss of solvent from the blocks over the exposure period. While we avoided exposure to elevated temperatures for drying and sterilization, it was necessary to condition the blocks at warmer temperatures for a long period before and after fungal exposure to obtain stable initial and final weights. These long exposures may have increased solvent volatilization from the test blocks. As a result, the biological tests should be ignored.

The analyses suggest that the fires may have resulted in slight decreases in penta content in the outer shell of the poles, however, the residual levels remained above those required for protection against fungal attack.

Table III-1. Residual pentachlorophenol in through-bored and non-through bored Douglas-fir poles following exposure to a grass fire.			
Treatment	Residual pentachlorophenol (kg/m^3)		
	0-10 mm	10-20 mm	20-30 mm
Non-Through Bored	20.8 (2.5)	24.8 (12.6)	28.9 (6.5)
Through-bored	17.9 (3.6)	24.0 (2.9)	28.0 (4.1)

D. Seasonal Variations in Moisture Contents of Douglas-fir and Western Redcedar Poles

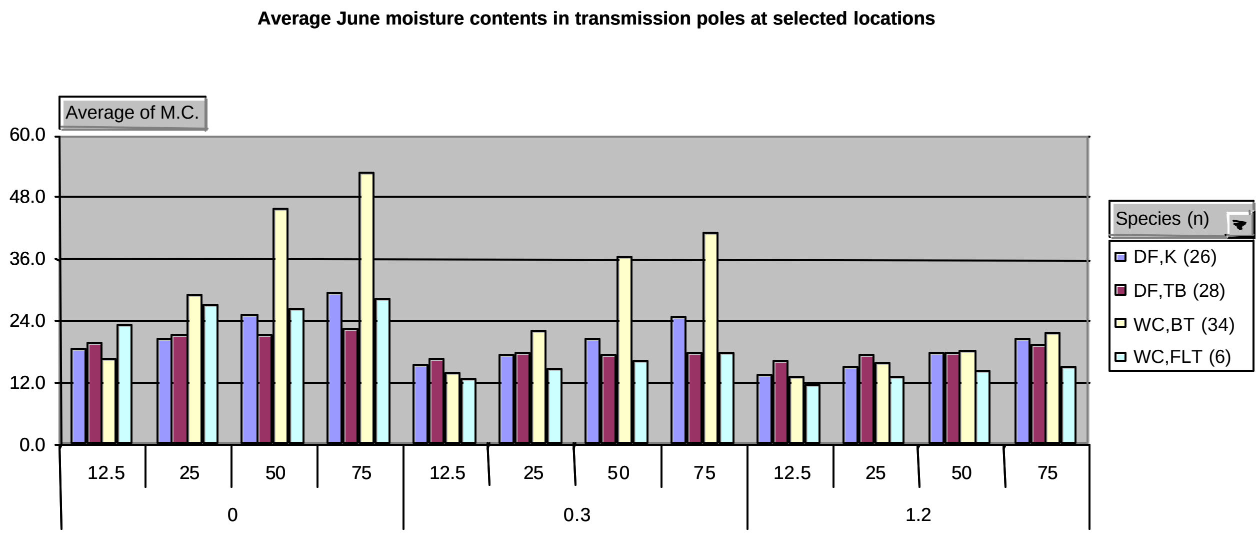
The American National Standards Institute Specification for wood poles typically specifies wood poles on the basis that they will be used in a wet or green state. Bending strength for wood is typically higher when the wood is dry, meaning that wet use classification could potentially penalize wood strength values. In order to determine if wood poles should be classified on a wet or dry basis, we undertook the following survey.

Douglas-fir and western redcedar transmission poles in the Willamette Valley of Western Oregon were selected for study. A resistance type moisture meter equipped with 75 mm long pins was used to assess moisture content. At each pole, moisture contents were taken 12.5, 25. 50, and 75 mm from the wood surface at four equidistant points around the pole at groundline, 0.3 m and 1.2 m above groundline. The Douglas-fir poles selected for study were either kerfed or through-bored at groundline. The western redcedar poles were either butt treated or full-length treated. The first moisture sampling was performed in June at the end of the rainy season, a second one will take place in September, prior to the start of the rainy season and the third sample will be performed in mid-Winter when pole moisture contents are presumably at their peak.

Most moisture contents were below the fiber saturation point of about 24 %, particularly near the surface, where most of the pole bending strength is concentrated (Figure III- 22). Moisture contents near the surface were slightly higher near the groundline, but the differences were relatively minor. Moisture contents tended to be similar near the surface regardless of wood species or treatment. The outer zones would tend to be more directly affected by short term weather changes and these appear to affect all of the poles similarly. Moisture contents deeper in the poles tended to be higher for western redcedar, particularly if the poles were only butt treated. While many of the moisture contents in these zones were above the range where the meter is most accurate, the readings suggest that the cedar poles were fairly wet deep in the wood. These higher moisture contents may reflect increased moisture ingress in the absence of a water-repellant oil barrier or the decayed nature of the older poles. This effect was only present 0.3 m above and at the groundline.

Further sampling is planned to develop a better understanding of the seasonal moisture changes in poles in service.

Figure III-22. Wood moisture contents at selected depths from the wood surface at groundline and 0.3 or 1.2 m above groundline in kerfed or through bored Douglas-fir poles or butt treated or full length treated western redcedar poles.



E. **Moisture Requirements for Initiation of Carpenter Ant Attack of Western Redcedar and Douglas-fir**

Due to their habit of nesting in wood, carpenter ants have long been recognized as important pests of wooden structures (Akre and Hansen, 1995, Fowler 1986, Pricer, 1908). Although originally considered to be a nuisance pest (Fowler, 1986) carpenter ants have recently been categorized as much more economically damaging (Akre and Hansen, 1995, Akre, et. al., 1995, Hansen and Akre, 1985). In an extensive study of carpenter ant infestation in Washington state, Hansen and Akre (1985) found that these ants were responsible for a minimum of 42,000 annual structural treatments by pest control operators. Fowler 1986 estimated from several sources in the northeastern U.S. that these ants cause millions of dollars in damage annually, but hard data are lacking.

Aside from damage to structures, carpenter ants also have been observed to cause extensive damage to utility poles (Shields, 1996, Friend and Carlson, 1937) as well as to shade and ornamental trees (Fowler, 1983). Hansen and Akre (1985) postulated that infestations and loss of merchantable timber by carpenter ants could be a major, yet undocumented problem in the northern U.S. and southern

Canada for many tree species.

Carpenter ants belong to the largest genus in the family Formicidae, *Camponotus*. This genus is found worldwide but has a primarily holoartic distribution with the majority of economically damaging species occurring in nearctic forests (Fowler, 1983). Although they are referred to as carpenter ants, most *Camponotus* species nest in soil, under debris, or in plants and function as efficient predators of forest insects (Akre, et, al, 1995). The few species considered pests typically excavate wood or other fibers to create nesting cavities (Akre and Hansen, 1995). Twenty-three species of *Camponotus* occur in North America are considered nuisance or structural pests. Of these, seven cause extensive damage to wood and structures (Akre, et, al, 1995).

The most common species in the Pacific northwest in structures are *C.modoc* and *C.vicinus* (Hansen and Akre, 1985). Of the two species, *C. modoc* is more common in structures. These ants prefer wall voids and will mine insulation (Akre and Hansen, 1995). Although carpenter ants commonly occur in moist wood that is in some state of decay, they also extend their galleries into sound wood surrounding decayed areas (Akre and Hansen, 1995). As colonies mature, they may form satellite colonies composed of workers, older larvae, and pupae. These satellite nests are generally found in drier locations than the parent colony. The parent colony, contains the queen, eggs, and early instar larvae (Hansen and Akre, 1985, Akre and Hansen, 1995).

Current control strategies for carpenter ants employ combinations of preventative and chemical techniques. Preventative techniques include the lowering of excessive moisture contents in structures, and removing vegetation and wood debris from under or around structures. Chemical controls include both dusts and sprays that are applied around the perimeter of a structure to act as barriers to ant movement, or directly on colonies and nests. To achieve effective chemical control via dusts or sprays the colony, which is often hidden, must be found. Other control techniques employ baits that foraging workers carry back to the colony, but these baits have performed poorly.

Controlling carpenter ants requires a thorough understanding of their biology, but only a few species of carpenter ants in North America have been studied and the majority of these occur in eastern North America. Hansen (Hansen and Akre, 1985) studied the occurrence, distribution, and biology of several western species, but did not examine how moisture content affected colony development. Carpenter ants are reported to prefer moist or decaying wood, but optimal wood moisture or decay levels for colony initiation are unknown (Fowler, 1986, Pricer, 1908, Hansen and Akre, 1985, Akre et., al., 1995). *Camponotus vicinus* is found in both dry and wet regions of the west and it may therefore be more tolerant of dry conditions. The ability to initiate colonies in dry wood would be essential for success of *C. vicinus*, but the ability of queens of this species to initiate colonies at lower relative humidities such as those found in a structure is unknown.

