DRYING WESTERN JUNIPER
Winema National Forest / Oregon State University
Larry Swan / Mike Milota
Completed - July, 1995

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INTRODUCTION

Approximately four million acres of western juniper (*Juniperus occidentalis*) exist in Central and Eastern Oregon and California. Some of this is used for fence posts, fire wood, and other small items. The potential exists for some increase in its use. This study was undertaken to evaluate the drying characteristics of the species and determine the effect drying on panel production.

The work done in this study included

kiln dry two 1MBF charges of 4/4 juniper from green and give a written report of the defects (40-04U3-4-0472, item 01)

kiln dry one 2 MBF charge of 7/4 juniper from green and give a written report of the defects and potential causes (40-04U3-4-0472, item 02)

air dry and kiln dry one 1MBF charge of 4/4 juniper and give a written report of the defects (40-04U3-4-0472, item 03)

transport the wood to and from Rainier Wood Products in Sweethome where 3' by 8' panels were produced (40-04U3-4-0472, item 04)

mask half and spray 3' by 8' panels, cycle their moisture content (MC) and evaluate defects (40-04U3-4-0481)

determine moisture meter correction factors for capacitance- and resistance-type hand-held moisture meters (40-04U3-4-0554)

MATERIALS AND METHODS

Delivery

The Western Juniper (*Juniperus occidentalis*) was delivered to the Oregon State University Forest Research Laboratory on Sunday, September 25, 1994, by Mike Kilpatrick. The wood came from the John Day area. The five bundles of 4/4 and three bundles of 7/4 lumber were transported tarped on a flat bed trailer.

At the time of delivery we were informed that the lumber was cut from logs harvested during the previous fall, spring, and recently. The lumber had been sawed one month earlier and stored in a shed, solid piled.

Sorting

On September 26, 1994, the five 4/4 bundles were mixed and stacked into three piles. Every third board from each bundle went to a different pile, to mix the material into three homogeneous and equal groups. One pile was stacked with a two-foot sticker spacing in preparation for loading into the dry kiln (charge #1). One pile was tight packed, covered by a tarp and placed under a sprinkler to keep it cool (charge #2). The third pile was placed on stickers and left to air dry in a shed open on four sides (charge #4). The 7/4 material (charge #3) was left tight packed, placed under a tarp and sprinkler, along with the tight packed bundle of 4/4.

During the sorting, it was noticed that one package, the wider boards, had grub worms and some borers present. Sapstain and patches of mold were also observed in all bundles. This is indicative of old wood. End checks to six inches were common, to a foot were less common, surface checks were not noted at this time. There were tiny beads of pitch, most of which were solid, on the surface of many boards. Quality was quite poor with most pieces having numerous knots, often 1-2 inches in diameter and 10 or more per board. It was believed that many boards will result in no usable stock simply because of the knots and grain.

Kiln MC and Stress Samples

For each charge, six boards were selected according to wood type; two sapwood, two heartwood, and two mixed (heart/sap). One 24 inch sample was cut from each board, the ends were coated with Black Gacoflex N-1700 neoprene coating to prevent end drying. Samples were labeled and weighed, then placed into the stack. This is the conventional sample board approach to MC monitoring as described in the Dry Kiln Operator's Manual[1]. The samples were periodically removed from the kiln and weighed, to measure their moisture content, then returned to the kiln. An average of these moisture contents was used as the moisture content of the entire charge.

An additional 48" board of each sapwood and heartwood were also prepared at this time for stress and shell-core MC determination during drying. This type of sampling was performed on all the charges, including the air dry pile.

The average thickness of the 4/4 boards was 1.024" when green. Seventeen readings were taken with calipers -

1.051 0.995 1.115 1.034 1.034 1.011 0.960 1.043 1.045 1.067 1.049
1.020 1.031 1.059 0.876 1.015 1.007

[1]USDA. 1989. Dry Kiln Operator's Manual. Ag. Handbook #188. Forest Service. Forest Products Lab. Madison, WI.

Kiln Schedules

On September 27th charge #1 (4/4) was stacked in two piles to form a 16-foot-long load and top-loaded to 50 lbs/ft^2 with concrete slabs. Because lumber was below 20% average moisture content, the schedule shown in Table 1 was used. On September 30th charge #1 was removed from the kiln and left indoors on stickers. The bundle of 4/4 that was under the sprinkler was stacked into two stickered piles and prepared for the kiln (charge #2). The wood's moisture content increased under sprinklers, and its initial moisture content was much higher than the first charge. The schedule for charge 2 was similar to charge 1 (Table 2).

On October 3 charge #2 was unloaded and left indoors on stickers. The three bundles of 7/4, that were under the sprinkler, were stacked into two stickered piles and prepared for the kiln (charge #3). The schedule in Table 3 was used. This is similar to #290[2], but a little faster because of the dryness of the wood.

On October 11, charge #3 was removed from the kiln and left on stickers indoors along with charges 1 and 2. The last charge of 4/4, the one that was air drying, was unstacked then restacked into two stickered piles and prepared for the kiln (charge #4). New MC samples were prepared. This charge was dried at a lower temperature (Table 4) in an attempt to preserve some of the juniper's natural scent. It also represents extremely mild drying. On October 17 charge #4 was dry. Like charges 1, 2, and 3 it was stored indoors on stickers until October 31.

