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Rocky Mountain Research Station

Research Paper RMRS-RP-17

May 1999

Service Life of Fence Posts Treated by Double-Diffusion Methods

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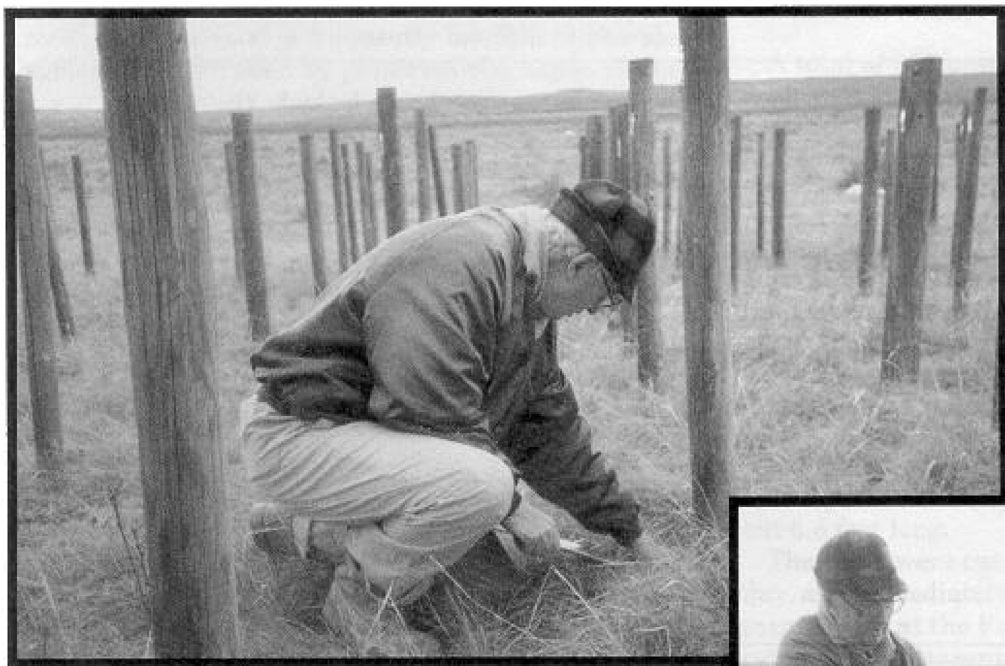

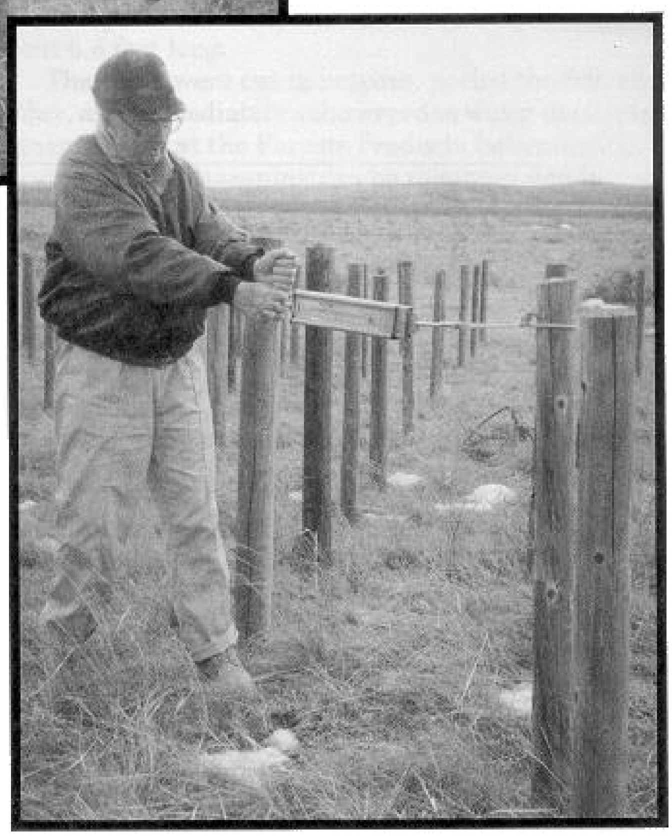

Abstract

Markstrom, Donald C.; Gjovik, Lee R. **1999. Service life of fence posts treated by double-diffusion methods.** Res. Pap. RMRS-RP-17. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 5 p.