The objective of this experiment was to assess colony initiation and development of either ant species in different types of wood that are conditioned at different relative humidities.

Camponotus modoc and *C. vicinus* queens were collected in May-June 1998 and reared in test tubes into which damp paper toweling had been placed. The tubes were incubated in the dark at 25° C. Chambers for housing collected ant queens consisted of a plastic food container with an air-tight lid. Relative humidity in the chambers was controlled by placing a solution of water or saturated sodium chloride in the bottom of the container. Twenty-four wood blocks measuring 90x40x50mm were cut from Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), Western redcedar (*Thuja plicata* Donn ex D. Don), and Styrofoam®. Each block was further cut into a bottom section measuring 90x40x32mm and a top section measuring 90x40x18mm A 25mm diameter by 6mm deep hole was bored into the top of the bottom section. A 5mm diameter hole was bored through the top section. The top section was then placed on each bottom section and held in place with a rubber band. Blocks were oven dried at 54° C, weighed and placed into the plastic chambers on waxed cardboard discs over either a salt solution or water to control relative humidity. Blocks were left to equilibrate to their respective moisture contents for two weeks prior to the addition of the queens.

The inseminated queens were removed from the test tubes after two weeks and placed, with any eggs they had laid, into the lower sections of each wood block. A total of twenty *Camponotus modoc* queens and fourteen *Camponotus vicinus* queens were used in each substrate type in this experiment (Table III-2).

Table III-2: Number of queens in each species and number evaluated in blocks of different materials conditioned at 70% and 100% relative humidity.

	Replicates Tested	
Single Queens	70% Relative Humidity	100% Relative Humidity
Camponotus modoc	4	4
Camponotus vicinus	3	3
Queen Pairs		
Camponotus modoc	3	3
Camponotus vicinus	2	2

The chambers were incubated at room temperature and monitored every 14-21 days for changes in wood weight and numbers of eggs, larvae, pupae, and worker ants produced. Once the first brood had enclosed, they were supplied with sugar water and chopped insect parts (Hansen and Akre, 1985, Gibson and Scott, 1989). Final brood counts for the season were made after 13 weeks. This time was picked because the addition of food and water four weeks before may have altered the wood EMC. At the end of August 1998, final counts of brood numbers produced for this first season were recorded and used to analyze the effects of wood species and wood moisture content on colony initiation. Cultures will be maintained for one year after which they will be dismantled and rates of wood excavation and colony development in the various treatments will be assessed.

If one or more adults were produced from either single queens or queen pairs, then initial colony formation was recorded. Initial analysis revealed that similar trends existed between queen pairs and single queens and these data were combined for part of the analysis. PROC Genmod was used to analyze the effects of species and wood moisture on colony initiation and the contrast option was used to compare numbers of colonies started for queens exposed to different moisture contents (SAS).

Brood development over the 13-week experimental period is shown for each species of wood and Styrofoam® in III-23. Development times for each species from egg to adult ranged from 8 to 10 weeks. These times support those of Hansen [4] who found development time from egg to adult for these two ant species to be 8 and 9 weeks for *C. modoc* and *C. vicinus* respectively. Although fewer adults were produced at the lower relative humidity by *C. modoc*, the time from egg to adult was the same.

Development of *Camponotus modoc* adult workers in Douglas-fir appeared to be lower at 70% relative humidity (.43 workers) then at 100% (3.29 workers). Development of *C.vicinus* in Douglas-fir was similar for both moisture contents with 4.6 and 4.2 workers produced at 70% and 100% relative humidity respectively. Both ant species produced more eggs after 7-10 weeks at the 100% relative humidity, but egg production was more prevalent with *C. vicinus* at this relative humidity (Figure III-23).

Brood development in western redcedar (Figure III-23) was hindered by containment in this wood species especially at the higher relative humidity. Both species of ant developed to the pupal stage at the lower relative humidity in cedar but no adults were produced. Although *C.vicinus* queens laid more eggs at the 7 and 10-week points, the eggs failed to develop. Eggs placed in the cedar blocks at the high humidity shriveled up and turned brown after 5 to 7 days. Some queens were also observed removing eggs from the blocks at the high relative humidity suggesting cedar blocks at this moisture content were not a preferable substrate for colony initiation and acted as a deterrent to the ants.

Development in the non-wood, Styrofoam® blocks produced trends similar to those found in Douglas-fir. *Camponotus modoc* queens produced more workers at the higher relative humidity than at the lower relative humidity (Figure III-23). This was also the case with *C. vicinus*, but the differences were not as large. These results suggest that *C.vicinus* was less sensitive to substrate moisture than *C. modoc* in Douglas-fir and Styrofoam®.

Figure III-24 shows the results of the statistical analysis of the numbers of adult workers produced by each species of ant at the two relative humidities for Douglas-fir, cedar, and the Styrofoam® control. The number of workers produced by *C. vicinus* did not significantly differ between blocks incubated at high or low relative humidity for either Douglas-fir or Styrofoam® (Figure III-24). However, the number of colonies initiated for *C. modoc* did significantly differ between relative humidities.

The final equilibrium moisture contents (EMC) of the Douglas-fir blocks after 13 weeks were 23-24% at the higher relative humidity and 11% at the lower relative humidity. The equilibrium moisture contents for western redcedar were similar at 21-20% and 9.8% for the high and low relative humidities, respectively, while Styrofoam® EMCs corresponded with the relative humidity in the chambers. The EMC for the Styrofoam® blocks into with *C. vicinus* was placed was higher at 70% relative humidity than at the same relative humidity for *C. modoc*. The reason for this is unknown.

There was strong evidence (Pr>Chi=0.0001) that the number of colonies initiated for *C. modoc* was significantly different between the two relative humidities in Douglas-fir. *Camponotus modoc* queens initiated significantly more colonies (produced more workers) on wood conditioned at 100% relative humidity. No significant differences were found between the number of colonies produced by *C. vicinus* at the two humidities in this substrate type (Pr>Chi=0.76, Figure III-24).

No significant differences existed for either ant species between moisture contents in western redcedar blocks (Figure III-24) because no colonies were initiated in this substrate type regardless of relative humidity.

The numbers of colonies initiated in Styrofoam® were similar to those of Douglas-fir with strong evidence that *C. modoc* produced significantly more workers at 100% relative humidity than at 70% (Pr>Chi=0.0001). No significant difference were found in the number of colonies initiated by *C. vicinus* at the two humidities (Pr>Chi=0.08, Figure III-24).

The effect of relative humidity on wood moisture and number of workers produced for queen pairs and single queens of each ant species were similar to the combined data (Figure III-24). Queen pairs produced more adults, but relative humidity appeared to have the same effects on the number of workers produced as those described for the combined data.

Colony initiation in *C. vicinus* was less affected by humidity than *C. modoc* for Douglas-fir and Styrofoam. Western redcedar was detrimental to the development of early colonies for both *C. modoc* and *C. vicinus*. Carpenter ants are often found in cedar trees, logs and utility poles, but our results suggest that occupation of these substrates by carpenter ants may be by satellite colonies that do not consist of a queen and her young brood. Western redcedar may be tolerated by older worker castes or aged cedar heartwood may contain fewer detractant substances allowing occupation by carpenter ant satellite colonies.

The results indicate that carpenter ants particularly, *Camponotus vicinus*, are capable of initiating colonies in woods that are relatively dry. This finding contradicts previous findings and suggests that colonies can begin virtually anywhere in a structure.

Figure III-23: Effect of relative humidity on brood development in C. modoc and C. vicinus on A) Douglas-fir, B) Western redcedar, and C) Styrofoam® blocks.

