1989

ACA and CCA Preservative Treatment and Redrying Effects on Bending Properties of Douglas-Fir[1]

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This report evaluates the effects of two waterborne preservative treatments, ammoniacal copper arsenate and chromated copper arsenate, and subsequent redrying at temperatures of $\leq$ 170°F (77°C) on the bending properties of small, clear specimens of Douglas-fir. In addition, we studied the possibility of a differential effect on bending strength resulting from differences in initial treatability of specimens.

At redrying temperatures of up to 170°F, ammonical copper arsenate had no significant negative effect on bending properties at three levels of retention (0.34, 0.41, and 2.29 pcf (5.4, 6.6, and 36.6 kg/m³)). Conversely, for material treated with chromated copper arsenate at 0.6 pcf (9.6 kg/m³) and redried at 170°F, mean modulus of elasticity, modulus of rupture, and moment ——— carrying capacity were significantly reduced. Initial treatability of specimens did not influence the effect of treatment on bending properties.

Keywords: Bending properties, engineering properties, ACA, CCA, treatments, preservatives, kiln-drying, redrying, Douglas-fir.

INTRODUCTION

In the United States, chromated copper arsenate (CCA) is the most popular waterborne preservative treatment. This preservative is often used to treat southern, red, and ponderosa pines and western hemlock, but it does a poor job of penetrating difficult-to-treat (refractory) species. Thus, ammoniacal copper arsenate (ACA) and its closely related counterpart, ammoniacal copper zinc arsenate (ACZA), have become the preferred treatments for many refractory species. Accordingly, ammoniacal preservative treatments represent the second most widely used waterborne preservative system in North America. In the western United States and Canada, ammoniacal treatments have long been successfully used to treat Douglas-fir, hemlock, and the eastern spruces. In many refractory species where adequate penetration is a primary concern, ACA is the preferred treatment.

Two reasons exist for the increased penetration of ACA treatments. First, ammonia is a natural swelling agent for wood. Swelling enhances preservative penetration, especially in refractory species. Second, American Wood-Preservers' Association (AWPA) standards allow ACA to be used at temperatures of $\leq 150°F$ (66°C) during the treating process, which further improves the activity of the ammonia. In addition, ACA is alkaline and CCA is acidic. Thus, the chemical mechanisms by which the two chemicals affect wood strength are different. The CCA undergoes hydrolytic reduction upon contact with a wood substrate; ACA undergoes precipitation and insolubilization upon evaporation of the ammonia. Except for adding copper and arsenic, ACA treatment appears to be rather inert with wood, whereas CCA treatment significantly alters both the carbohydrate and the phenolic components of the wood.

Although the mechanisms of chemical fixation and/or precipitation are different for ACA and CCA, no modifications for ACA and CCA treatment effects are currently required in "normal" (10-year load

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duration) or long-term allowable design stresses (NFPA 1986) for lumber. However, the National Design Specification (NFPA 1986) recommends that the modification factor (increase) for impact loading not be applied to material treated with waterborne preservatives at the high retentions required for marine applications.

The effects of waterborne preservative treatments on bending properties of wood have recently been reviewed; these treatments generally reduce bending strength approximately 5 to 10 percent depending upon the chemical, retention, and redrying method and temperature employed (Winandy 1987). Although some studies have shown ACA is less deleterious towards bending strength than CCA (Bendtsen et al. 1983), other studies have shown little difference between the two treatments in their effect on strength (Eaton et al. 1978; Resch and Parker 1982). However, the effect of redrying on the bending properties of pine treated with waterborne preservative can be considerable, especially at temperatures $\geq 180°F$ (82°C) (Barnes and Mitchell 1984; Winandy et al. 1985). Thus, for treated Douglas-fir, the impact of the temperature sustained during redrying after treatment becomes especially important because untreated Douglas-fir appears to be more sensitive to thermal degrade than Southern Pine (Gerhards 1979; Kozlik 1967,1968,1976,1982). Because no data exist on the influence of redrying temperature on treated Douglas-fir, it has been presumed that ACA-treated Douglas-fir is reduced in strength to approximately the same degree as CCA-treated Southern Pine. The purpose of our study was to determine at what temperatures ACA-treated and CCA-treated Douglas-fir may be redried without excessive thermal degrade.

Objective

The objective of our study was to evaluate the effects of ACA preservative treatment at different levels of retention in combination with different redrying temperatures on the bending properties of small, clear specimens of Douglas-fir. A retention of 0.6 pcf (9.6 kg / m³) CCA was included for comparative purposes. Treatments with water and a mixture of water and ammonia were also included to identify the difference between chemical treatment effects and treatment effects. Finally, because the effect of treatment might be a function of chemical penetrability, two treatability classes or levels of penetrability were studied. This information will be useful to treaters who need to know if the value of their treated product is being needlessly reduced by excessive redrying temperatures.

Design

The experiment was an incomplete factorial with an independent control. The factors were chemical retention, redrying temperature, and treatability (Table 1).

Small, clear bending specimens of Douglas-fir were pressure treated with water (water-treated control), ammonia and water, CCA at 0.6 pcf (9.6 kg/ m³), or one of three levels of ACA (target retentions: 0.4, 0.6, and 2.5 pcf) (6.4, 9.6, and 40.0 kg / m³). The molar concentration of ammonia was chosen to be identical to the 0.4 pcf ACA treatment. A separate untreated control was also included (Table 1).

After treatment, the specimens were dried at one of three temperature levels: 80°F (27°C), 140°F (60°C), and 170°F (77°C).