Service-life tests indicate that Engelmann spruce, lodgepole pine, and Rocky Mountain Douglas-fir fence posts treated by double-diffusion methods performed excellently after field exposure of 30 years with no failures. The test site was located in the semiarid Central Plains near Nunn, Colorado. Although Engelmann spruce posts generally defy treatment by other treating processes, double-diffusion results in long service life. The annual service cost of the untreated posts ranged from $1.39 to $1.60 per post depending upon the species. The annual cost of the treated posts was $1.10 per post based on 1998 dollars.

Keywords: preservative, *Picea engelmannii, Pinus contorta, Pseudotsuga menziesii* var. *glauca*

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Service Life of Fence Posts Treated by Double-Diffusion Methods

Donald C. Markstrom
Lee R. Gjovik

Fence posts from Engelmann spruce (*Picea engelmannii*), lodgepole pine (*Pinus contorta*), and Rocky Mountain Douglas-fir (*Pseudotsuga menziesii* var. *glauca*) resist conventional treatment to preserve the wood when placed in the ground. Heartwood of lodgepole pine and Douglas-fir is resistant to treatment. The sapwood is frequently too thin to provide sufficient penetration by preservatives, especially in wood from densely stocked stand that would benefit most from thinning. Neither the heartwood nor the sapwood of Engelmann spruce can be treated effectively with conventional methods (MacLean 1930; Wood and Blew 1953).

However, the market for fence posts may expand if the double-diffusion treatment method can prove to extend service life (Baechler and Roth 1964). Expanded markets could provide more outlets for small roundwood and enhance local economies through sales of unutilized tree resources.

During 1968, Engelmann spruce, lodgepole pine, and Douglas-fir fence posts were treated by regular and modified double-diffusion methods. Treated and untreated posts were installed in a semiarid test plot at the Central Plains Experimental Range near Nunn, Colorado. The test was designed to evaluate and compare the effectiveness of the three species and preservative retention levels. Initial results of the service test were reported in a progress report by Markstrom (1984). Details of the treating procedure were reported by Markstrom and others (1970). This paper describes the treating procedures and results of the 30-year service test.

The study was conducted cooperatively among the Rocky Mountain Research Station, the U.S. Forest Products Laboratory, the Roosevelt National Forest, and the Agricultural Research Service.

Methods

Materials Treated

A total of 378 posts, 126 for each species, were cut from east slope stands of the Rocky Mountains near Fort Collins, Colorado, in 1968. Both Douglas-fir and lodgepole pine posts were cut from typical densely stocked, slow-growth stands. The Engelmann spruce posts were selected from an area in which a heavy sawlog cut had been made. Two or three posts were cut from most trees for all species. Average diameters at the small and large ends, and growth rate (rings per outer inch), were measured (see table 1). Sapwood thickness was measured on 60 posts after debarking. Sapwood was distinguished from the heartwood by color difference, except in Engelmann spruce, where the difference was not sufficiently apparent on most of the posts to make this distinction. All posts were cut 6.5 feet long.

The posts were cut in batches, peeled the following day, and immediately submerged in water until treatment. Work at the Forests Products Laboratory indicated partial seasoning can be tolerated and in some cases can improve penetration (Gjovik and others 1972). The peeling was done with a cutter-head type debarker at a commercial treating plant in accordance with its regular practices. This type of debarker removes surface irregularities and generally improves the appearance of a post or pole. It removes some of the sapwood in the process, however, so that sapwood thicknesses in table 2 are generally less after debarking.

Table l-Characteristics of Douglas-fir, lodgepole pine, and Engelmann spruce sample posts.