The decrease in wet-bulb depression towards the end of each schedule was to allow equalization of the dry and wet pieces. After equalization, the 4/4 and 7/4 lumber were conditioned for 8 and 12 hours, respectively, at T_{DB}=160°F and T_{WB}=152°F.

Sampling During Kiln Run

Periodically the kiln was paused so the sample boards could be removed and weighed. The samples were then returned to the charge and the kiln schedule was continued. At the same time, two one-inch samples were cut 4-6 " from the end of each 48-inch sample. The end was recoated with Neoprene and the sample was placed back in the stack. One sample was cut to indicate stress in the sample. The second was cut in such a way, interlocking L's, such that the outer shell was cut off the inner core. The shell and core were then weighed separately and oven dried at 220°F, so moisture content could be obtained. These are shown in Figure 1.

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[2] Boone, R. Sidney, Charles J. Kozlik, Paul J. Bois, and Eugene M. Wengert. 1988. Kiln Schedules for Commercial Woods: Temperate and Tropical. USDA Forest Service. FPL-GTR-57.

TABLE 1. Kiln schedule for charge #1 (4/4).

Schedule Step	Time (hr)	Dry-bulb (°F)	Wet-bulb (°F)
Start	0	80	73
1	2	130	123
2	8	150	135
3	24	180	140
4	31	180	140
5	32	160	136
end	39	160	136

TABLE 2. Kiln schedule for charge #2 (4/4).

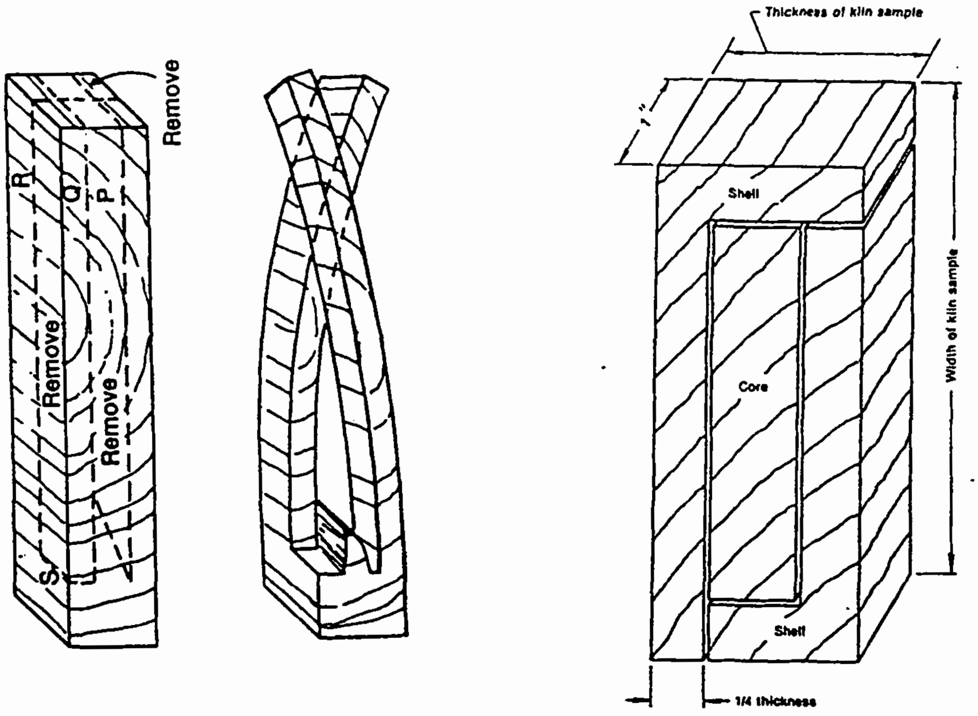
Schedule Step	Time (hr)	Dry-bulb (°F)	Wet-bulb (°F)
Start	0	80	73
1	2	130	123
2	8	150	135
3	16	160	130
4	24	180	140
5	30	180	140
6	31	160	140
end	38	160	140

TABLE 3. Kiln schedule for charge 3 (7/4).

Schedule Step	Time (hr)	Dry-bulb (°F)	Wet-bulb (°F)
Start	0	80	73
1	2	130	123
2	6	135	125
3	12	140	125
4	36	150	135
5	48	155	135
6	60	180	140
7	96	180	140
end	120	180	140

TABLE 4. Kiln schedule for charge 4 (4/4, air dried).

Schedule Step	Time (hr)	Dry-bulb (°F)	Wet-bulb (°F)
Start	0	80	73
1	2	130	123
2	24	130	120
3	48	130	115
4	72	130	110
5	74	130	100
end	99	130	95



(a) (b)

FIGURE 1. The prong test for stress (a) and a shell and core MC sample (b).

Defect Evaluation

On October 31 the four charges in the lab were tight packed, analyzed for defects (surface checks, through checks, end splits), and prepared for shipping to Rainier Wood Products of Sweet Home Oregon. Boards had surface checks if there was a split in the boards surface that did not go all the way through the board. Through checks extended from one face to the other. End splits were counted if they extended from the end of the board lengthwise, extended from face to face, and were longer than 1/2 of the board width. Defects were simply tallied. Only the worst defect in a particular board was tallied.