METHODS

Green Douglas-fir (coastal) 2- by 4-in. (51- by 102-mm) material, 16 ft (4.9 m) long, was obtained from western Oregon and shipped to the Forest Products Laboratory (FPL) in Madison, WI. This material was ungraded and mostly clear (no defects). At FPL, it was cut into 8 ft (2.4 m) lengths, stickered, and air dried (under cover) to approximately 10 percent moisture content (MC). The wood was 100 percent heartwood with 3 to 12 growth rings per inch.

The specimens used in the experiment were chosen on the basis of treatability. To ascertain treatability, short samples, about 12 in. (305 mm) long, were cut from each 8-ft 2 by 4, coded for identification, and treated with ACA to 0.4 pcf. After treatment, each 12-in. sample was split open on a bandsaw at a 0.4 in. (10.2 mm) depth from the surface of the wide face. The treatability of each 12-in. piece was then evaluated based on a visual assessment of chemical penetration on the sawn face of the larger piece at a 0.4 in. depth from the surface. Specimens were sorted into four treatability classes: Class A, > 75 percent of the 4- by 12-in. cross section penetrated at the 0.4 in. depth; Class B, 51 to 75 percent penetrated; Class C, 26 to 50 percent penetrated; and Class D, ≤ 25 percent penetrated. Only 2 by 4 material from the two highest classes (Classes A and B) was selected for further consideration.

The selected 2 by 4's were scribed to determine slope of grain; those with grain straighter than 1 in 12 were then sawn into small, clear specimens (¾ by ¾ by 16 in.) (19 by 19 by 406 mm) such that the annual rings were parallel to one face when viewed on a cross section. After planing to a ⁵/₈-in. (16-mm)-square cross section, the sticks were crosscut into 10 in. (254 mm) lengths, eliminating all defects (such as knots and deviated grain) in the process. The ⁵/₈-in.-

Table 1.-- Incomplete factorial design.

Treatment	Target Retention (pcf)	Treatability class[a]	Number of specimens at various posttreatment drying temperatures			
			(None)	80°F	140°F	170°F
ACA	2.5	A	--	12	12	12
		B	--	30	30	30
	0.6	A	--	12	12	12
		B	--	30	30	30
	0.4	A	--	12	12	12
		B	--	30	30	30
CCA	0.6	A	--	12	12	12
		B	--	30	30	30
Water	0	A	--	12	12	12
		B	--	30	30	30
Water and ammonia[b]	0	B	--	30	--	--
Control	--	A	12	--	--	--
	--	B	30	--	--	--

[a] Only material shown to accept treatment at a level of penetration of >75 percent (Class A) and 51 to 75 percent (Class B) were selected.

[b] Only Class B specimens were assigned to this treatment group because of an insufficient number of Class A specimens.

square specimen size was selected to minimize the impact of preservative treatment gradients in a refractory species like Douglas-fir. Specimens containing <4 or > 10 annual rings per inch were discarded. Specimens were limited from 4 to 10 rings per inch to further reduce variability in preservative treatment and bending properties.

A total of 702 small, clear specimens were assigned to 17 groups (Table 1) in such a manner as to randomly distribute the specimens from any one 2 by 4 in as many groups as possible.

Treatment

Specimens were treated at FPL. The composition (by weight) of ACA and CCA was as follows:

Preserv-ative	Composition(percent)		
	Copper (CuO)	Arsenic (AS$_2$O$_5$)	Chromium (CrO$_3$)
ACA	49.8	50.2	—
CCA	18.5	34.0	47.5

Each specimen was weighed and measured (three dimensions) before treatment. Specimens were treated by full-cell process as outlined in AWPA Standard C2-86 (1986). For each treatment, an initial vacuum of 27 inHg (91.2 kPa) for 30 min was followed by a pressure of 75 psi (517.1 kPa) for 2 hr; a final vacuum was not employed. These treating parameters were chosen to minimize wood cell collapse in the small Douglas-fir specimens. A treating temperature of 135°F (57°C) was used for ACA treat-

ments were performed at room temperature. The treating solution concentrations at each treatment level were based upon the average water absorption of the water-treated control specimens.

All specimens were weighed to the nearest 0.01 g before and immediately after treatment. The ACA or CCA retentions for the individual specimens were calculated based on weight gain. The specimens were kept in sealed polyethylene bags for 5 to 8 days to retard drying and enhance fixation and precipitation reactions before redrying.

Redrying

In kiln drying after treatment (KDAT), we used a technique intended to simulate in $5/_8$-in.-square specimens the conditions to which nominal 2-in. (51-mm) dimension lumber is exposed during redrying. The simulation technique has been described by Boone et al. (1985). Our method differed only in specimen size and KDAT temperature. To adapt the simulated drying procedures to our study, it was necessary to determine (a) the time required for treated 2-in. Douglas-fir lumber to dry to an average MC of 15 percent (19 percent maximum) at each scheduled kiln temperature (140°F or 170°F), and (b) the time required for treated $5/_8$-in.-square specimens to dry to 20 to 25 percent MC at the same two temperatures.

To achieve drying time (a), 2 by 4 Douglas-fir lumber was treated with ACA using a full-cell process to retentions of 0.4 or 2.5 pcf and kiln dried at 140°F or 170°F (60°C or 77°C). At 140°F (dry-bulb temperature), the wet-bulb temperature was 110°F; at 170°F (dry-bulb temperature), the wet-bulb temperature was 140°F. Drying times at each desired temperature were determined by monitoring the MC of sample boards. A similar process was then used to determine drying time (b), the time required to dry treated small, clear specimens at 0.4 and 2.5 pcf retentions to an average MC of 20 to 25 percent. The specimens for this second process were randomly drawn from remaining samples of the initial specimen pool. The drying time for the 0.6 pcf retention level was determined by linear interpolation between the drying times for the 0.4 and 2.5 pcf retention levels.