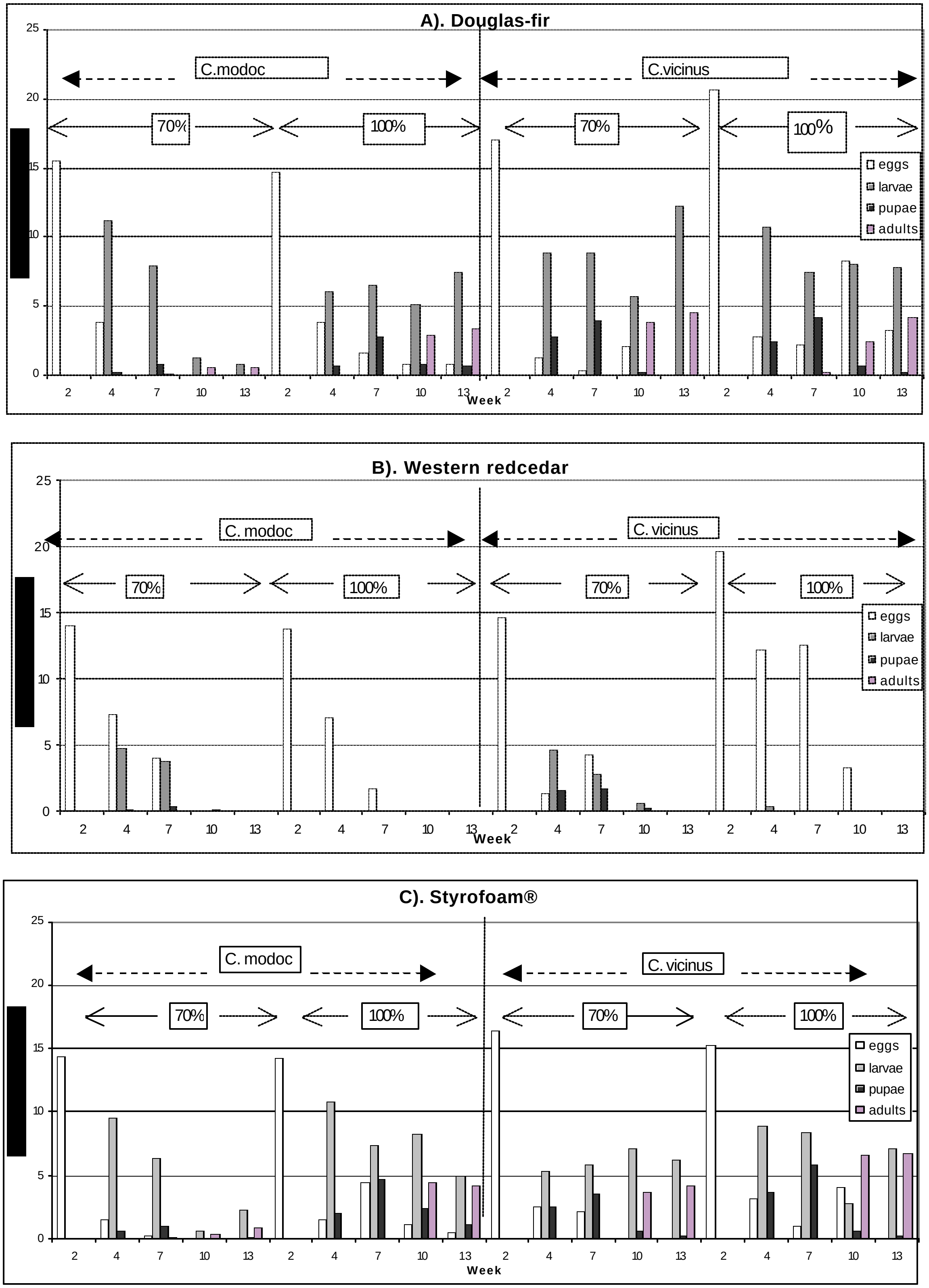
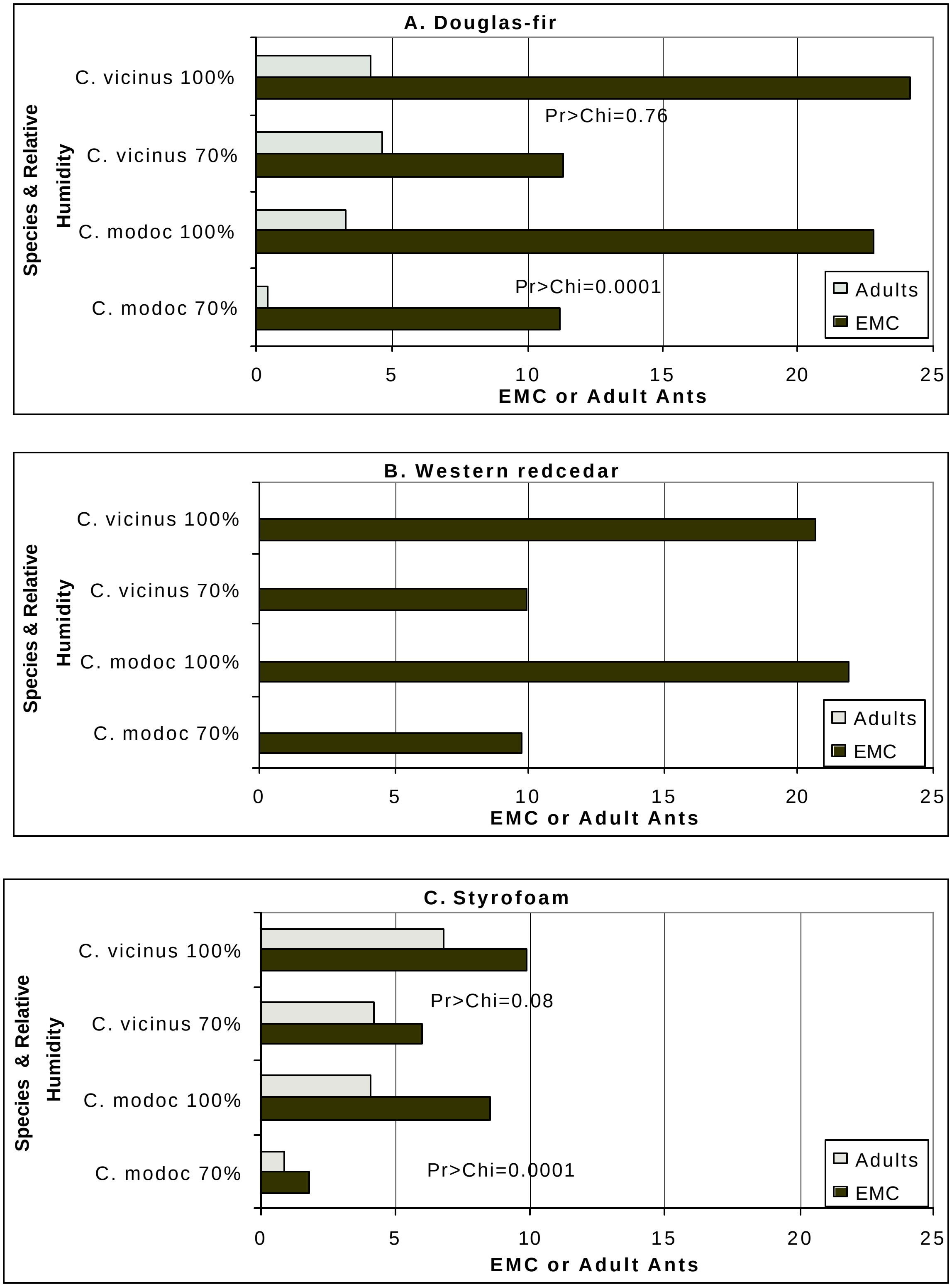


Figure III-24: Effect of relative humidity on wood moisture content and number of workers produced by C. modoc and C. vicinus on A) Douglas-fir, B) Western redcedar, and C) Stryrofoam blocks.



F. Above Ground Decay: Is it the next Big Utility Pole Problem?

Wood utility poles have provided excellent performance under a variety of environmental conditions. The service lives of wood poles have been markedly enhanced by developments in initial treatment, inspection and remedial treatments. Through boring, radial drilling, deep incising and kerfing have combined to markedly reduce the incidence of internal decay at or near the groundline (Graham, 1983). Improved inspection techniques and more consistent application of these methods have increased the likelihood that a decaying pole will be detected before the strength declines below minimum National Electric Safety Code (NESC) levels (Morrell, 1996). Finally, improvements in both external pastes and internal fumigants have markedly improved the ability to arrest decay in structures and limit the potential for renewed attack (Morrell and Corden, 1986).

As a result, internal decay is virtually absent in the groundline of newer poles that have received any of the pretreatments. The ability to inspect for and arrest the progress of any decay around the groundline has further enhanced the performance of wood poles. While most utilities routinely consider wood pole service live to range from 30 to 40 years, emerging information suggests that service lives in the range of 80 to 100 years are more likely (Stewart, 1996; Morrell, 1999). While prolonging service life produces enormous investment savings and improves system reliability and safety, it comes with a darker side. When poles had average service lives approaching 40 years, most of the decay occurred at or near the groundline, where the risk of decay is most severe and where it can be most easily detected. Improved specifications and remedial treatments have the potential to eliminate or sharply reduce decay in this zone. In most cases, however, little concern is given to developments further up the pole. Yet, the above ground zones of utility poles is where utilities have the potential to generate additional capital as a result of the increasing use of this zone of the pole for telecommunications, cable and other activities. These uses have increased the risk of decay since attachments are usually installed using field drilled holes that penetrate beyond the treated shell and expose untreated wood to possible fungal attack. While specifications typically require topical application of fungicides to field damage on poles (AWPA, 1999), few line personnel complete this requirement and the damage is quickly covered by a connector. The result is a hidden, slowly developing problem (Morrell et al., 1990).