Post measurement[a]	Douglas-fir Mean	Douglas-fir Coeff. of var. (%)	Lodgepole pine Mean	Lodgepole pine Coeff. of var. (%)	Engelmann spruce Mean	Engelmann spruce Coeff. of var. (%)
Diameter, large end (in.)	4.43	17	4.37	9	4.53	16
Diameter, small end (in.)	3.90	18	4.06	14	4.02	17
Growth rate (rings per inch)	35.9	20	41.3	21	37.0	47

[a]Each measurement is calculated from 126 posts.

Table 2—Chemical penetration and sapwood thickness of sample posts.

	Treatments[a]							
	A		B		C		D	
	Mean (In.)	Coeff. of var. (%)	Mean (In.)	Coeff. of var. (%)	Mean (in.)	Coeff. of var. (%)	Mean (in.)	Coeff. of var. (%)
Lodgepole pine								
Chemical penetration								
Maximum	0.92	14	1.00	33	1.14	28	1.30	15
Minimum	0.48	23	0.66	38	0.82	28	0.94	18
Sapwood thickness[b]								
Maximum	1.12	24	1.14	43	1.14	25	1.30	15
Minimum	0.70	29	0.70	39	0.82	28	0.94	18
At maximum penetration	1.00	19	1.10	39	1.14	25	1.30	15
At minimum penetration	0.84	46	0.76	46	0.82	28	0.94	18
Douglas-fir								
Chemical penetration								
Maximum	0.38	11	0.46	24	0.60	17	0.72	32
Minimum	0.06	150	0.16	81	0.24	46	0.40	43
Sapwood thickness[b]								
Maximum	0.38	11	0.46	24	0.60	17	0.72	32
Minimum	0.06	150	0.16	81	0.24	46	0.40	43
At maximum penetration	0.38	11	0.46	24	0.60	17	0.72	32
At minimum penetration	0.06	150	0.16	81	0.24	46	0.40	43
Engelmann spruce								
Chemical penetration								
Maximum	0.86	24	1.38	31	1.34	53	1.70	51
Minimum	0.38	68	1.10	47	1.00	92	1.30	72
Sapwood thickness[c]								

[a]Treatment A = 1 day in $CuSO_4$ + 1 day in Na_2 HAs O_4 - Na_2CrO_4.
Treatment B = 3 days in $CuSO_4$ + 3 days in Na_2 HAs O_4 - Na_2 CrO_4.
Treatment C = 8 hours in $CuSO_4$ (200 °F) + 1 day in Na_2 HAs O_4 - Na_2 CrO_4.
Treatment D = 1 day in $CuSO_4$ + 1 day in Na_2 HAs O_4 - Na_2CrO_4 (posts incised)
[b]All sapwood measurements taken after debarking.
[c]The color difference in the wood of Engelmann spruce was not sufficiently apparent on most of the posts to distinguish heartwood from sapwood

Treatment

The following treating schedules and procedures were followed:

Treatment A: 1 day in $CuSO_4$ + 1 day in Na_2HAsO_4 - Na_2CrO_4.
Treatment B: 3 days in $CuSO_4$ + 3 days in Na_2HAsO_4 - Na_2CrO_4.
Treatment C: 8 hours in hot $CuSO_4$ (200 °F) + 1 day in cold Na_2HAsO_4 - Na_2CrO_4.
Treatment D: (posts incised) - 1 day in $CuSO_4$ + 1 day in Ha_2HAsO_4 - Na_2CrO_4,

Twenty-four posts (eight of each of three species) were treated in each charge. The posts were labeled, placed in a rope sling, and submerged in the copper sulfate solution for the appropriate treating time. After the prescribed time, posts were removed from the copper sulfate solution, rinsed with cold water, allowed to drain, and then submerged in the tank of sodium arsenate-sodium chromate solution. Again after the prescribed time, the posts were removed from the solution and rinsed with cold water. The treated posts were then tightly piled and covered with polyethylene to allow the chemicals to diffuse further into the wood.