In our simulation technique, specimens designated for kiln drying were exposed to dry-bulb kiln temperatures of either 140°F or 170°F for the same time required to dry the 2 by 4 lumber; wet-bulb temperatures at 140°F and 170°F were 110°F and 140°F, respectively. First, the specimens were stickered and dried to 20 to 25 percent MC in the kiln for drying time (b). The specimens were then sealed in autoclave bags to retard further drying and maintained at the designated kiln temperature for drying time (a). After drying, the specimens were removed from the bags and weighed. In each case, the simulated drying technique successfully retarded further drying in the individual specimens to only 2 to 5 percent, resulting in a final MC of 16 to 22 percent. The specimens were then allowed to equilibrate under 12 percent equilibrium moisture content (EMC) condition of 74°F (23°C) and 65 percent relative humidity(RH).

Specimens designated for drying at 80°F were first dried after treatment at 80°F and 90 percent RH for 2 weeks and then allowed to equilibrate at 74°F and 65 percent RH.

Testing

The specimens were tested in bending over an 8.75-in. (222-mm) span using center-point loading. Rate of loading was 0.5 in. (12.7 mm) of load-head travel per minute, imposing failure in from 30 to 70 sec. Modulus of elasticity (MOE), modulus of rupture (MOR), and work to maximum load (WML) were calculated from loads and deflections digitally measured during testing and from specimen dimensions recorded immediately prior to test. In addition, because preservative treatments usually induce some amount of bulking, the moment-carrying capacity (RZ) of the entire beam, which is independent of cross-sectional dimensions, was calculated from the maximum load. After testing, all specimens were ovendried to determine MC and specific gravity at time of test.

Analysis

This experiment was an incomplete factorial. Initially, an analysis of covariance seemed appropriate; traditional covariates include MC and specific gravity. However, this method of analysis was really inappropriate because both MC and specific gravity were affected by the ACA and CCA treatments. Instead, because the bending properties were highly correlated, a multivariate analysis of variance (MANOVA) was used to determine if these properties were consistently affected by the different treatments and drying schedules and to test for interactions between the factors. Where significant effects (a ≤ 0.05) were found using MANOVA, univariate analyses of variance (ANOVA) were performed to determine which bending properties were affected. When a statistically significant difference existed in ANOVA, Tukey's test was used to compare mean property values.

Tukey's test is a method of multiple comparison for factorial data. Although similar in nature to the more well-known Duncan test of means, Tukey's test minimizes Type I error. In other words, it is less likely to indicate that a statistically significant difference exists where it does not in fact exist.

RESULTS AND DISCUSSION

We initially thought that treatability might influence the effects of treatment on properties. However, for each treatmentdrying combination, no significant ($a \leq 0.05$) difference was found between the mean properties of the two treatability classes (Classes A and B). Thus, data from the two classes were combined for each treatment-drying combination.

The trends exhibited by the mean property values show the interactive nature of the factors on each property (Figs. 1–4). The ANOVA suggested that
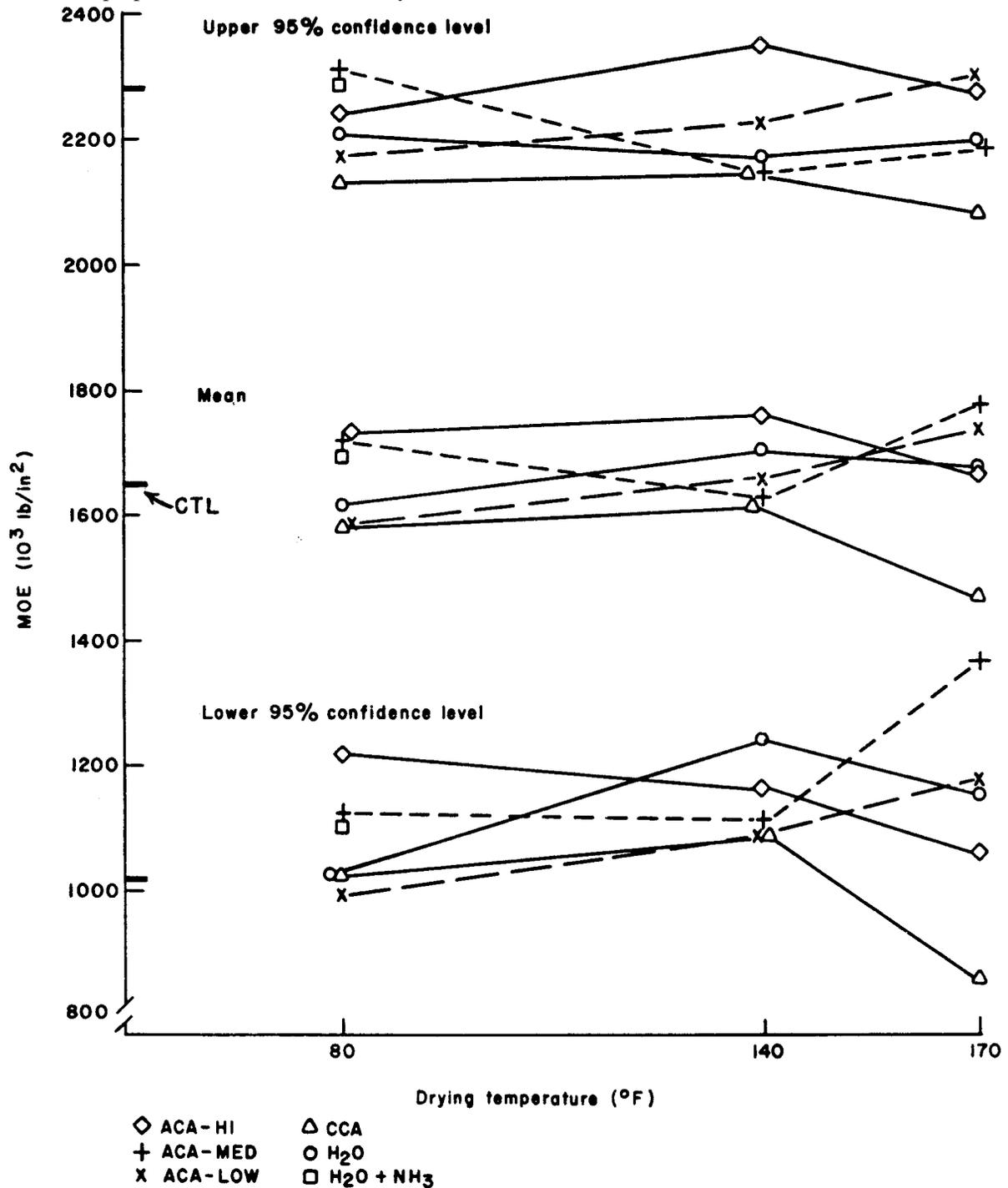