Decay development above the ground typically occurs more slowly due to unfavorable moisture regimes and the absence of the large population of potential decay fungi that are present in the soil. In addition, the preservative shell sharply reduces the points where fungi can enter above the ground. Despite these limitations, there remains a potential for fungi to invade the above ground zones of older utility poles. The potential for decay out of soil contact can be estimated using the average monthly temperature and number of days per month with more than 1 mm of rainfall (Scheffer, 1971). The Scheffer climate index is a reasonable predictor of decay risks for untreated wood exposed out of soil contact, but it is not directly applicable to treated poles because the preservative shell influences the rate of fungal invasion.

Above ground decay has the potential to sharply reduce the potential long term benefits of prolonged groundline performance. A preliminary survey of Douglas-fir distribution poles suggested that about 15 percent of the poles sampled had some decay above the groundline (Morrell and Schneider, unpublished), but the sample size was relatively small. In this report, we summarize a larger series of studies on the incidence of decay and decay fungi above the groundline in Douglas-fir poles in the Pacific Northwest. While the applicability of the results appears to be limited to the Pacific Northwest, the Scheffer Climate Index tells us that other regions will experience similar problems, albeit at rates appropriate for their climatic conditions.

Douglas-fir poles in the systems of 2 utilities in the Pacific Northwest were selected for evaluation. At the first utility, the poles were all transmission size poles, while only distribution poles were examined at the other. Both utilities had regular inspection and remedial treatment programs at approximately 10 year cycles. The transmission poles located in Oregon and Washington were divided among five regions; Oregon coast, Washington cost, Puget Sound, southwest Washington/Willamette, and eastern Oregon. Each pole was inspected by removing two 150 mm long increment cores 120 degrees apart at three heights: 1.5, 3.0, and 4.5 m above the groundline. The poles were not sampled at groundline because the cooperating utility specified through-boring for the groundline. Previous experience had shown us that this zone was heavily treated and could not support the growth of decay fungi. The depth of preservative penetration on each core was measured, then the cores were placed in plastic drinking straws which were stapled shut and returned to the laboratory. The cores were then removed, flamed briefly to kill any contaminating fungi on the wood surface, and placed onto the surface of petri dish containing 1% malt extract agar. The plates were incubated for 30 days at room temperature (21 to 23 C), and any fungi growing from the wood were examined for characteristics typical of basidiomycetes, a group of fungi containing many important wood decayers. A total of 496 poles were sampled.

In the second sampling, creosote or pentachlorophenol treated distribution poles that had been in service for 43 to 53 years were selected. The poles were sampled by removing two 150 mm long increment cores 120 degrees apart 4.5, 6.6, 8.4, and 9.0 m above the groundline. Two more increment cores were removed from opposite sides of the pole at groundline. The cores were placed into plastic straws and cultured as described above. In addition, the condition of the cores was visually mapped in an attempt to relate isolations to the presence of decay fungi. A total of 440 cores were removed from 44 poles.

<u>Transmission Poles</u>: Decay fungi were isolated from poles in every region sampled, although the levels varied widely with age and location (Table III-3). The incidence of decay was low in poles less than 10 years old (7% of poles), but increased to 17 percent in poles 11 to 20 years old and remained around that level for poles that were 21 to 30 and 31 to 40 years old (Table III-4). These results concur with previous studies suggesting that internal decay in Douglas-fir poles increases rapidly between 10 and 20 years of age (Morrell and Blake, 1991). The reasons for this are unclear. In a pole that has been subjected to a sterilizing treatment prior to installation, the only pathway for fungi to invade is through checks that develop as the pole dries in service. Seasoning to an in-service moisture level may take a year or more, delaying the potential entry of decay fungi. In addition, the fungus must find a location through which it can invade, adding further time to the process. Finally, the fungus must develop in the wood to the point where it is likely to be detected. Thus, the seemingly sudden appearance of decay fungi, may reflect the end result of a combination of chance events that are most likely to become apparent after a decade or more of service.

While a relatively high percentage of poles contained at least one decay fungus, it is important to note that the distribution of these fungi in the wood was relatively confined. In all cases, less than 10 percent of the cores at a given height for a given age group contained a decay fungus and most poles only contained a single isolate.

Climatic condition clearly had a large effect on the potential for fungal isolations above ground. Isolation frequencies were consistently higher in poles exposed along the coastal regions. These poles tend to be exposed to more moderate temperatures, elevated rainfall and wind driven rain and or fog. As a result, the conditions are more suitable for decay development. The incidence of decay was slightly lower in poles from further inland, but it was most interesting to note that almost 10 percent of poles sampled in the drier regions contained decay fungi. The poles sampled were located in a region receiving less than 250 mm of rainfall per year. It is apparent that decay fungi can colonize wood, even under extremely unsuitable conditions.

Table III-3. Incidence of decay fungi at selected heights above the groundline of Douglas-fir poles in service for up to 40 years in five regions in the Pacific Northwest (Source: Morrell and Schneider, 1994).

Location	# Poles	Cores with decay fungi (%)			Poles w/Decay Fungi (%)
		1.5 m	3.0 m	4.5 m	
Oregon Coast	93	7	6	10	19
Washington Coast	80	11	7	8	24
Puget Sound	89	12	11	12	27
SW Washington/Willamette	129	5	3	2	16
Eastern Oregon	105	2	1	2	10

Table III-4. Incidence of decay fungi at selected heights above the groundline of Douglas-fir poles in service for up to 40 years in the Pacific Northwest (Source: Morrell and Schneider, 1994).

Pole Age (Yr.)	# Poles	Cores with decay fungi (%)			Poles w/Decay Fungi (%)
		1.5 m	3.0 m	4.5 m	
1-10	14	0	0	4	7
11-20	132	8	5	5	17
21-30	79	8	5	4	23
31-4	271	7	6	6	19
Total	496	7	5	5	19

While culturing provides a measure of the potential for decay development, the isolated fungi may not necessarily be actively growing in the wood. Inspecting the core for the presence of decay provides measure of fungal activity in the wood. The incidence of decay voids in poles varied between regions (Table III-5). A portion of this variation reflected the ages of poles at the various sites; however, above ground decay voids were most prevalent in poles in the Puget Sound area. Interestingly, voids were also found in the poles in eastern Oregon. The latter finding implies that the conditions in the poles were suitable for decay development during at least sometime during the year, despite the overall low rainfall levels. The presence of voids in poles at all of the sites implies that conditions are suitable for decay development during at least part of the year. As a result, some type of above ground inspection program will eventually be necessary for poles that are subjected to routine groundline inspection and maintenance. While this can be viewed as somewhat onerous, it must be weighed against the fact that many of these poles have the potential to provide nearly double their original estimated service life.

<u>Distribution Poles</u>: The incidence of decay fungi from distribution poles was far lower than that found with in transmission poles. Only 9 increment cores from 6 poles contained decay fungi. Most of these fungi were found 6 to 8.4 m above the groundline. Small decay pockets, however, along the length of many poles suggest that decay fungi had been active in the poles at some point during their service (Table III-6). Decay fungi were generally absent from the groundline, reflecting the prior treatment of these poles with fumigants. Decay fungi were also absent near the very tops of the poles and the incidence of decay pockets was also lower in this region. This lower incidence of decay probably reflect the benefits of end penetration of preservative. In many instances, cores from the upper sampling zone contained evidence of initial preservative treatment that would inhibit fungal colonization, particularly out of ground contact.

Table III-5. Incidence of decay voids at selected heights above the groundline of Douglas-fir poles in service for up to 40 years in the Pacific Northwest (Source: Morrell and Schneider, 1994).

Region	# Poles	Poles w/1 void	Poles w/multiple voids	Pole w/voids (%)
Washington Coast	80	3	1	5
Puget Sound	89	13	13	29
SW Washington	80	3	3	8
Eastern Oregon	58	5	0	9
Total	307	24	17	13

The lower incidence of decay fungi in the distribution poles may reflect several factors. First, smaller poles are more likely to be drier at the time of treatment. As a result, any checks in the poles are more likely to be treated, thereby reducing the pathways by which decay fungi can enter the wood. In addition, smaller poles are more likely to be sterilized during treatment with oilborne preservatives. Both of these characteristics will combine to reduce the risk of decay development in service. A final factor was the utility specification in force at the time these poles were treated which called for pre-drilling of holes for several key attachments. Pre-boring reduces the risk that decay fungi will invade through attachments. In addition, pre-boring increases the percentage of the cross section that is treated. The transmission poles in the earlier study were all field drilled for attachments. While specifications in force required filed treatment, there was no way to confirm that the treatment was actually applied.

Decay above the groundline appears to be a common feature of aging Douglas-fir poles. The problem appears to be more prevalent in larger poles, but distribution poles are also affected. While the results are specific to the Pacific Northwest, the range of climatic conditions in which decay was found imply that poles in other regions may experience similar decay as utilities extend their expected service lives out beyond the typical 30 to 40 year range.

Table III-6. Incidence of decay fungi and decay pockets in Douglas-fir distribution poles in service for 43 to 53 years in the Willamette Valley, Oregon.