The 10 percent copper sulfate solution was prepared by mixing calculated amounts of water and copper sulfate in a plywood tank. The 13 percent sodium arsenate-sodium chromate solution was prepared by adding calculated amounts of sodium arsenate and sodium chromate to water in a metal tank. The sodium arsenate was added first. The concentration of the solutions was checked with a hydrometer after each charge of treated posts was removed. To compensate for chemicals absorbed in the previous charge, chemicals were added in amounts based on the specific gravities of the solutions. Also, samples of the solutions were taken before each charge and later analyzed.

In Treatment C, the copper sulfate was heated with a ½-inch copper steam coil attached to a portable kerosene steam generator. A steam pressure of 60 psi heated the solution and posts to 200 °F.

The posts for Treatment D were incised to a depth of $^5/_8$-inch with a hand incising hammer over an area extending from about 1 foot below to 1 foot above the ground line.

Sampling and Chemical Analyses of Posts

Sixty posts (five in each of 12 species-treatment combinations) were selected for the penetration and retention analyses. The five sample posts consisted of one large, one small, and three randomly selected. These posts were shipped to the Forest Products Laboratory for retention and penetration determinations. A composite assay for each treatment combination was determined from an equal number of $^1/_8$-inch cross sections from each of the five posts. The unincised posts were sampled at midpoint, and the incised posts were sampled at the midpoints of both the incised and unincised portions. Preservative salts in the composite samples were determined in accordance with American Wood-Preservers' Association (1970). Penetrations were determined from a l-inch cross section sawn from the middle of the incised and unincised portions of the incised posts. Chrome azurol-S, a stain for copper penetration, was used.

Installation and Annual Inspection of Posts

A total of 225 treated posts and 75 untreated posts were installed in a test plot at the Central Plains Experimental Range. The rectangular plot consisted of 25 rows of 12 posts set 2.5 feet deep and 3 feet apart in each direction. One post for each treatment and species combination and one untreated post from each species were randomly located in each row.

An annual inspection to test service life consisted of applying a 50-lb load laterally with a spring scale to the top of each post. Any post that broke off when pulled or that could no longer hold a staple was recorded as a failure.

Results

Chemical Retention and Penetration

The retention results given in table 3 showed that Engelmann spruce and lodgepole pine may be treated to meet the retention requirement of 0.40 lb/ft of chromated copper arsenate (based on the oxides CrO_3, CuO, and AS_2O_5) as given in AWPA Standard C-5 Posts. All variations of the treatment met this requirement except the l-day plus l-day treatment with unincised posts. The only treatment that met the retention requirement for Douglas-fir was the l-day plus 1-day treatment on incised posts. This treatment also introduced the most salts into Engelmann spruce and lodgepole pine.

Table 2 shows the average maximum and minimum penetrations with corresponding sapwood thicknesses for different species-treatment combinations. The double-diffusion method can provide full sapwood penetration in lodgepole pine and Rocky Mountain Douglas-fir. The treatment did not penetrate the heartwood of these species to any significant extent, however, except for the incised areas. Since the depth of treatable wood is severely limited, the thin sapwood in these species resulting from overstocking is still a problem.

Table 3—Retentions of chemicals[a] in posts for the different species and treatments[b].