Figure 1. Mean modulus of elasticity (MOE) and upper and lower 95 percent confidence limits of various treatment-redrying temperature combinations. Individual treatments are slightly offset at each redrying temperature to enhance visual separation. ACA-HI, 2.5 pcf; ACA-MED, 0.6 pcf; ACA-LOW, 0.4 pcf; CCA, 0.6 pcf. CTL indicates control. (ML88 5663)
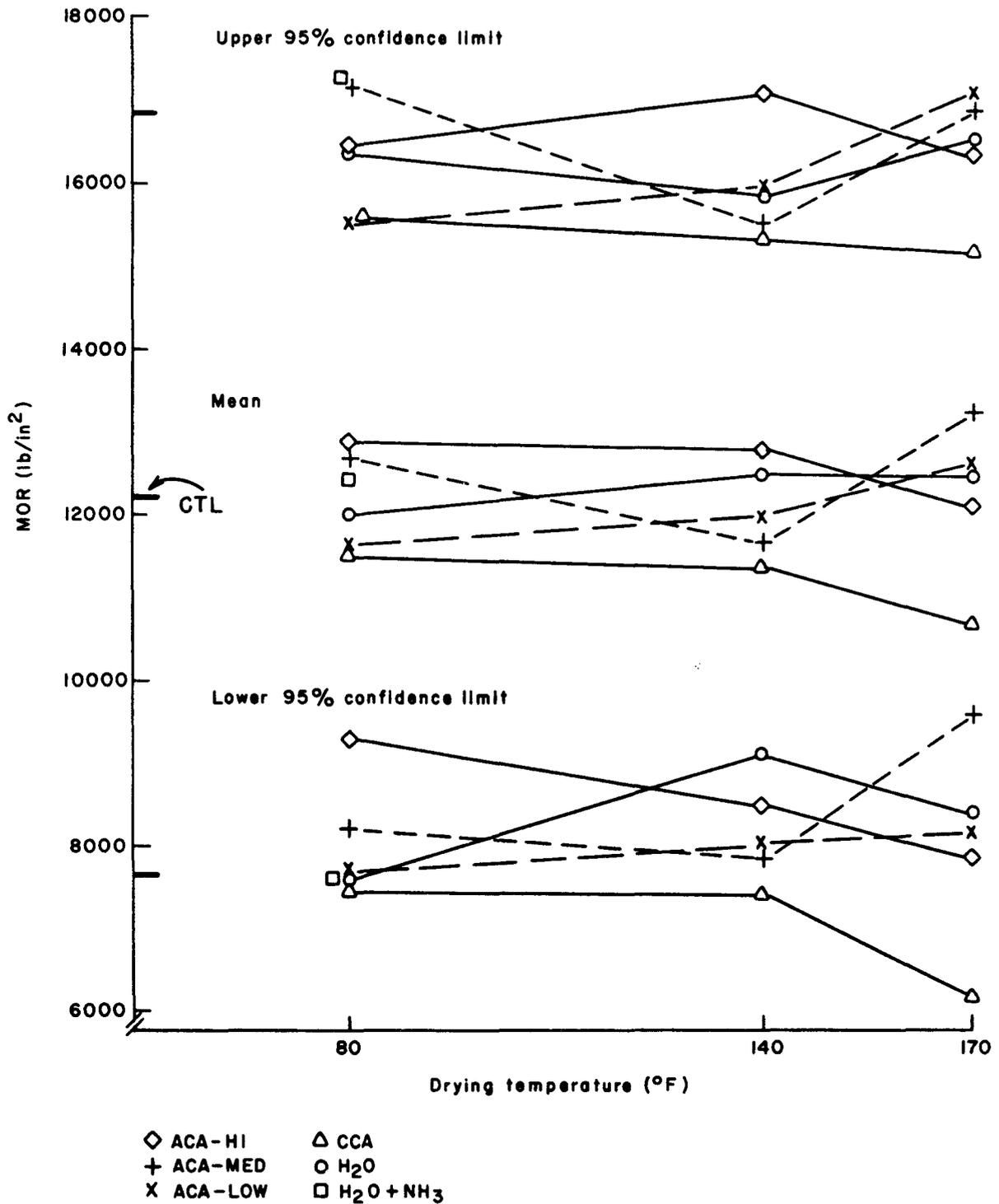
Figure 2. Mean modulus of rupture (MOR) and upper and lower 95 percent confidence limits of various treatment-redrying temperature combinations. Individual treatments are slightly offset at each drying temperature to enhance visual separation. ACA-HI, 2.5 pcf; ACA-MED, 0.6 pcf; ACA-LOW, 0.4 pcf; CCA, 0.6 pcf. CTL indicates control. (ML88 5664)
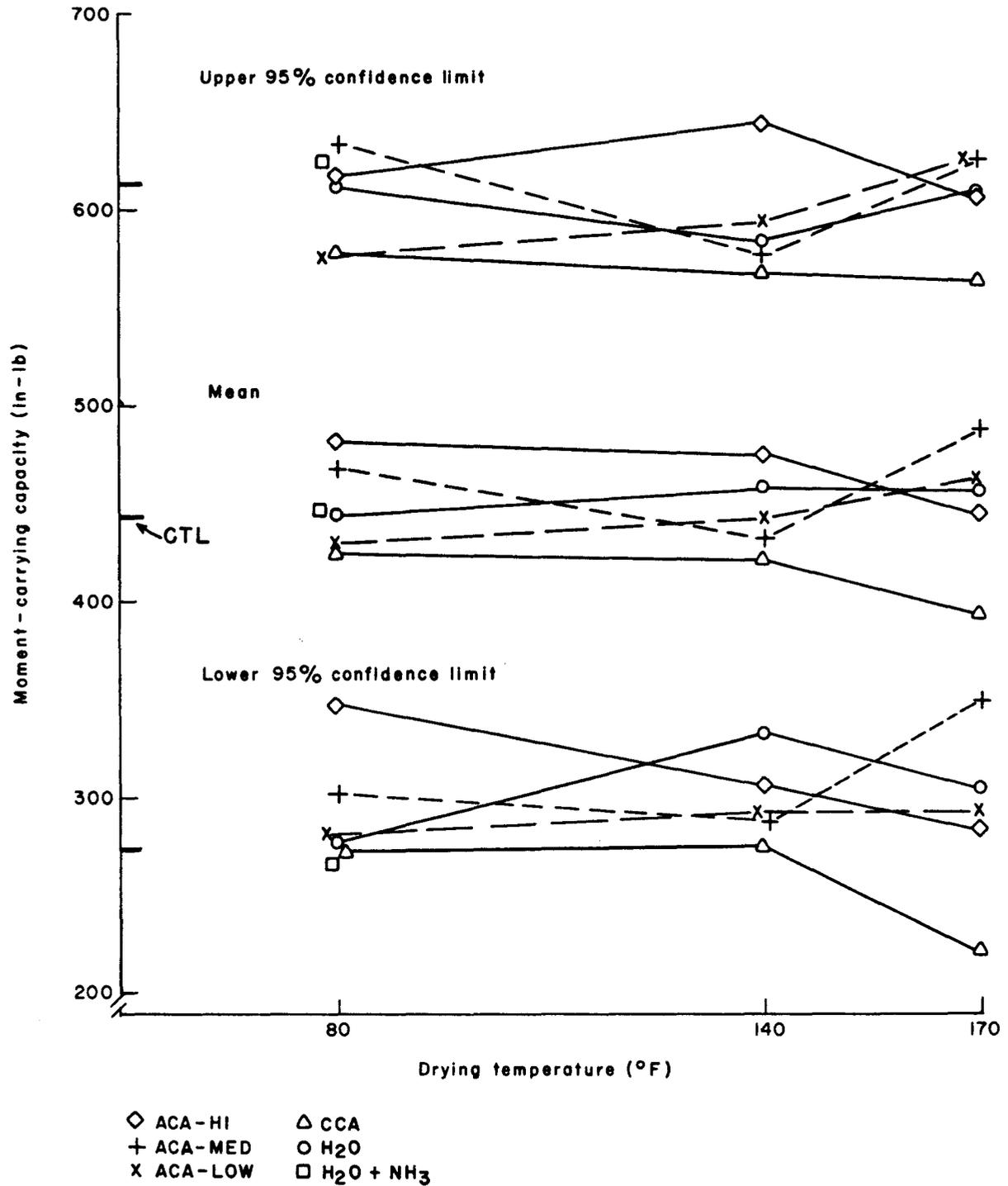