Preservative Treatment	Distance From GL (m)	# Cores Sampled	Cores with Decay Fungi (%)	Increment Cores with Decay Pockets (%)			
				No void	<50 mm	51-100 mm	>100 mm
Creosote	-	50	-	66	14	10	10
	4.5	51	4	68	18	12	2
	6.0-8.4	98	6	71	17	8	4
	9.0	47	-	91	6	-	3
Pentachlorophenol	-	30	-	73	23	4	-
	4.5	35	5	86	14	-	-
	6.0-8.4	56	-	80	11	9	-
	9.0	32	-	81	16	3	-
ACA	-	8	-	63	37	-	-
	4.5	8	-	50	50	-	-
	6.0-8.4	16	-	50	31	13	6
	9.0	6	-	83	-	17	-
Total	-	88	-	68	19	7	6
	4.5	94	4	73	19	7	1
	6.0-8.4	170	4	72	16	9	3
	9.0	85	-	87	9	2	1

OBJECTIVE IV
PERFORMANCE OF EXTERNAL GROUNDLINE BANDAGES

Pressure treatment of wood with conventional preservatives continues to be the most effective method for preventing fungal and insect attack. Over time, however, the effectiveness of some preservatives declines and, for optimum performance, should be supplemented by application of external remedial preservatives. Typically, external preservative pastes have been used to treat creosote or pentachlorophenol-treated southern pine along with butt-treated western redcedar and Douglas-fir treated by the Cellon or Dow Processes. These systems are also recommended for supplemental treatment when poles are moved or when they are set in concrete or other materials that will preclude future groundline inspections.

The preservatives formerly used for this purpose included pentachlorophenol, creosote and sodium dichromate. The decision to restrict the use of these preservatives to those who are licensed by their respective states has encouraged many utilities to seek alternative systems. Over the past decade, copper naphthenate, boron and sodium fluoride have emerged as the external preservatives of choice for supplemental groundline treatment. Despite their prior use in other preservative formulations, there was relatively little data on the performance of these systems on utility poles. In order to assist utilities in making better decisions regarding their external decay control programs, we established three field tests with various pole species. The first, in Corvallis, evaluated systems on untreated Douglas-fir. This test is largely completed, but we recently added several new treatments. In addition, we have established two utility field test sites in California and New York. The California site evaluates Douglas-fir, western redcedar and ponderosa pine poles, while the New York site evaluates southern pine and western redcedar.

A. **Evaluation of Selected Groundline Bandage Systems on Douglas-fir, Western Redcedar, and Ponderosa Pine in Merced, CA**

The field test to evaluate copper naphthenate, sodium fluoride and copper naphthenate/boron wraps near Merced, California was sampled in 1997, 7 years after chemical application. These poles are next scheduled for sampling 10 years after treatment.

B. **Evaluation of External Preservatives in Southern Pine and Western Redcedar Poles in Binghamton, NY**

The field test in New York was established in a distribution line located near Binghamton. The western redcedar and southern pine distribution poles ranging in age from 13 to 69 years were treated with CUNAP Wrap, CuRap 20, or Patox II. These systems contain copper naphthenate, copper naphthenate plus boron, and sodium fluoride, respectively.

The poles were sampled 2, 3 and 4 years after treatment by removing plugs from the poles at three equidistant sites around each pole 150 mm below groundline. The cores were cut into zones corresponding to 0 to 4, 4 to 10, 10 to 16, and 16 to 25 mm from the wood surface. Samples from the same treatment group from a given zone were combined prior to being ground to pass a 20 mesh screen. The resulting wood dust was analyzed for copper by x-ray fluorescence, then for fluoride or boron using the appropriate American Wood Preserver's Association Standard.

Copper levels in poles treated with CUNAP were all below the threshold for protection against fungal attack at all three sampling points (Figure IV-1). Preservative levels differed little from the surface inward in southern pine poles, while there was a steep concentration gradient in the western redcedar. The latter gradient reflects the thin sapwood and relatively impermeable heartwood of this species. Copper levels in CuRap 20 treated poles were above the threshold in the outer zone of both southern pine and western redcedar 4 years after treatment (Figure IV-2). Copper levels tended to be higher in CuRap treated southern pine and followed a steadily decreasing gradient from the outer to inner zones 4 years after treatment.

Boron levels in both southern pine and western redcedar poles remained just above the threshold for fungal attack 4 years after treatment. In addition, there was relatively little evidence of a preservative gradient 4 years after treatment. This suggests that the boron has become uniformly distributed across the assay zones although the levels are declining below the protective threshold.

Fluoride levels in the outer zones of poles treated with PATOX II were generally well above the threshold for fungal attack over the entire four year test, although the levels have begun to decline at all sampling locations (Figure IV-3). Fluoride levels were slightly higher in southern pine than western redcedar, although the differences were slight. Once again, chemical levels followed a declining gradient from the surface inward, but the differences between the three inner zones were slight. These results suggest that the fluoride is becoming evenly distributed within the poles.

The results indicated the three external preservative systems are performing in a manner similar to that found in the California and Oregon tests.

Figure IV-1 Residual copper naphthenate (as Cu) at selected distances from the wood surface in southern pine or western redcedar poles 2 to 4 years after groundline treatment with CUNAP Wrap.

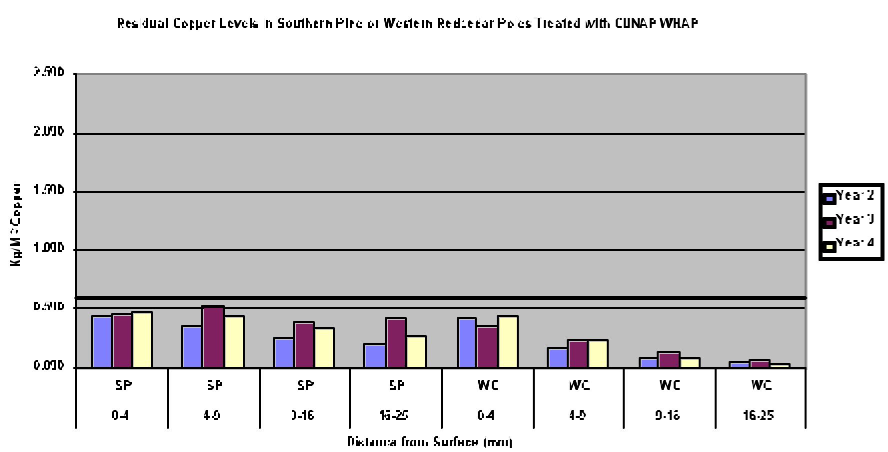
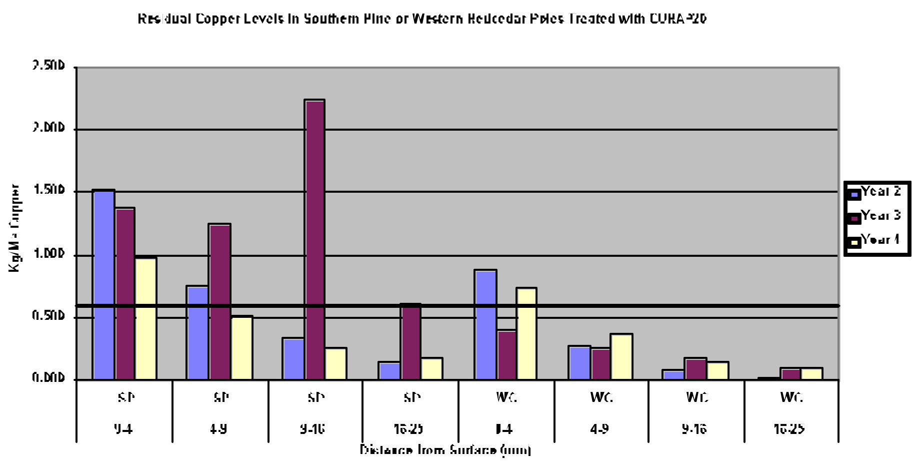


Figure IV-2. Residual copper naphthenate (as Cu)(a) or boron (b) at selected distances from the wood surfaces of southern pine or western redcedar poles 2 to 4 years after groundline application of CuRap 20.