Samples for Moisture Meter Correction Factors

Boards for the moisture meter study, were selected prior to drying. Twenty-five boards with enough clear wood to get three 12 inch samples were selected as follows:

- 10 all-heartwood
- 10 all-sapwood
- 5 mixed heart/sapwood
- all boards were at least 3.5 " wide

The boards were numbered from 1 to 25. Three samples were cut from each board and numbered 1-1, 1-2,... 2-1, 2-2, etc. The boards were sorted according to the arbitrary extension number given to the board (i.e., all the -1's were put together).

-The -1's were put into the hot-dry room
-The -2's were put into the standard room
-The -3's were put into the hot-wet room

The boards were placed on stickers with a fan blowing through the stack. The samples were monitored to determine when the samples had equilibrated with the environment in which they had been placed. After testing it was felt that there were not enough boards in the low MC range that registered on the meter. Therefore, a fourth group of samples was selected from the dried material which had been exposed to the lab environment for several months. This group was simply wrapped in plastic for two weeks to reduce moisture gradients, then tested.

Two dielectric-type[3] and two resistance-type[4] meters were used in the study according to the manufacturers' instructions. A calibrated capacitance plate and a calibrated resistance block were used to verify that the meters calibrations during the study.

Specific gravity was calculated from the oven-dry weight and volume and reported based on oven-dry weight and volume at 12% moisture content using the conversion method in ASTM D-2395.

The moisture content for each sample at each equilibrium condition was calculated based on its oven-dry weight. An average of the two readings for each type of meter was calculated for each condition and sample. A linear regression was done for each type of meter with average moisture meter reading as the dependent variable and oven-dry moisture content as the independent variable (Equation 1).

$$\text{Meter reading} = \beta_1 * \text{Oven-dry MC} + \beta_0 + \epsilon \qquad (1)$$

[3]Model L-600, Wagner Electronic Products, Rogue River, OR

[4]Model RDM-1v, Delmhorst Instrument Company, Towaco, NJ

The correction factors were then determined by subtracting the predicted value of the regression from the oven-dry moisture content using equation 2.

$$\text{C.F.} = ((\text{ Meter reading } - \beta_0) / \beta_1) - \text{Meter reading} \qquad (2)$$

Panel preparation and evaluation

On January 12, 1995 the 8'X3' Juniper panels and scrap wood were picked up and brought to the Forest Research Laboratory of OSU. On January 20, one 4-foot end of twelve panels from each of the four charges was masked off. The paper and the side (edge) of each panel was labeled according to the charge and it's I.D. (1-12) in that charge, for later identification and analysis. On January 25 both faces, of the exposed portion of each panel were sprayed with 80% lacquer, 20% lacquer thinner. The lacquer was allowed to dry while the panel stood vertically then harden while the panels were stacked horizontally on stickers. When the coated surfaces were hard, they were lightly sanded with 320 grit sand paper attached to a random orbital sander. The panels were then wiped down with cheese cloth in preparation for the second coat of lacquer. Each panel was wiped with a Tac cloth just prior to the second application of lacquer. The panels were allowed to dry standing vertical then stacked horizontally on stickers to harden. On January 26, the panels were sanded with 600 grit sandpaper attached to a random orbital sander then wiped with a cheese cloth. On January 28 the panels were wiped with a Tac cloth and the third and final coat of lacquer was applied to both exposed faces each panel. The panels were again allowed to dry while standing vertical then stacked horizontally on stickers to harden.

February 3, 1995, the panels were unmasked and analyzed for end check length. The end of each check was marked with a black felt pen. This was done for both ends, coated and uncoated, of one face of each panel. The panels were then restacked, horizontally on stickers and put into the a room at a 10% EMC with a fan blowing air through the stacks.

March 16, 1995 the end check length was again analyzed and the end of each check marked with a blue felt pen. Checks were only marked if they had changed in length or were "new". The panels were weighed and stacked on the cart of the 16' kiln. The kiln was set to 90°F and a 7 percent EMC. Kiln fans circulated the air through the pile. After reaching a constant weight, the end checks were again marked and the panels returned to the kiln, this time at 100°F and a 14 percent EMC. After the panels reached a constant weight, the checks were again marked and the panels returned to the kiln for the last time at 90°F and a 7 percent EMC. The average length and number of checks were reported. This process was completed in late May.

RESULTS AND DISCUSSION

Drying

Each of the kiln schedules for 4/4 gave satisfactory results. The drying times were 39, 38, and 99 hours, respectively, for the three 4/4 charges. The 7/4 took 120 hours. Charge one and the air dry pile started well below 20% moisture content indicating that the wood had dried significantly prior to arriving at OSU. The published value for the moisture content of fresh juniper ranges from 64 to 178%. Given the large difference between the MC of the wood in this study and the published values, there is probably little to be learned about the drying times for juniper in a production situation. For comparison, Kozlik[5] dried juniper in about 100 to 130 hours with starting temperatures as high as 160°F with acceptable results. The drying curves based on the sample boards are shown in Figures 2-6.

Figure 7 contains photos of the stress samples. They follow the pattern that would be expected to occur during kiln drying.

Degrade

The defect tallies are shown in Table 5. Despite the schedules being similar for the first and second charges, the defect tallies are quite different. This gives a feel for the inherent variability in this type of work. Air drying followed by mild kiln drying reduced the number of through checks, but probably didn't have much effect on the other types of degrade. The 7/4 had an unacceptable amount of surface checking indicating that a slower schedule would be more desirable. It's important to note that what happens to the wood before it goes into the kiln is often more important than how it is dried.

