AREMA 2010 Orlando, FL

ACZA-Treated Douglas fir Ties: Alternative Preservative, Alternative Species

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Word Count: 3387 words

ABSTRACT

For more than a century, crossties and switchties have been made predominantly from hardwood species pressure-treated with creosote preservative. These ties have performed reliably. However, issues related to creosote availability have prompted searches for alternative ties with the desirable properties of creosoted hardwoods. A promising candidate is Douglas fir treated with ammoniacal copper zinc arsenate (ACZA). Douglas fir is recognized as a strong, stable species of wood, and has been used for decades for saltwater piling, utility poles, structural timbers, and other heavy duty applications. ACZA is an effective preservative with its own long history, protecting wood – mostly Douglas fir – against marine borers, termites and decay fungi. In this paper, the author examines the records of Douglas fir and ACZA, and reports on their use and testing relevant to track installations. Strength, longevity, spike-holding, and fire resistance are among the characteristics considered.

INTRODUCTION

Pressure-treated wood products have been the backbone of the growth of America since the first pressure-treated creosote crossties were produced in 1875. Railroads have always been a large user of pressure-treated wood with approximately 3500 ties installed per mile. Over the years many products have tried to replace pressure-treated wood ties but none has been able to fully replace the attributes that are grown into wood. The major energy source for their production is solar - from the time a seedling bursts forth from the soil until it harvested, and for most ties the sun and wind continue to be part of the production process by providing the means of drying.

Since 1875, there has not been much that was new in wood ties. Other preservatives have been tried and used particularly during war time and the treating process has been steadily refined, but its essentials today are similar to those of a century ago. There have been improvements in standards, creosote solutions, and the understanding of tie performance, but few quantum leaps. Not since pressure-treated creosote ties replaced untreated ties has there been a choice that was practical.

Perhaps until now. The combination of creosote scarcity, a suitable and sustainable softwood, and an effective yet often overlooked preservative has resulted in an option that indicates excellent properties at an economical price. It could be especially advantageous for short lines and industrial spurs.

This option is the Douglas fir tie pressure-treated with Ammoniacal Copper Zinc Arsenate (ACZA), often known by its trade name, Chemonite. ACZA is an ammoniacal waterborne wood preservative.

HISTORY OF ACZA

ACZA is not a recent development but has a history. It was developed by University of California researchers in the years 1924 - 1926 specifically to combat disease in fruit trees by protecting them from attack by destructive organisms. During its formation period its ability to protect refractory or difficult-to-treat species of wood from organic attack was also evaluated. Originally formulated as ACA, it consisted of copper and arsenic in an ammoniacal waterborne system. Its protection of easily decayed white fir for a minimum of 9 years led to the first commercial Chemonite plant being built in 1935. Between 1941 and 1942 over 95,000 Douglas fir and White fir cross ties were treated with ACA.

In 1983 Advances in science and chemistry led to the formula change where 50% of the arsenic was replaced with zinc. The current formulation is referenced as AZCA. The change improved efficacy, reduced leaching, improved corrosion characteristics and reduced the environmental footprint of the preservative. Additionally, ACZA has properties that while being a waterborne preservative make it similar to creosote. It is heated during the treating process and has a distinctive odor. In the case of ACZA the odor arises from the ammonia used to help it move deep into the wood; the odor dissipates during gas off. Like creosote, ACZA imparts a dark color to the ties, typically a dark bluish green/black. A major difference is the fact that ACZA fixes in the wood as the ammonia gasses off while creosote migrates out of the tie over time. ACZA in Douglas fir can also be analyzed with X-ray fluorescence devices where creosote treated hardwoods have required a calculation based on the gage retention.

EFFICACY

ACA and ACZA have both shown the ability to protect wood from various organisms that attack wood. They are able to further protect wood from difficult-to-control insects – Formosan termites and Carpenter ants. ACZA has been classified as a Type III termiticide. Type III termiticides are slow acting, non-repellant materials, which means termites will move to other parts of the colony before they die – affecting the entire colony. Type I termiticides are repellants and Type II termiticides kill quickly in the treated area rather than affecting the colony. Table 1 below shows how ACZA protects wood against termites when compared to untreated wood. Samples are treated and weighed prior to and after exposure to termites to determine the level of attack.

Table 1

Mean pre- and post-test weights of ACZA treated Douglas fir Exposed to Formosan Subterranean Termite in the ASTM D 3345 – 74 Test

Retention #/cu.ft.	Pre-Test Weight (gms)	Post-Test Weight (gms)	Gain/loss (gms)	Percent Diff.
0.00	2.06	1.22	-0.84	-40.8
0.11	2.04	2.04	0.00	0.0
0.20	2.05	2.05	0.00	0.0
0.31	2.05	2.06	0.01	0.5
0.41	2.06	2.05	-0.01	-0.5
0.62	2.09	2.08	-0.01	-0.5

Carpenter ants are another challenge, because they do not actually ingest the wood but remove it to build their colonies and pathways. In tests conducted at Spokane Falls Community College. ACZA was found to be an excellent repellant and preventative for carpenter ants at all retention levels. Since the ants do not ingest wood, it is surmised that the ants' habitually cleaning of each other leads to the ingestion of the AZCA.