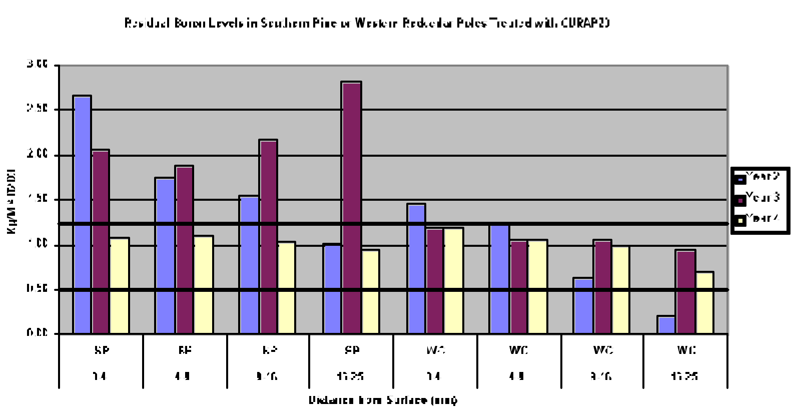
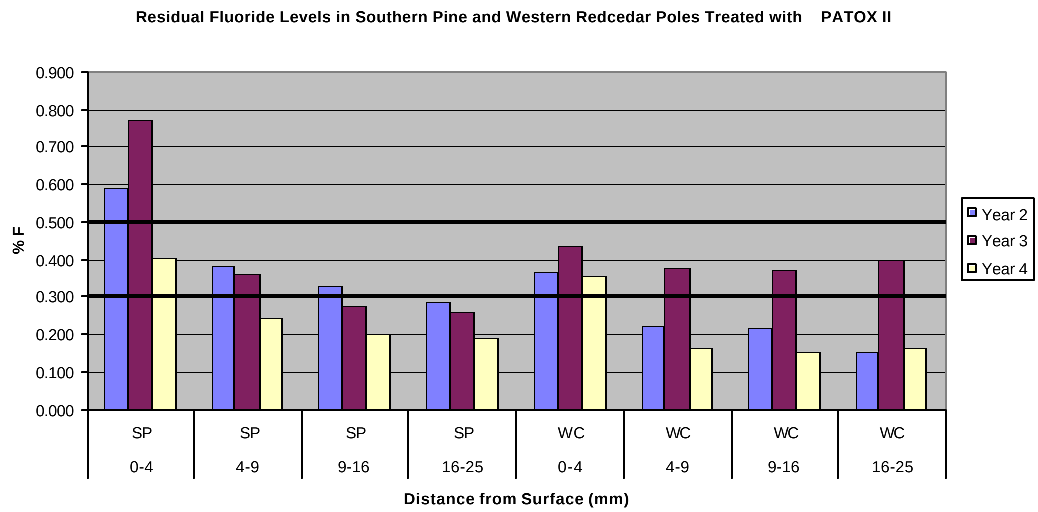


Figure IV-3. Fluoride levels at selected distances from the wood surfaces of southern pine or western redcedar poles 2 to 4 years after groundline application of Patox II.



C. **Performance of Copper/boron/fluoride, Copper/boron, and Propiconazole Wraps on Untreated Douglas-fir Poles**

Seasoned Douglas-fir poles (250 to 300 mm in diameter by 2 m long) were treated with one of three formulations according to manufacturer's instructions. The first formulation was CuRap 20, a mixture containing copper naphthenate and sodium tetraborate decahydrate, the second contained sodium fluoride, copper carbonate and sodium octaborate tetrahydrate and the third consisted of a thickened propiconazole. The Cu/B/F formulation is a self-contained system on a foam backing, while the CuRap 20 and propiconazole were applied as pastes, then covered with polyethylene film. The tops of the wraps were about 0.1 m above the groundline**.**

The pole sections were set to a depth of 0.6 to 0.7 m in the ground and were sampled one year after treatment by removing increment cores from three equidistant sites around the poles 150 mm below the ground. The cores were divided into zones as described above prior to being ground to pass a 20 mesh screen.

Copper was analyzed by x-ray fluorescence, boron was analyzed using the azomethine-H method, and fluoride was analyzed by extraction and determine of fluoride in the extracts using a specific ion electrode

Copper levels in the CuRap and Dr. Wolman formulations followed a somewhat perplexing trends one year after installation (Table IV-1). Copper levels in both systems followed a reverse gradient with the highest levels in the innermost zone of each treatment. Boron and fluoride levels followed similar trends. A careful check of our records indicated that the zones were partitioned correctly; however, we plan to perform additional sampling this summer to determine if these gradients accurately reflect chemical content in poles treated with these two wraps.

Propiconazole levels followed a more normal trend, with retentions being highest near the wood surface. Propiconazole had moved well into the outer 16 mm. Although the levels declined nearly 50 % from the outer 4 mm to the next 5 mm inward, the chemical appears to be moving well into the wood and remains well above the threshold for wood protection. This system is the only organic external preservative we have evaluated and it will be interesting to see if it resists leaching and soft rot attack over the course of the test.

D. **Evaluation of External Preservative Systems in Laboratory Trials**

1. Evaluation of a propiconazole on Douglas-fir heartwood

Although field trials are ideal for assessing the ability of various external preservative systems to move into and protect wood against fungal attack, they are also variable and prone to environmental effects such as weather. We have used laboratory tests as an alternative to assess the ability of various external preservative systems to migrate through Douglas-fir under selected wood moisture regimes. In our procedures, Douglas-fir heartwood blocks (100 mm square) are pressure impregnated with water, then conditioned downward to a target moisture content. These blocks have a small well pre-drilled into one face of the block to allow application of a measured amount of chemical. The well is covered with duct tape, then the block is dipped in molten wax to limit further moisture changes. The blocks are stored at 5 C until needed. Treatments are applied by weighing the desired dosage directly into the well, then recovering the well with duct tape and incubating the block for 1 to 6 months at room temperature. At each time point, blocks are removed and the area directly beneath the well is removed and cut into sections corresponding to 0-6, 6-13, 13-25, and 25 - 37 and 37 - 53 mm from the wood surface. The wood from each zone is ground to pass a 20 mesh screen and then analyzed for the appropriate chemical.

This past year, we examined the ability of propiconazole to diffuse through Douglas-fir heartwood blocks at 10 or 70 % moisture content over a 12 month period. Propiconazole levels were generally extremely high in the outer 6 mm of the blocks, regardless of moisture content. The threshold for this chemical is reported to be 0.12 kg/m^3, while levels ranging from 28.2 to 84.2 were found in the test blocks (Figure IV-4). Clearly, the levels in the surface zone were protective. Chemical levels declined precipitously further inward, with propiconazole levels in the 6- 13 mm zone ranging from 1.6 to 18.3 kg/m, but were still far about the threshold. Chemical levels continued to decline with depth, but in most cases, were still above the threshold 25 mm from the surface. In addition, moisture content appeared to have little or no effect on chemical movement in to the wood. The absence of a substantial moisture effect also suggests that this chemical may be less sensitive to subsequent leaching losses over time.

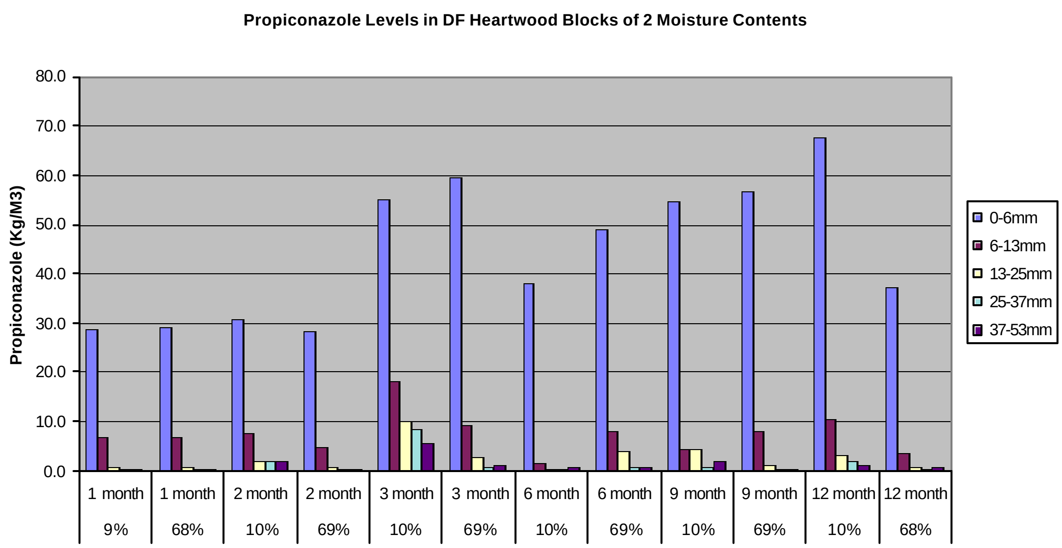
Table IV-1. Residual chemical at various depths from the surface of Douglas-fir poles 1 year after application of CuRap 20, Dr. Wolman wrap, or a propiconazole-based external preservative.