Figure 3. Mean moment-carrying capacity (RZ) and upper and lower 95 percent confidence limits of various treatment-redrying temperature combinations. Individual treatments are slightly offset at each redrying temperature to enhance visual separation. ACA-HI, 2.5 pcf; ACA-MED, 0.6 pcf; ACA-LOW, 0.4 pcf; CCA, 0.6 pcf. CTL indicates control. (ML88 5665)
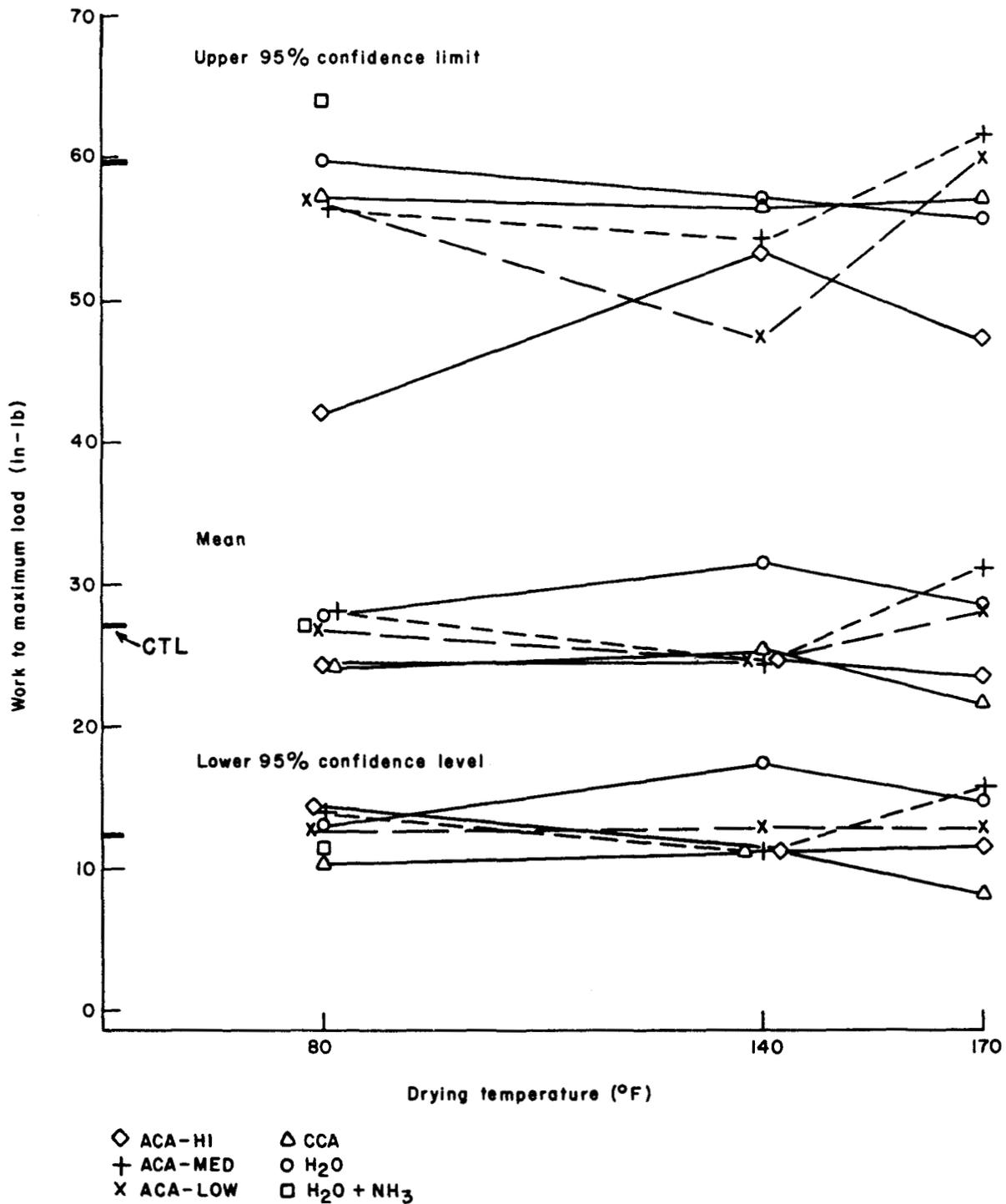
Figure 4. Mean work to maximum load (WML) and upper and lower 95 percent confidence limits of various treatment-redrying temperature combinations. Individual treatments are slightly offset at each redrying temperature to enhance visual separation. ACA-HI, 2.5 pcf; ACA-MED, 0.6 pcf; ACA-LOW, 0.4 pcf; CCA, 0.6 pcf. CTL indicates control (ML88 5666)