Moisture Meter Correction factors

Average specific gravity for the samples was 0.43 with a standard deviation of 0.031. The readings obtained with a capacitance-type meter are highly dependent on specific gravity. Since the specific gravity of the juniper samples was lower than Douglas-fir (the calibration species) a positive correction factor would be expected for the capacitance-type meter. The specific gravity estimate is for the samples in this study and may not be representative of the population.

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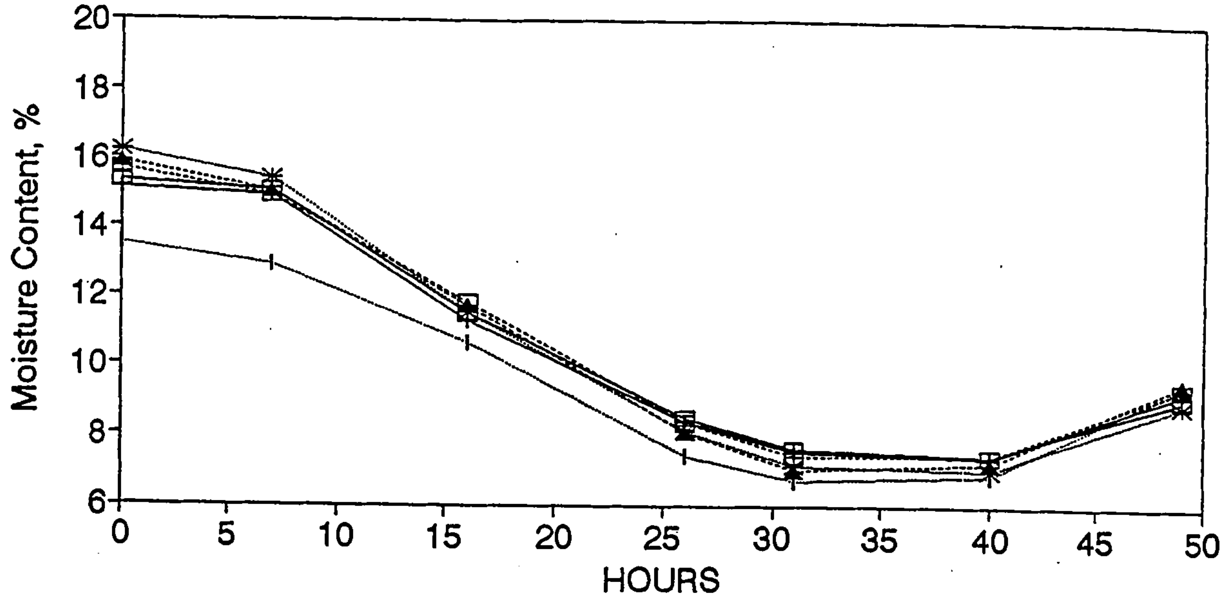
[5]Kozlik, C.J. 1976. Kiln-drying of Western Juniper. Forest Products J. 26(8):45-46.