Treatment	Assay Zone (mm)	Residual Chemical			
		Copper (kg/m^3	Boron Oxide (kg/m^3)	Propiconazole (kg/m^3)	Fluoride (%)
CuRap 20	0-4	0.028	0.262	-	-
	4-9	0.020	0.489	-	-
	9-16	0.033	0.750	-	-
	16-25	0.118	1.361	-	-
Dr. Wolman	0-4	0.017	0.207	-	0.002
	4-9	0.015	0.167	-	0.003
	9-16	0.014	0.156	-	0.009
	16-25	0.038	0.185	-	0.027
Propiconazole	0-4	-	-	0.211	-
	4-9	-	-	0.117	-
	9-16	-	-	0.121	-
	16-25	-	-	0.073	-

Values represent tests on 5, 15, and 6 poles treated with CuRap 20, Dr. Wolman or propiconazole systems, respectively

Figure IV-4. Residual propiconazole in Douglas-fir heartwood blocks conditioned to 10 or 70 % moisture content and incubated 1 to 4 months after application of a propiconazole paste.

2. <u>Ability of a copper-/boron/fluoride paste to migrate through Douglas-fir heartwood blocks</u>



Douglas-fir blocks were conditioned to 30 or 60 % moisture content, then treated with a copper/boron/fluoride system contained on a foam-backed wrap. The wrap was applied by placing a section of wrap in the well area normally used to apply paste. Wells were oriented so that the chemical would have to either diffuse longitudinally (labeled top) or radially (labeled side). The blocks were incubated for 1 or 4 months at room temperature before being dissected as described above.

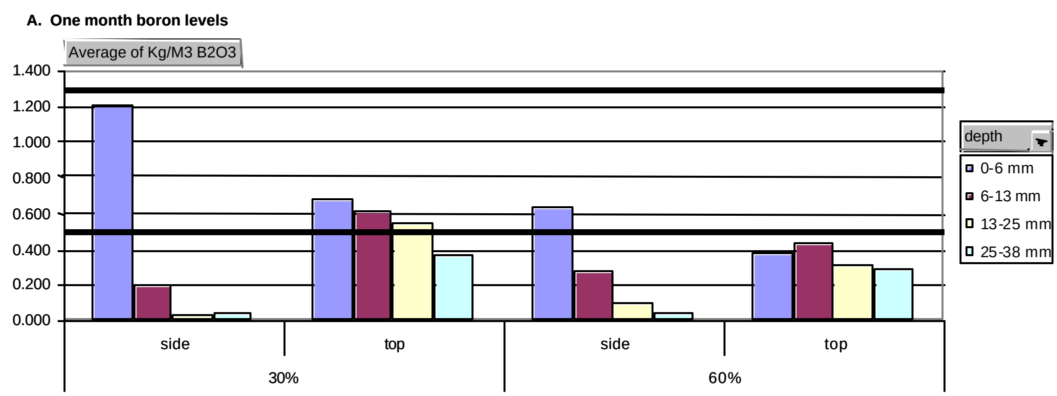
Boron levels in blocks one month after treatment tended to follow a fairly steep gradient in blocks at 30 % moisture content, particularly in the blocks where radial diffusion was the primary pathway (Figure IV-5). The gradient was shallower in the wetter blocks, although diffusion was still more restricted in the radial direction. Boron levels 4 months after treatment were lower and there was less difference in boron levels between the surface and interior of the blocks. It is unclear whether this reflects diffusion further inward from the point of application or inherent variation in boron movement.

Copper levels were generally elevated in the outer assay zone one month after treatment at both moisture contents regardless of orientation (Figure IV-6). Copper levels declined precipitously further inward when the primary pathway was radial diffusion. Limited copper diffusion reflects the lower water solubility of this component of the formulation. Copper compounds in most external preservative systems are designed to present a barrier against renewed infestation and are not presumed to move for long distances into the wood to arrest existing fungal attack. Copper levels were slightly lower 4 months after treatment, but the trends were similar to those found at one month.

Fluoride levels in the blocks 1 and 4 months after treatment were all below the reported threshold for this chemical against fungal attack (Figure IV-7). In addition, there was little evidence of substantial fluoride gradients in the longitudinal direction. Gradients were noted with the radial orientation. Fluoride penetration was slight in the radial direction at either moisture content, suggesting that the level of fluoride in the system or its availability may have limited movement.

The results indicate that none of the wrap components are moving through the wood at fungitoxic levels; however, it is important to consider the possible benefits of sub-threshold levels of multiple biocides. We will continue to monitor these blocks for an additional 8 months to determine if diffusion continues to occur.

Figure IV-5. Boron levels in Douglas-fir heartwood blocks at 30 or 60 % moisture content (a) one or (b) four months after application for a copper/boron/fluoride external preservative bandage.



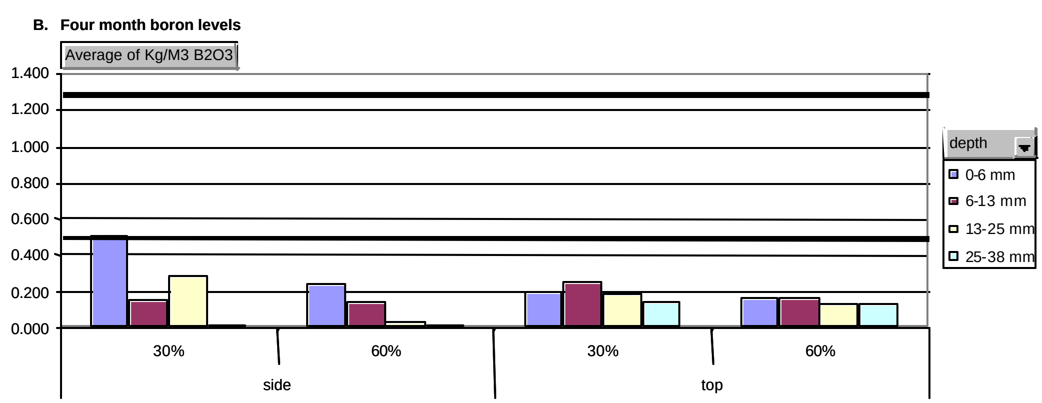
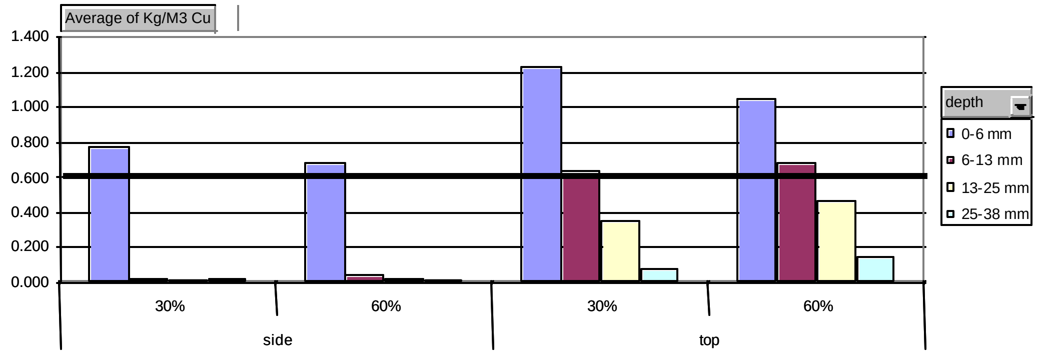


Figure IV-6. Copper levels in Douglas-fir heartwood blocks at 30 or 60 % moisture content (a) one or (b) four months after application for a copper/boron/fluoride external preservative bandage.