Treating schedule	$CuSO_4$	Na_2CrO_4	Na_2HAsO_4	Total salts
		lb/ft²		
Engelmann spruce				
1 day Cu, 1 day As-Cr, incised[c]	0.30 (.15)	0.52 (.32)	0.40 (.29)	1.22 (.76)[d]
1 day Cu, 1 day As-Cr, unincised[c]	.17 (.08)	.15 (.09)	.10 (.07)	.42 (.24)
1 day Cu, 1 day As-Cr	.20 (.10)	.14 (.09)	.18 (.13)	.52 (.32)
3 days Cu, 3 days As-Cr	.29 (.14)	.19 (.12)	.21 (.15)	.69 (.41)[d]
8 hrs. hot Cu, 1 day As-Cr	.26 (.13)	.31 (.19)	.27 (.19)	.84 (.51)[d]
Lodgepole pine				
1 day Cu, 1 day As-Cr, incised[c]	.29 (.14)	.55 (.34)	.41 (.29)	1.25 (.77)[d]
1 day Cu, 1 day As-Cr, unincised[c]	.22 (.11)	.07 (.04)	.06 (.04)	.35 (.19)
1 day Cu, 1 day As-Cr	.24 (.12)	.12 (.07)	.14 (.10)	.50 (.29)
3 days Cu, 3 days As-Cr	.33 (.16)	.39 (.24)	.35 (.25)	1.07 (.65)[d]
8 hrs. hot Cu, 1 day As-Cr	.38 (.19)	.24 (.15)	.23 (.16)	.85 (.50)[d]
Douglas-fir				
1 day Cu, 1 day As-Cr, incised[c]	.27 (.13)	.31 (.19)	.24 (.17)	.82 (.49)[d]
1 day Cu, 1 day As-Cr, unincised[c]	.18 (.09)	.06 (.04)	.06 (.04)	.30 (.17)
1 day Cu, 1 day As-Cr	.15 (.07)	.08 (.05)	.08 (.06)	.31 (.18)
3 days Cu, 3 days As-Cr	.26 (.13)	.16 (.10)	.16 (.11)	.58 (.34)
8 hrs. hot Cu, 1 day As-Cr	.22 (.11)	.18 (.11)	.15 (.11)	.55 (.33)

[a]Numbers in parentheses represent retentions based on oxides (CuO_1, CrO_3, and As_2O_5).
[b]Analysis was made on composites of five posts for each treatment.
[c]Incised and unincised cross sections cut from same five posts.
[d]Treatment met total salts retention requirement of 0.40 Ib/ft of chromated copper arsenate (based on the oxides CrO_3, CuO_1, and As_2O_5) as given in AWPA C-5 Posts.

The average penetration in Engelmann spruce was greater than a minimum of $^3/_4$ inch for all treatments except the 1-day plus 1-day with unincised posts. For lodgepole pine, the average penetration was greater than a minimum of $^3/_4$ inch for all treatments except the 1-day plus 1-day with unincised posts and the 3-day plus 3-day. Also, these two treatments did not penetrate all of the sapwood while the other two did for lodgepole pine. The average penetration of Douglas-fir was less than a minimum of $^3/_4$ inch for all treatments. Douglas-fir had complete sapwood penetration with all treatments, but no heartwood penetration.

Service Life of Posts

Performance of the posts was measured by (1) survival data analysis (Lee 1980; Lee and Desu 1972), (2) percentage of posts that failed, and (3) average service life of the failed posts. The percentage of posts that failed in each treatment was the number of failed posts divided by the total number of posts in the treatment. The average service life of the failed posts was the total years of service before failure divided by the number of failed posts. The results for all three performance measurements are given in table 4.

Survival Data–This analysis grouped the treatments by years of service. The analysis (p = 0.05) indicated (1) that there was a significant difference between the treated posts and the untreated posts and (2) that there was no signficant difference between the treatments.

Percentage of Failure-None of the treated posts failed during the 30-year period. Failure values for the untreated posts were: Engelmann spruce, 84 percent; lodgepole pine, 60 percent; and Douglas-fir, 44 percent.

Service Life-Obviously, all that can be said about the treated posts is that their service life is greater than 30 years. The average service life of the untreated posts was: Engelmann spruce, 16 years; lodgepole pine, 17 years; and Douglas-fir, 9 years.

All of the untreated post failures resulted from decay at or near the ground line. Eight of the treated posts showed cross checking from excessive longitudinal shrinkage probably resulting from the presence of compression wood. No posts, however, had either checked or cross checked to the extent that fence staples would not have held.

Implications

Treated Engelmann spruce, lodgepole pine, and Douglas-fir fence posts have a longer service life than the untreated posts. All of the treated posts performed equally well in that none of the posts failed during the 30-year service test period. This good performance occurred even though some of the post treatments had not met the total salt requirement of 0.40 lb/ft of chromated copper arsenate (see table 3). Thin sapwood possibly contributed to the low salt retention of the posts not meeting the 0.40 lb/ft level. Natural durability of the heartwood, however, may have contributed to the good performance of these posts in service.