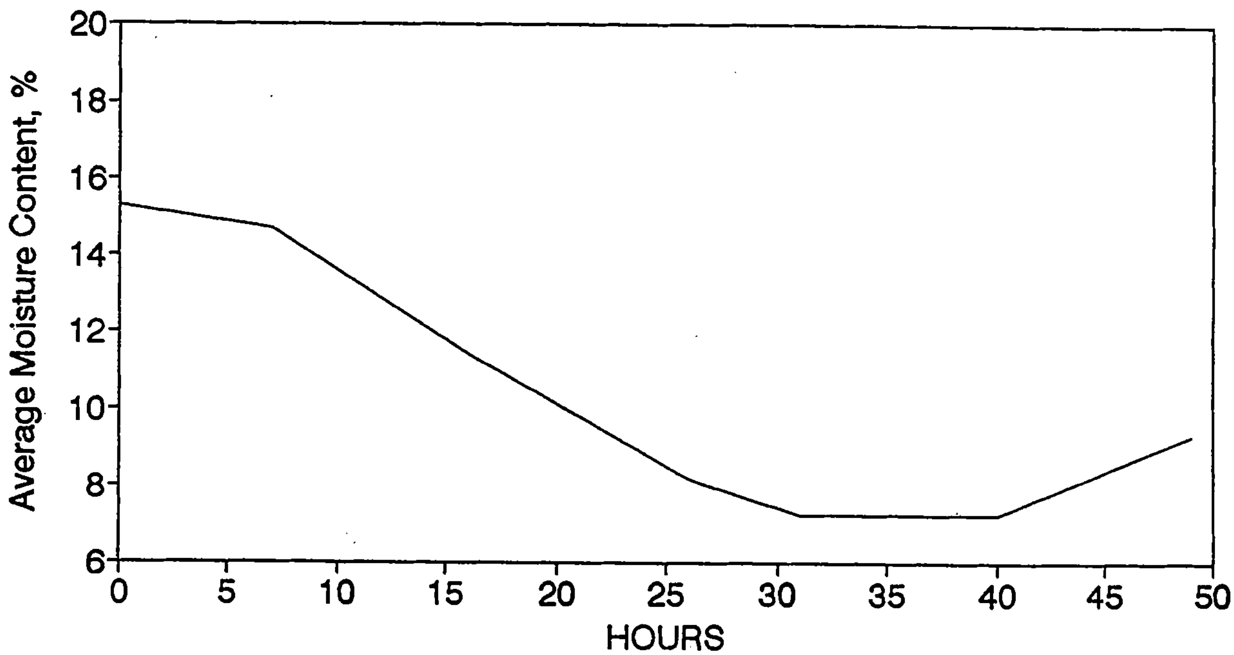
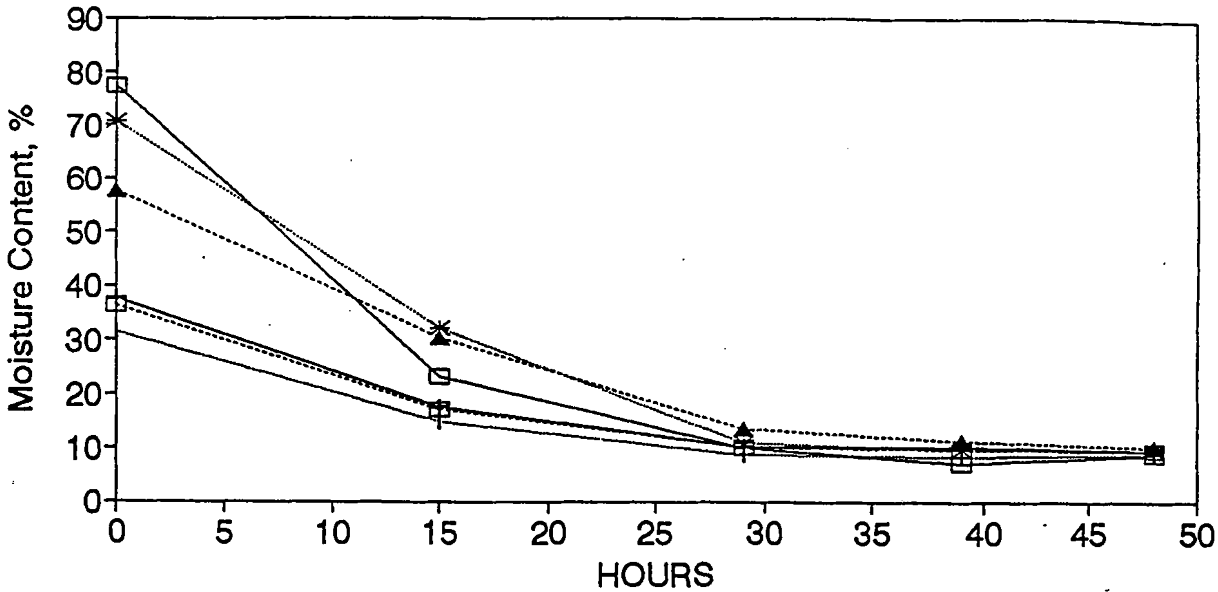


FIGURE 2. Drying curves for charge #1. Top graph shows individual sample board MCs while lower graph shows the average.



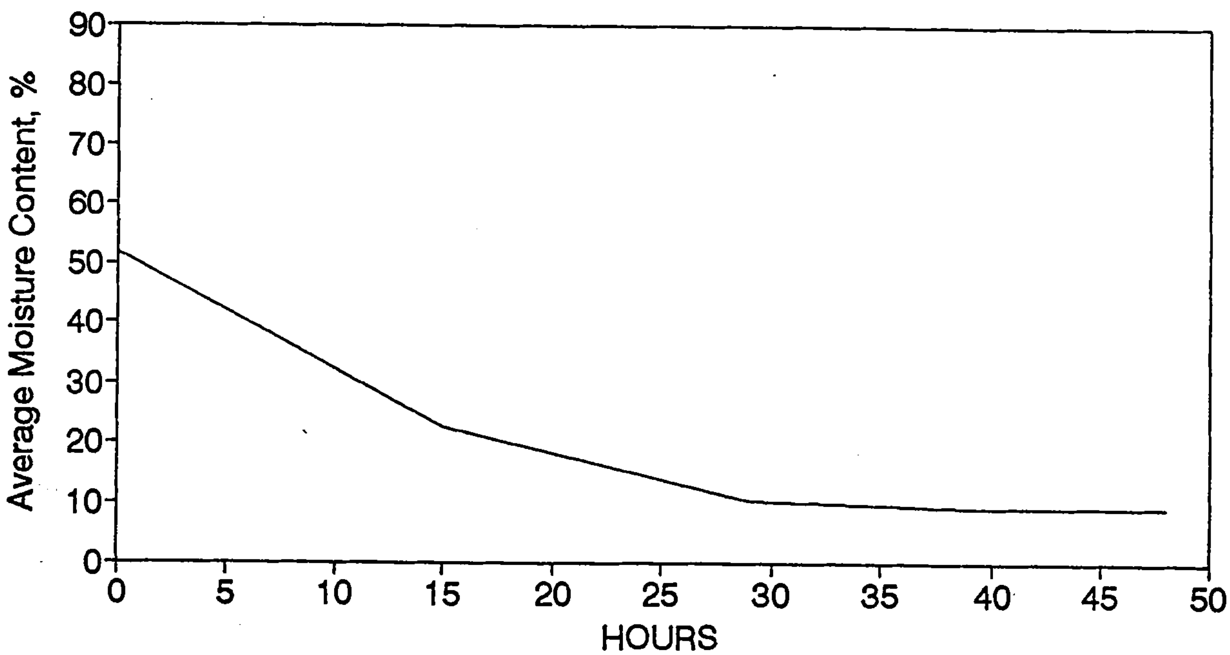
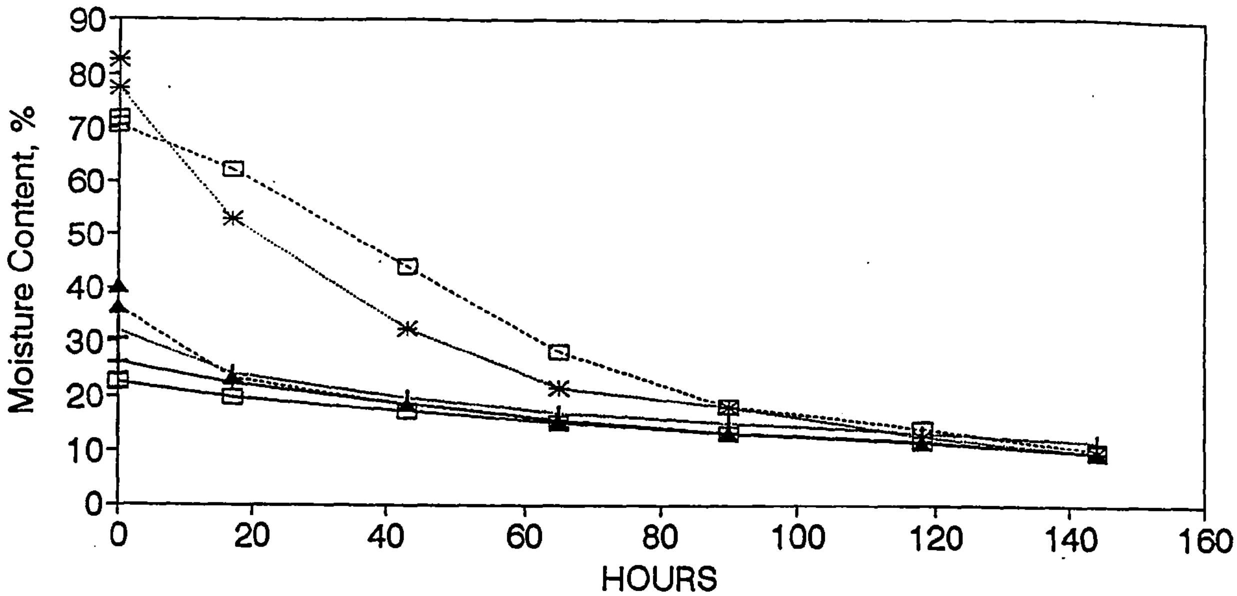