SUITABILITY OF DOUGLAS FIR FOR TIES

While Douglas fir is considered a softwood tree, it is similar in many ways hardwoods. It is dense, close-ringed wood that is strong and resilient, with a heartwood resistant to wood-destroying organisms while being refractory i.e., difficult-to-treat. The trees themselves are slow growing and achieve great heights and diameters. The wood to be used for ties and for most treated applications is the coastal variety, which has better structural and treating characteristics than other varieties. Douglas fir has long been used in applications where strength and straightness are desired, such as cross arms, timber bridges, poles and construction timbers.

ATTRIBUTES OF ACZA DOUGLAS FIR TIES

Railroad cross and switch ties have been historically over-designed from the standpoint of rail loads. Tie life depended largely upon deterioration rather than mechanical damage. However, due to advances in decay-inhibiting treatment and increased axle loads, adequate structural design is becoming more important in reducing tie replacement costs. These greater Rail loads induce stresses in bending and shear as well as in compression perpendicular to the grain in railroad ties. Specific gravity and compressive strength parallel to the grain are also important properties to consider in evaluating crosstie materials. These properties indicate the wood's resistance to both pullout and lateral thrust of spikes.

Early service records for ACA treated crossties were published but over time the practice of following up unfortunately has been lost. Table 2 below is a good example of the longevity of ACA Douglas fir ties which did not have the added benefits of the later improved formulation or the improved treating and analytical methods of today's ACZA ties. The ties were also treated at retentions that are below the current AWPA minimum retention for ACZA pressure-treated Douglas fir ties of 0.40 pcf. Current requirements are that the retention is determined by assay of the preservative components in the wood rather than the gauge readings of solution. Of the 180,000 ties inspected, it was reported that many were older ties and that some had decay prior to being treated, contributing to their premature failure.

Table 2

Service Record of ACA Treated Ties

Species	**Avg. Gauge Retn.**	**Quantity Location**	**Year of Inspection**	**Years in Service**	**Removed for Decay or insects**	**Removed for Other**	**% Removed Decay/insects**
WF & DF Exp. ties	N/A	297 Butte, Co, CA	1945	9	4	33	1.3
WF & DF	0.15	180,000 Butte, Co, CA	1945	Up to 9	2,000	4,000	1.1
WF	0.15	51 Butte Co., CA	1945	7	0	0	0
DF	0.30	50 Lewis Co., WA	1945	8	0	0	0
DF	0.30	45 Tacoma, WA	1945	8	0	0	0
Totals		180,443			2004	4033	1.1

STRENGTH

As shown in Table 3 below from the US Department of Agriculture Wood Handbook, Douglas fir ties have comparable strengths to hardwoods currently used to make crossties. With the exception of Gum and Douglas fir the other species listed are groupings of related tree types so the numbers are averaged to develop the value shown in the table.

Table 3

Comparative Strengths of Common Crosstie Species with Douglas fir

Species	Specific Gravity	Modulus of Rupture (MOR)	Modulus of Elasticity (MOE)	Crushing Strength	Compression Perpendicular to Grain
Red Oak (9)	.64	14,567	1.83	7117	825.7 (7)
White Oak (8)	.69	14,352	1.51	7237.5	786.7 (6)
Gum	.52	12,500	1.64	6320	760
Douglas-fir (Coastal)	.48	12,400	1.95	7230	710
SYP (4)	.55	14,175	1.88	7752.5	750 (3)

As part of the approval process of the AWPA, preservatives are tested to evaluate their effect on the strength properties of wood species. The data in Table 4 is the accumulation of data submitted in the approval process of ACA. The numbers recorded show that preservative treatment with ACZA has negligible effect on the strength properties of Douglas fir.