A. One month copper levels



B. Four month copper levels

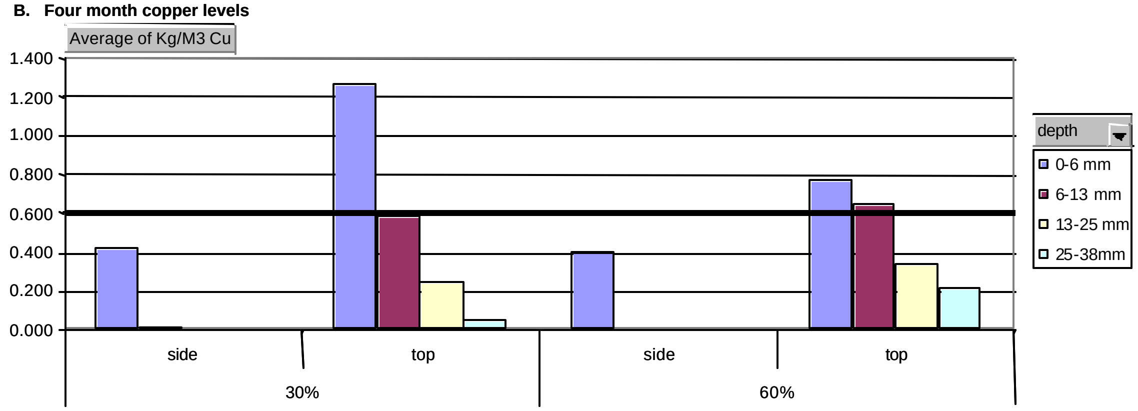
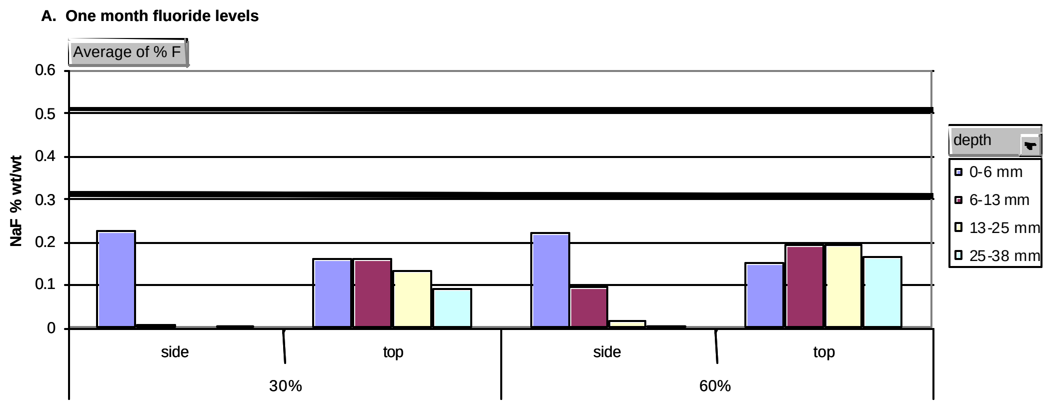
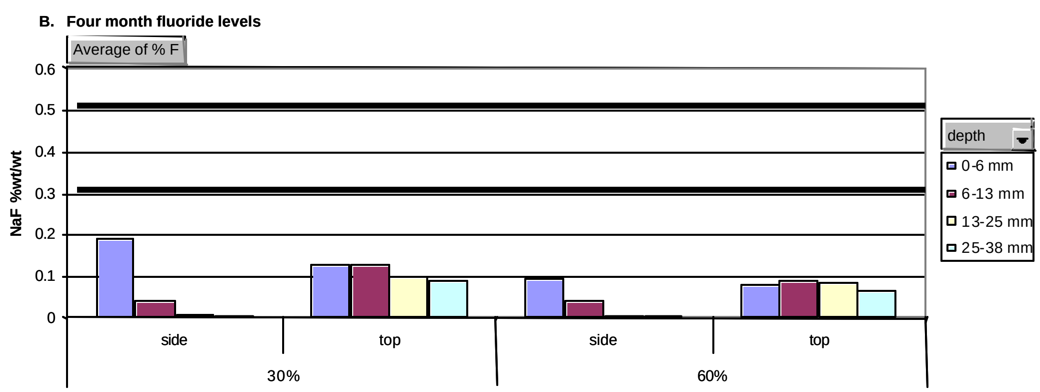


Figure IV-7. Fluoride levels in Douglas-fir heartwood blocks at 30 or 60 % moisture content (a) one or (b) four months after application for a copper/boron/fluoride external preservative bandage





OBJECTIVE V
PERFORMANCE OF COPPER NAPHTHENATE-TREATED WESTERN WOOD SPECIES

A. Decay Resistance of Copper Naphthenate-treated Western Red-cedar in a Fungus Cellar

The naturally durable heartwood of western redcedar makes it a preferred species for supporting overhead utility lines. For many years, utilities used cedar without treatment or only treated the butt portion of the pole to protect the high hazard ground contact zone. The cost of cedar, however, encouraged many utilities to full-length treat their cedar poles. While most utilities use either pentachlorophenol or creosote for this purpose, there is increasing interest in alternative chemicals. Among these chemicals is copper naphthenate, a complex of copper and naphthenic acids derived from the oil refining process. Copper naphthenate has been in use for many years, but its performance as an initial wood treatment for poles remains untested on western redcedar.

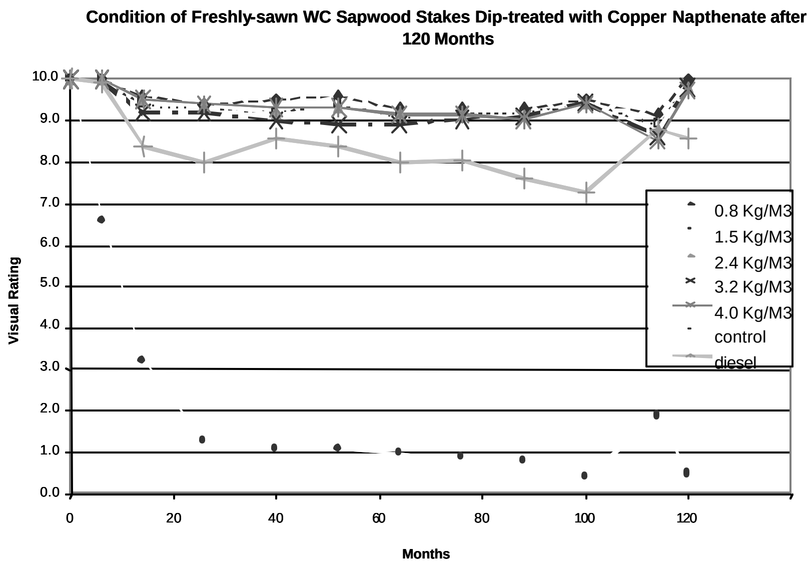
Copper naphthenate performance on western redcedar was evaluated by cutting sapwood stakes (12.5 by 25 by 150 mm long) from either freshly sawn boards or from the aboveground, untreated portion of poles which had been in service for about 15 years. Weathered stakes were included because of a desire by the cooperator to retreat cedar poles for reuse. In prior trials, a large percentage of cedar poles removed from service due to line upgrades were found to be serviceable and the utility wanted to recycle these in their system.

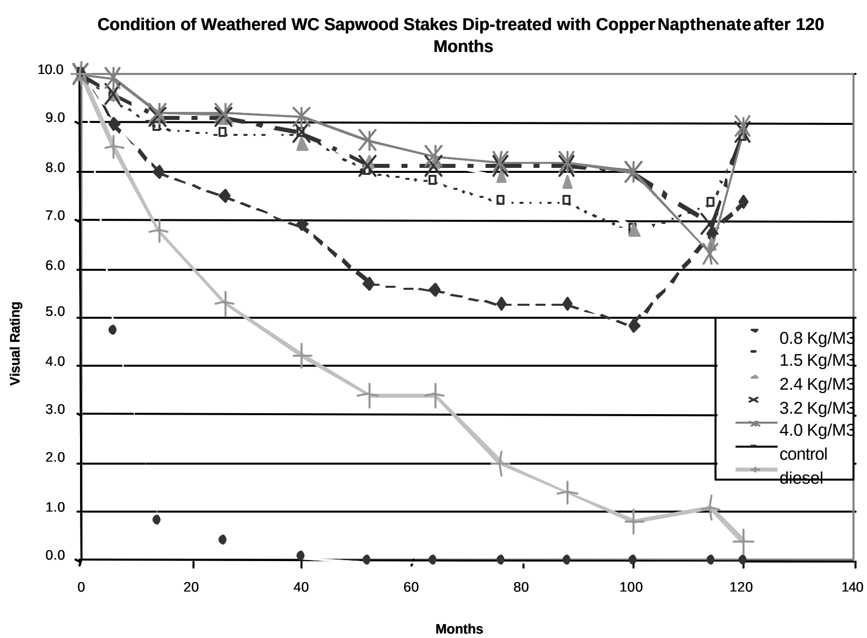
The stakes were conditioned to 13% moisture content prior to pressure treatment with copper naphthenate in diesel oil to produce retentions of 0.8, 1.6, 2.4, 3.2, and 4.0 kg/m^3. Each retention was replicated on ten stakes.

The stakes were exposed in a fungus cellar maintained at 28/C and approximately 80% relative humidity. The soil was a garden loam with a high sand content. The original soil was amended with compost to increase the organic matter. The soil is watered regularly, but is allowed to dry between watering to simulate a natural environment. The condition of the stakes has been assessed annually on a visual basis using a scale from 0 (failure) to 10 (sound).

Untreated control stakes have essential failed for both freshly sawn and weathered stakes 10 years after installation. Diesel-treated freshly sawn stakes continue to perform well, while weathered stakes treated with solvent have largely failed (Figure V-1). All of the freshly sawn stakes treated with copper naphthenate continue to remain sound and free of visible decay 10 years after installation, while weathered stakes treated to the same retentions have produced more variable results. Samples treated to the lowest copper retention (0.8 kg/m^3) have visible decay and average ratings of 7.4. Stakes treated to the higher retentions all had average ratings between 8.5 and 9.0, suggesting that they were beginning to be attacked. The results continue to show that copper naphthenate provided diminished protection to weathered wood. Weathering increases surface permeability and may hasten leaching losses. While retreatment of in-service poles represents an ideal method for retaining otherwise sound western redcedar within the system, it is clear that the performance expectations with these poles should be somewhat reduced from those for poles from recently harvested trees.

Figure V-1 Condition of freshly harvested and weathered western redcedar stakes treated with copper naphthenate and exposed in a fungal cellar for 120 months.





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