The equivalent uniform annual cost per post for each of the treatments are shown in table 5. These costs are for an analysis period of 30 years. The

Table 4—Survival groups, percent failures, and average age of failures for each combination of tree species preservative treatment of fence posts.

Treatment	Survival groups[a]	Percent failures	Average age of failures (years)
Rocky Mountain Douglas-fir			
1 day Cu, 1 day As-Cr	a	0	—
3 days Cu, 3 days As-Cr	a	0	—
8 hrs. hot Cu, 1 day As-Cr	a	0	—
UNTREATED (CONTROL)	b	44	9
Lodgepole pine			
1 day Cu, 1 day As-Cr	a	0	—
3 days Cu, 3 days As-Cr	a	0	—
8 hrs. hot Cu, 1 day As-Cr	a	0	—
UNTREATED (CONTROL)	b	60	17
Engelmann spruce			
1 day Cu, 1 day As-Cr	a	0	—
3 days Cu, 3 days As-Cr	a	0	—
8 hrs. hot Cu. 1 day As-Cr	a	0	—
UNTREATED (CONTROL)	b	84	16

[a]Survival groups with each plot location with the same letter are not significantly different at the p = 0.05 level.

Table 5—Annual service cost of treated and untreated Engelmann spruce, lodgepole pine, and Douglas-fir posts at the semiarid Central Plains Experimental Range plot near Nunn, Colorado.

Treatment	Retention of total salts	Equivalent uniform annual cost per post'
	lb/ft³	*Dollars*
Engelmann spruce		
1 day Cu, 1 day As-Cr	.52 (.32)[b]	1.10
3 days Cu, 3 days As-Cr	.69 (.41)	1.10
8 hrs. hot Cu, 1 day As-Cr	.84 (.51)	1.10
UNTREATED (CONTROL)	—	1.60
Lodgepole pine		
1 day Cu. 1 day As-Cr	.50 (.29)	1.10
3 days Cu, 3 days As-Cr	1.07 (.65)	1.10
8 hrs. hot Cu, 1 day As-Cr	.85 (.50)	1.10
UNTREATED (CONTROL)	—	1.39
Rocky Mountain Douglas-fir		
1 day Cu, 1 day As-Cr	.31 (.18)	1.10
3 days Cu, 3 days As-Cr	.58 (.34)	1.10
8 hrs. hot Cu, 1 day As-Cr	.55 (.33)	1.10
UNTREATED (CONTROL)	—	1.50

[a]The equivalent uniform annual cost is based on the following:
A capital recovery factor with 10 percent compound interest
An analysis period with no salvage value of 30 years.
An installed cost of $10.35 for untreated posts and $10.75 for the treated posts. A new post replacing a failed post was assumed to have the same service life and installed cost as the failed post
[b]The numbers in parentheses are retentions based on oxides (CuO_1, CrO_3, and As_2O_5).

financial analysis indicates that the annual service costs for the treated and untreated posts are different, given the assumptions as footnoted in table 5. The annual service costs of the untreated posts were the highest, averaging $1.50 per post and ranging from $1.39 to $1.60 per post depending upon the species. The annual service cost of all treated posts was $1.10.

This study shows that double-diffusion treatment results in long service life of Engelmann spruce posts. This species generally defies treatment by any of the other treating processes. Because of its good form and general availability, spruce can be a good source of poles and posts when treated satisfactorily.

Fence posts currently treated with water borne arsenicals are available on the market. The use of these posts is not restricted by the Environmental Protection Agency (Webb and Gjovik 1988). Present EPA restrictions apply only to the operating procedures at treating plants. Consequently, after being certified, any do-it-yourself treater can treat wood with these chemicals.

The double-diffusion process may be of interest in developing countries since it is simple and probably would not require the capital expenditures in comparison to other wood treating processes. Readers should realize that the double-diffusion treatments reported here may perform differently in other geographic areas depending upon the species of wood treated and exposure to different climates and organisms.

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