these interactions were statistically significant. Thus, the analysis was broken down by treatment and then drying schedule for each bending property. These ANOVA indicated that significant differences sometimes existed between the various treatment, retention level, and drying schedule combinations.

Chemical Retention Effect

The targeted retentions for ACA were not attained (Table 2). To avoid confusion between actual and targeted retentions, the three targeted ACA retention levels of 2.5, 0.6, and 0.4 pcf will from now on be referred to as ACA-HI, ACA-MED, and ACA-LOW (actual mean retentions 2.29, 0.41, and 0.34 pcf, respectively). Because the actual ACA retentions were lower than the target levels, it could be misleading to compare CCA and ACA only at the target level of 0.6 pcf. The comparison of these treatments is also limited by the interaction of treatment type, retention level, and redrying temperature (Figs. 1–4). Thus, the data were analyzed by redrying temperature, with each treatment-retention combination considered a distinct treatment. The means and results of Tukey's multiple comparison test at each redrying temperature are shown in Tables 3 to 6

Table 2.--<u>Chemical retention based on specimen weight gain.</u>

Chemical and target retention (pcf)	Actual retention (pcf)		
	Mean	Minimum	Maximum
ACA-0.4	0.338	0.174	0.449
ACA-0.6	0.414	0.230	0.581
ACA-2.5	2.291	1.180	3.568
CCA-0.6	0.598	0.340	0.929

(note that the ammonia (NH_3) treatment was included only at 80°F).