Table 4

Table Summary of Test Results for Untreated and Chemonite Treated Douglas fir

A. Untreated Specimens

Specimen Number	3A	4A	5A	6A	Average
Modulus of Rupture (lbs./sq.in.)	12,100	14,000	14,400	12,800	13,300
Moisture Content (%)	8.6	8.0	8.7	9.0	8.8
Rings per inch	14	18	15	19	17
Percentage Summerwood	20	20	20	20	20
Percentage Sapwood	0	0	0	0	

B. Chemonite Treated Wood

Specimen Number	3B	4B	5B	6B	Average
Modulus of Rupture (lbs./sq.in.)	14,400	14,600	13,700	11,800	13,600
Moisture Content (%)	10.0	10.1	11.2	12.3	11.0
Rings per inch	15	16	17	19	17
Percentage Summerwood	20	20	20	20	20
Percentage Sapwood	0	0	0	0	0

CORROSIVITY

Early in its inception it was discovered that galvanized hardware attached to freshly treated ACA wood was attacked by the ammonia. Allowing the materials to fully gas off and become dry-to-the touch prior to installation eliminated the problem. However, that was not always allowed to occur. To verify that corrosion was not an issue over time the hardware from 30 years old utility poles was removed and tested, all of the hardware exceeded the original design criteria. The addition of zinc was accepted as reducing the corrosion effect but to what extent had not been documented. In late 1987 and early 1988 ACA and ACZA were tested for corrosion in accordance with Mil-L-19140E. The results are included in Table 5 below showing the improvement in the change of the formulation. The results listed quantify the reduction in corrosion improvement of the change in formulation from ACA to ACZA.

Table 5*

Treatment	No	Initial Wt. gms.	Final Wt. After 60 days gms.	Wt. Loss gms.	% Wt. Loss
ACZA	1	16.121	16.088	0.033	0.205
ACZA	2	16.057	16.039	0.018	0.112
ACZA	3	16.154	16.148	0.006	0.037
ACZA	4	16.849	16.825	0.024	0.142
ACZA				**Average**	**0.124**
ACA	5	15.774	15.740	0.034	0.216
ACA	6	17.459	17.402	0.057	0.326
ACA	7	15.979	15.879	0.100	0.626
ACA	8	17.454	17.395	0.059	0.338
ACA				**Average**	**0.377**

*Freshly treated wood was conditioned for 10 days at 70ºF and 50% Relative Humidity prior to the test. SAE 1010 steel was hot-dipped galvanized. ACA and ACZA treated Douglas fir sapwood treated to 0.60 pounds per cubic foot was used. Exposure time of clamped specimens was 60 days at 120ºF and 90% Relative Humidity. Four assemblies of each treatment were tested.

CONDUCTIVITY

Conductivity is a concern in tie installations due to signal equipment used by railroads. It is also a concern for utilities that have linemen climbing utility poles while there are non-insulated energized conductors above them. Several types of tests have been conducted using actual poles, boards and even pellets of the dried preservative. In all tests ACZA treated wood products were found to be equivalent to untreated wood and research showed moisture content was the determining factor in conductivity not the preservative. A short line in Western Oregon, which has been using ACZA Douglas fir ties for nearly a year, has installed the ties in switch/signaling applications and found no conductivity issues. The railroad operates in a very moist environment west of the Cascade Mountains. Note the dampness on the tie in Figure 1.

Figure 1 signaling connection on ACZA Douglas fir tie

FASTENER HOLDING CHARACTERISTICS

Over the years numerous tests have been conducted to evaluate the fastener-holding capabilities of ACZA treated Douglas fir. In 1998 a study was conducted at Oregon State University comparing untreated Douglas fir to ACZA treated incised Douglas fir. The conclusions were “Incising markedly improved the quality of treatment of both AZCA and CCA, and ACZA treatment appears to significantly improve resistance to nail withdrawal.” Creosote treated Douglas fir ties were installed in the High Tonnage Loop of the Transportation

Technology Center's Facility for Accelerated Testing (FAST track). These ties installed in a six degree curve remained in service for more than 1,000 Million Gross Tons of freight traffic. Regaging was not necessary until approximately the 200 MGT mark for Douglas fir and other softwood ties installed with cut spikes. Douglas fir ties installed with elastic fasteners were considered part of the "best" performers relative to track gage strength and did not need regaging during the time of the test, indicating that fastener choice can have a marked effect on tie performance.

ACZA treatment of Douglas fir has shown increased fastener holding capabilities over Douglas fir that was untreated or even treatment with other preservatives. Testing was done at Oregon State University to determine the effects of incising and preservative treatment on fastener-holding capabilities. Tests were performed by driving nails directly into an incision (incised zone) or into the clear wood between incisions. Values in parentheses represent one standard deviation. Means in the same column that are followed by the same capital letter(s) do not differ significantly by Bonferroni's t-test ($\alpha=0.05$). The data below from the Oregon State in Table 6 shows the enhancement that ACZA provides over CCA treated Douglas fir or untreated Douglas fir. In regards to spike holding, none of the early ties installed indicated removal for spike issues.