FIGURE 3. Drying curves for charge #2. Top graph shows individual sample board MCs while lower graph shows the average.



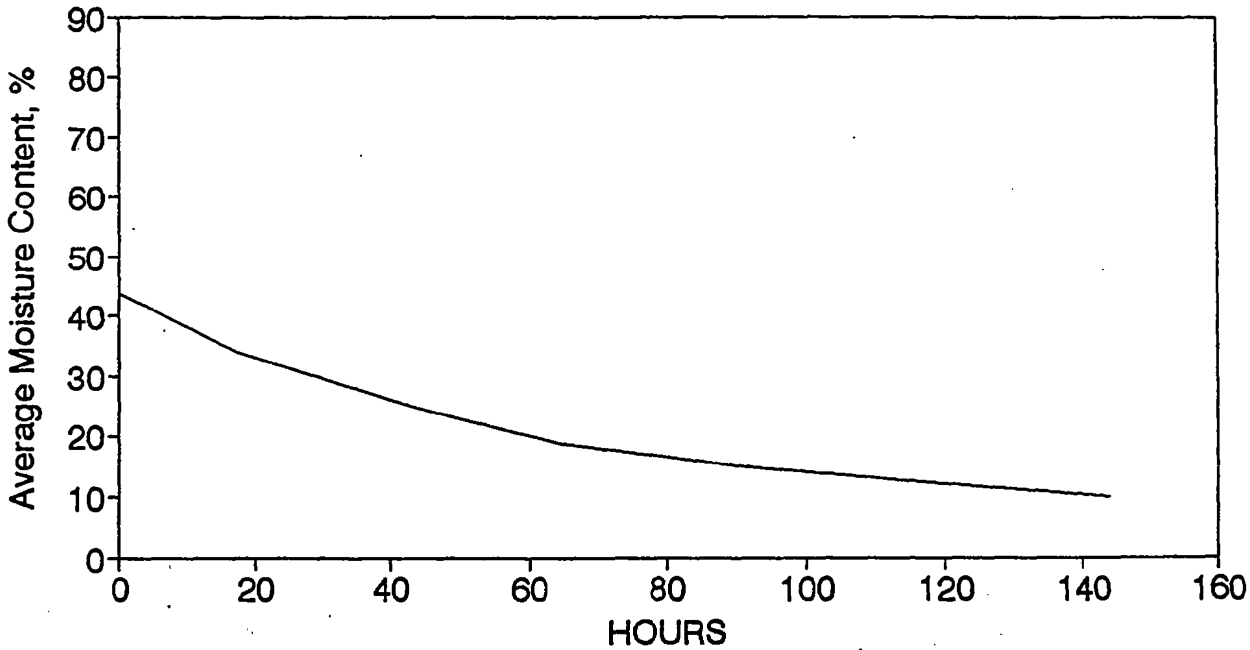
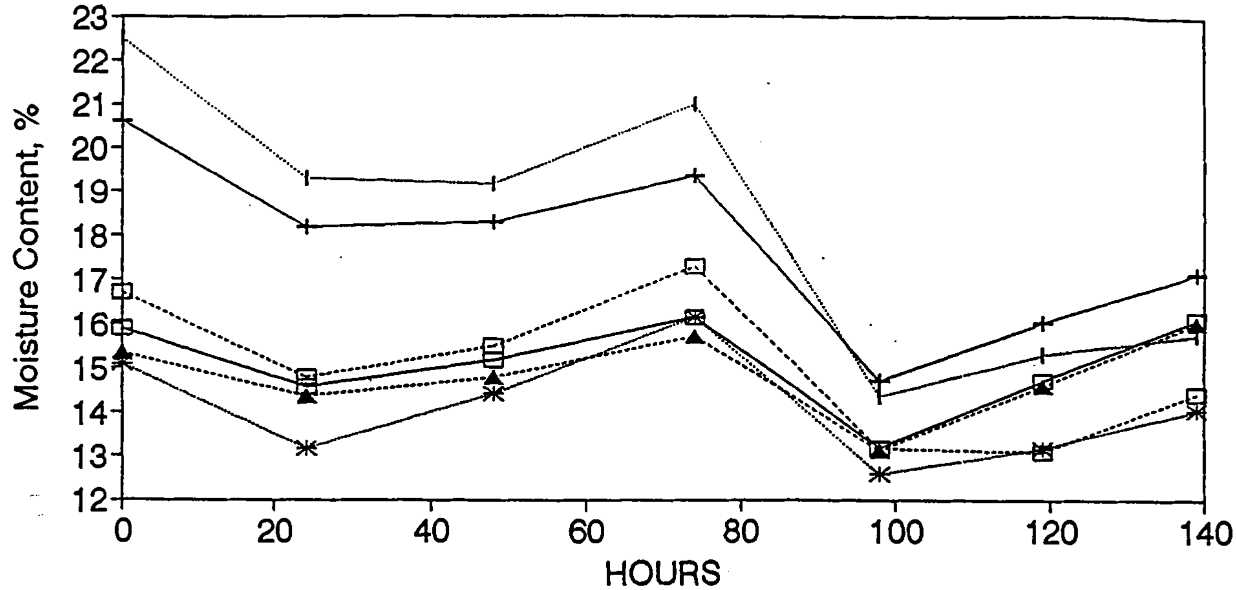