Retention of ACA did not have a consistent effect on bending properties as it increased, and at each redrying level the mean property values of ACA-treated specimens were generally comparable to each other (Figs. 1–4). Within the redrying limits of this study, there was no significant difference between the ACA-treated specimens and the water-treated or untreated controls (Tables 3 to 6). Also

Table 3.--<u>Effect of various treatments and redrying temperatures on modulus of elasticity.</u> [a,b]

Temperature (°F)	Ranked MOE values (10^6 lb/in^2) for various treatments						
80	ACA-HI	ACA-MED	NH$_3$	CTL	H$_2$O	CCA	ACA-LOW
	1.726	1.714	1.691	1.647	1.610	1.580	1.579
140	ACA-HI	H$_2$O	ACA-LOW	CTL	ACA-MED	CCA	
	1.749	1.699	1.652	1.647	1.625	1.616	
170	ACA-MED	ACA-LOW	H$_2$O	ACA-HI	CTL	CCA	
	1.771	1.727	1.670	1.658	1.647	1.468	

[a] Each bar represents mean values equivalent at a 95 percent level of significance.

[b] ACA, ammoniacal copper arsenate; ACA-HI, 2.5 pcf; ACA-MED, 0.6 pcf; ACA-LOW, 0.4 pcf: CCA, chromated copper arsenate; CTL, untreated control; H$_2$O, water-treated control; NH$_3$, ammonia and water.

Table 4. - –Effect of various treatments and redrying temperatures on modulus of rupture. [a,b]

Temperature ($^{\circ}$F)	Ranked MOR values (10^4 lb/in^2) for various treatments						
80	ACA-HI	ACA-MED	NH$_3$	CTL	H$_2$O	ACA-LOW	CCA
	1.287	1.268	1.244	1.221	1.198	1.161	1.154
140	ACA-HI	H$_2$O	CTL	ACA-LOW	ACA-MED	CCA	
	1.277	1.248	1.221	1.199	1.168	1.139	
170	ACA-MED	ACA-LOW	H$_2$O	CTL	ACA-HI	CCA	
	1.325	1.259	1.247	1.221	1.208	1.068	

[a]Each bar represents mean values equivalent at a 95 percent level of significance.

[b]ACA, ammoniacal copper arsenate; ACA-HI, 2.5 pcf; ACA-MED, 0.6 pcf; ACA-LOW, 0.4 pcf; CCA, chromated copper arsenate; CTL, untreated control; H$_2$O, water-treated control: NH$_3$, ammonia and water.

Table 5.--Effect of various treatments and redrying temperatures on moment-carrying capacity (RZ) [a,b]

Temperature ($^{\circ}$F)	Ranked RZ values (in-lb) for various treatments						
80	ACA-HI	ACA-MED	NH$_3$	H$_2$O	CTL	ACA-LOW	CCA
	482	468	445	444	443	428	427
140	ACA-HI	H$_2$O	CTL	ACA-LOW	ACA-MED	CCA	
	474	458	443	441	432	422	
170	ACA-MED	ACA-LOW	H$_2$O	ACA-HI	CTL	CCA	
	488	459	456	444	443	393	

[a]Each bar represents mean values equivalent at a 95 percent level of significance.

[b]ACA, ammoniacal copper arsenate: ACA-HI, 2.5 pcf; ACA-MED, 0.6 pcf: ACA-LOW, 0.4 pcf; CCA, chromated copper arsenate; CTL, untreated control; H$_2$O, water-treated control: NH$_3$, ammonia and water.

Table 6.--Effect of various treatments and redrying temperatures on work to maximum load. [a,b]

Temperature (°F)	Ranked WML values (in-lb) for various treatments						
80	ACA-MED	H_2O	NH_3	CTL	ACA-LOW	CCA	ACA-HI
	29.8	29.5	29.5	29.1	28.8	26.5	25.3
140	H_2O	CTL	CCA	ACA-HI	ACA-MED	ACA-LOW	
	32.9	29.1	27.6	26.5	26.5	26.2	
170	ACA-MED	H_2O	ACA-LOW	CTL	ACA-HI	CCA	
	33.1	30.3	29.8	29.1	24.8	24.2	

[a]Each bar represents mean values equivalent at a 95 percent level of significance.

[b]ACA, ammoniacal copper arsenate; ACA-HI, 2.5 pcf; ACA-MED. 0.6 pcf; ACA-LOW, 0.4 pcf; CCA , chromated copper arsenate; CTL , untreated control; H_2O, water-treated control; NH_3 , ammonia and water.

note that the NH_3 and water treatment, which was chosen to have the same molar concentration of ammonia as the ACA-LOW treatment, had no different effect than the ACA treatments or controls.

The CCA treatment reduced mechanical properties. When redried at a temperature of 170°F, the difference between CCA-treated specimens and untreated controls (CTL) was quite pronounced (– 11 percent MOE, –13 percent MOR, – 11 percent RZ, –17 percent WML), and the mean values of the CCA-treated specimens were significantly lower than the mean values of the other specimens for three of four properties (Tables 3 to 6). In no other cases were the mean values significantly different than CTL values. Overall, the negative effect of the 0.6 pcf CCA retention on MOE, MOR, and RZ was consistently greater than the effect of any ACA retention, particularly when specimens were redried at 170°F. These results agree with the results of two earlier studies. Bendtsen et al. (1983) found that ACA did not degrade strength as much as CCA, and Winandy et al. (1985) found that the weakening effect of CCA on Southern Pine became significant as redrying temperatures increased, especially when they exceeded 180°F.