Table 6

Preservative Treatment	Repetitions	Incision Depth (mm)	Nail Test Location	Mean Resistance to Nail Withdrawal (kg/cm)
ACZA	80	0	N/A	32.5 (7.0) A
ACZA	80	7	Incised zone	30.8 (8.2) AB
ACZA	80	7	Clear zone	30.5 (7.5) AB
ACZA	80	10	Incised zone	32.2 (8.0) A
ACZA	80	10	Clear zone	33.0 (7.2) A
CCA	80	0	N/A	28.5 (7.0) B
CCA	80	7	Incised zone	28.3 (6.6) BC
CCA	80	7	Clear zone	28.2 (6.5) BCD
CCA	80	10	Incised zone	27.6 (5.0) BCD
CCA	80	10	Clear zone	27.3 (6.0) BCD
None	80	0	N/A	24.5 (5.9) DE
None	80	7	Incised zone	24.8 (6.9) CDE
None	80	7	Clear zone	24.5 (6.2) DE
None	80	10	Incised zone	21.3 (4.9) E
None	80	10	Clear zone	21.2 (4.2) E

FIRE RESISTANCE

ACZA treated wood is more difficult to ignite than untreated wood and at a retention of 0.35 pcf showed a flame spread rating of 41.7 and smoke development of 115.8 which meets the requirements for a Class B/ fire retardant. Current AWPA minimum retention requirement is 0.40 pcf. for ACZA Douglas fir ties. At a retention of 1.86 pcf ACZA treated Douglas fir achieves a Class A/ 1 fire retardant rating with a flame spread of 24.8 and a smoke development of 78.2. Results of these tests are summarized in Table 7.

Table 7

Species	size	Solution Strength	Retention pcf	Flame Spread	Smoke Development
Doug fir	2x6	2.46%	0.35	41.7	115.8
Doug fir	2x6*	5.25%	0.95	40.0	80.0
Doug fir	2x6	6.96%	1.37	30.9	36.9
Doug fir	2x6	10.06%	1.86	24.8	78.2
Doug fir	2x6*	12.40%	3.20	25.0	20.0

*Samples were run by U.S. Testing labs, and by Underwriters Laboratories

USE AND HANDLING

ACZA wood can be stored, handled and worked like untreated wood. As with any wood, wear gloves to avoid splinters, wear eye protection and a dust mask when sawing, drilling and sanding. Wash hands before eating or smoking. Minimize any cutting to obtain the maximum benefit of the treatment by not exposing untreated wood to decay hazards. If you do cut ACZA treated wood, however, the exposed areas can be protected by applying copper naphthenate solution or other solution containing at least 1% copper—available over-the-counter at most home centers. Use a generous amount to completely cover any untreated areas of your project exposed by cutting or drilling.

DISPOSAL

Dispose of cut ends in a proper landfill. Treated wood should not be burned in open fires or in stoves, fireplaces or residential boilers. Treated wood from commercial or industrial use may be burned only in commercial or industrial incinerators or boilers in accordance with state and federal regulations.

ENVIRONMENTAL IMPACT

Chemonite crossties share the many environmental attributes of wood itself – most notably: renewable resource, low-energy production, and carbon sequestration. The preservative process adds to these benefits by extending service life, thereby reducing demands on forests and transportation of replacement material. Furthermore, ACZA bonds chemically to wood cells as insoluble precipitates, becoming very leach-resistant. The wood surface is non-oily and clean-to-the-touch, even in high temperatures or salt water, making ACZA crossties are a good choice in sensitive environments as in Figure 2.

Figure 2 ACZA Douglas fir ties on a bridge trestle over a stream

SPECIFYING

Grade

Douglas fir is currently an allowable species in both RTA and AREMA specifications.

Tie stock is graded under W.C.L.B. grading rules for crossties as either “SELECT”, “NO,1” or “NO.2”. Additional requirements are listed in RTA or AREMA chapter 30, and as specified by the purchaser.

Treatment

ACZA Preservative-treated crossties are listed under the American Wood Protection Association Standard U1, Commodity Specification C; Use Category UC4A at 0.40 pcf. AWPA standards are recognized by AREMA.

Conclusion

Wood crossties have shown their value in their 100 plus years of use. As uncertainties cause railroads to look at alternative materials to Creosote-treated hardwoods another preservative treated wood might be the answer. ACZA Douglas fir ties have the history and benefits to merit consideration.

AZCA has protected wood for over 70 years from wood destroying organisms, as well as being leach-resistant, offering fire retardancy, and improving the fastener-holding capabilities of Douglas fir. Douglas fir as a wood species has a long history of use as an industrial timber product from utility poles, to piling to construction timbers to ties. Together they offer another option for railroads to consider in their crosstie mixture of products approved for use.

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Tables and Figures

Figure 1 Carey N., “Photo of ACZA Douglas fir installation with signal switch” 2010

Figure 2 Smith D., “Photo of ACZA Douglas fir Tie installation over stream –due to sensitive environment concerns” 2010