FIGURE 4. Drying curves for charge #3. Top graph shows individual sample board MCs while lower graph shows the average.



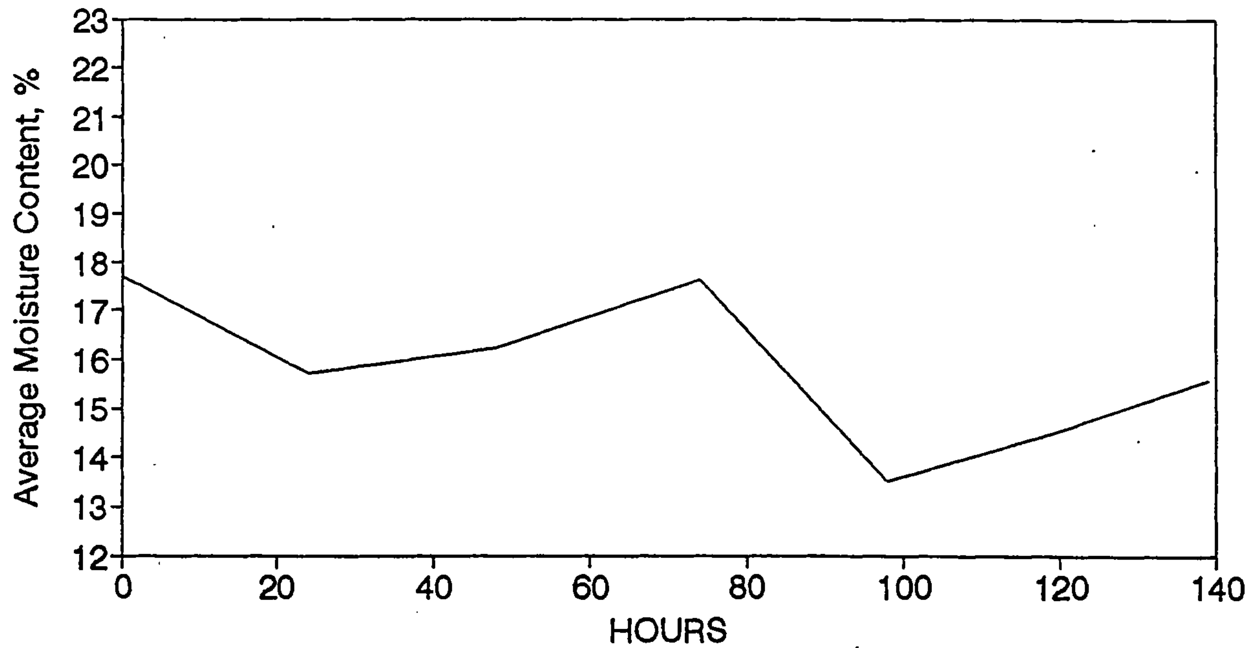
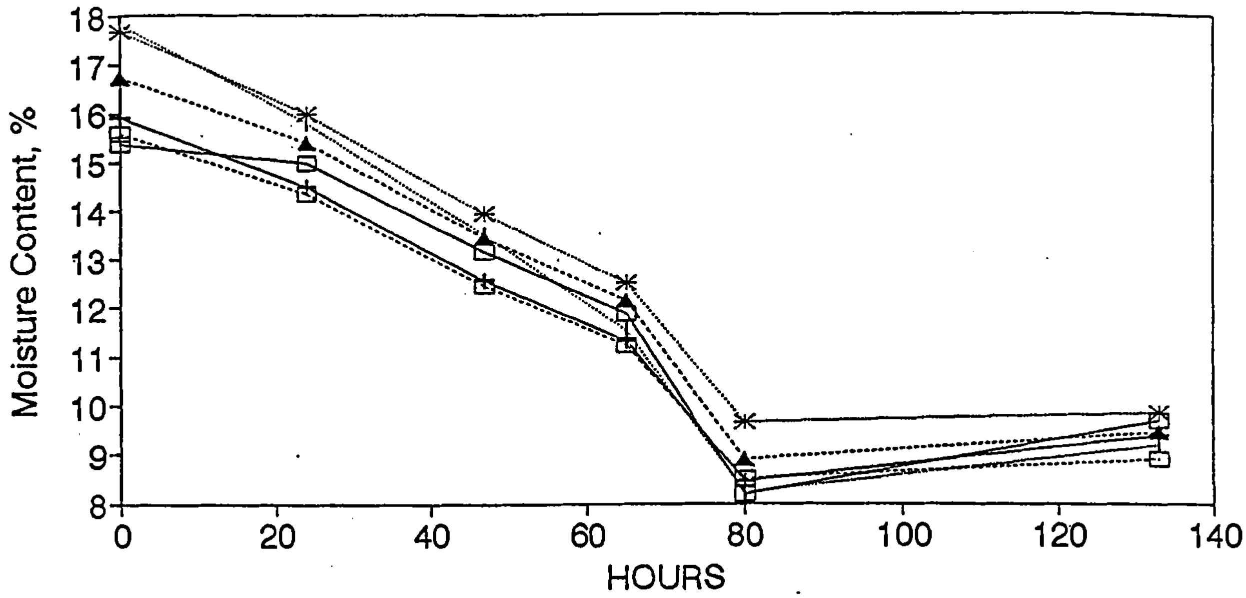