Temperature   Effect

The effect of drying temperature can be examined for specimens treated with ACA, CCA, and water since we varied the redrying temperature for specimens in these groups. Because of the interaction of drying temperature with treatment, the effect of drying temperature was examined separately for each treatment. Mean property values and the results of Tukey's multiple comparison test are found in Table 7.

For the ACA- and water-treated specimens, MOE, MOR, RZ, and WML did not consistently increase or decrease with increasing temperatures (Figs. 1– 4) and were generally not significantly different from each other (Table 7). On the other hand, the bending properties of CCA-treated material were always lowest at 170°F (Table 7). To a lesser degree, specimens treated at the ACA-HI retention exhibited a downward trend in mechanical properties as redrying temperature rose from 140°F to 170°F (Figs. 1–4). Although this trend was not statistically significant (Table 7), it may indicate that ACA-HI could be approaching its redrying temperature limit at around 170°F. The remaining treatment-retention-property

Table 7.--Effect of three redrying temperatures on bending properties for various treatments and retention levels.[a]

Treatment (Temperature[b])	MOR (10^4 lb/in^2)			MOE (10^6 lb/in^2)			RZ (in-lb)			WML (in-lb)		
H$_2$O (Temp.)	(140) 1.248	(170) 1.247	(80) 1.198	(140) 1.699	(170) 1.670	(80) 1.610	(140) 458	(170) 456	(80) 444	(140) 32.9	(170) 30.3	(80) 29.5
ACA-LOW (Temp.)	(170) 1.259	(140) 1.199	(80) 1.161	(170) 1.727	(140) 1.652	(80) 1.579	(170) 459	(140) 441	(80) 428	(170) 29.8	(80) 28.8	(140) 26.2
ACA-MED (Temp.)	(170) 1.325	(80) 1.268	(140) 1.168	(170) 1.771	(80) 1.714	(140) 1.625	(170) 488	(80) 468	(140) 432	(170) 33.1	(80) 29.8	(140) 26.5
ACA-HI (Temp.)	(80) 1.287	(140) 1.277	(170) 1.208	(140) 1.749	(80) 1.726	(170) 1.658	(80) 482	(140) 474	(170) 444	(140) 26.5	(80) 25.3	(170) 24.8
CCA-0.6 (Temp.)	(80) 1.154	(140) 1.139	(170) 1.068	(140) 1.616	(80) 1.580	(170) 1.468	(80) 427	(140) 422	(170) 393	(140) 27.6	(80) 26.5	(170) 24.2

[a]Each bar represents mean values equivalent at a 95 percent level of significance.
[b]Redrying temperature (°F) given in parentheses.

combinations (H$_2$O, ACA-LOW, ACA-MED) tended to increase or show little change at higher temperatures (Figs. 1–4).

At redrying temperatures of up to 170°F, ACA-treated specimens at retentions 0.41 pcf were apparently not reduced in strength. At 170°F, the effect of ACA treatment at the retention of 2.29 pcf is debatable. For CCA-treated specimens, the redrying temperature limit appears to fall somewhere between 140°F to 170°F.

CONCLUSIONS

Three ACA-retention levels and one CCA-retention level were studied at three redrying temperatures and two treatability levels. The bending properties of small, clear Douglas-fir specimens were not significantly reduced by ACA treatments at redrying temperatures of up to 170°F. Conversely, as CCA-treated Douglas-fir specimens were exposed to increasingly higher redrying temperatures, significant strength reductions were found. A retention of 0.6 pcf CCA tended to reduce strength only slightly when specimens were redried at 80°F and 140°F, but it reduced strength significantly when the redrying temperature was 170°F. The effects of treatment and redrying on bending properties were equivalent for the two treatability levels studied.

In general, ACA apparently has no effect on the bending strength of treated Douglas-fir because it precipitates upon evaporation of the ammonia co-solvent. On the other hand, CCA reduced the strength of Douglas-fir to an extent comparable to that reported previously for Southern Pine (Winandy et al. 1985). Therefore, CCA reduces the strength of wood when dried at higher temperatures apparently because it undergoes hydrolytic fixation with the wood cell wall.

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Discussion

S. W. CONKLIN: Would you expect any effect on the results for ACA due to the reformation of ACA to ACZA?

MR. WINANDY: If you want me to answer that question on purely a scientific basis, I don't know. What little insight the chemical effect in general and a lot of other researchers concur with me on that, and all of our data does seem to jive, that the reason for the lack of an effect with ACZA is the fact that you don't really have fixation with ACA. You have just basically the evaporation of ammonia and precipitation of the metals so you don't have that reaction with the wood material you have when you have chromium, and that is why there is a direct relation to chromium. I would tend to think that ACZA would react much more like ACA and CCA.

JOE MORGAN: I would like to thank the authors for researching the effects of treatment and redrying of waterborne preservative treatments on Douglas-fir. This is of great interest to treaters on the West Coast.

This paper and the results will undoubtedly be very helpful to design professionals anticipating using waterborne Douglas-fir. I would like to see future work done on ACZA rather than ACA.

Also you can treat Douglas-fir heartwood without incising with chemenite if you are very patient. I am not surprised to see you are experiencing some collapse at 150 psi. We normally use 125 in our process and about 130 F.

SESSION CHAIRMAN GJOVIK: Thank you, Jerry, well done. The next item for this Session is the Preservative Committee Reports. Bill McNamara is General Chairman.

W. S. MCNAMARA: Thank you, Lee. Will members of the Preservative Committees, especially Committee Chairman please come to the front of the room?