FIGURE 5. Drying curves for air drying. Top graph shows individual sample board MCs while lower graph shows the average.



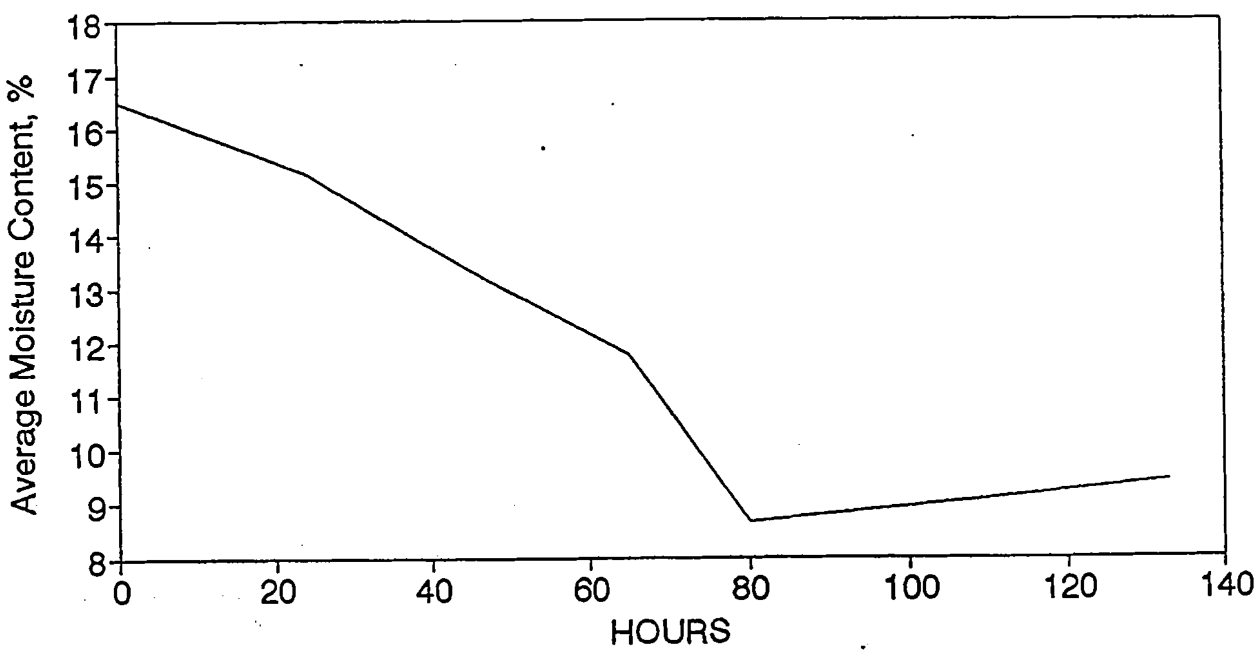


FIGURE 6. Drying curves for charge #4. Top graph shows individual sample board MCs while lower graph shows the average.

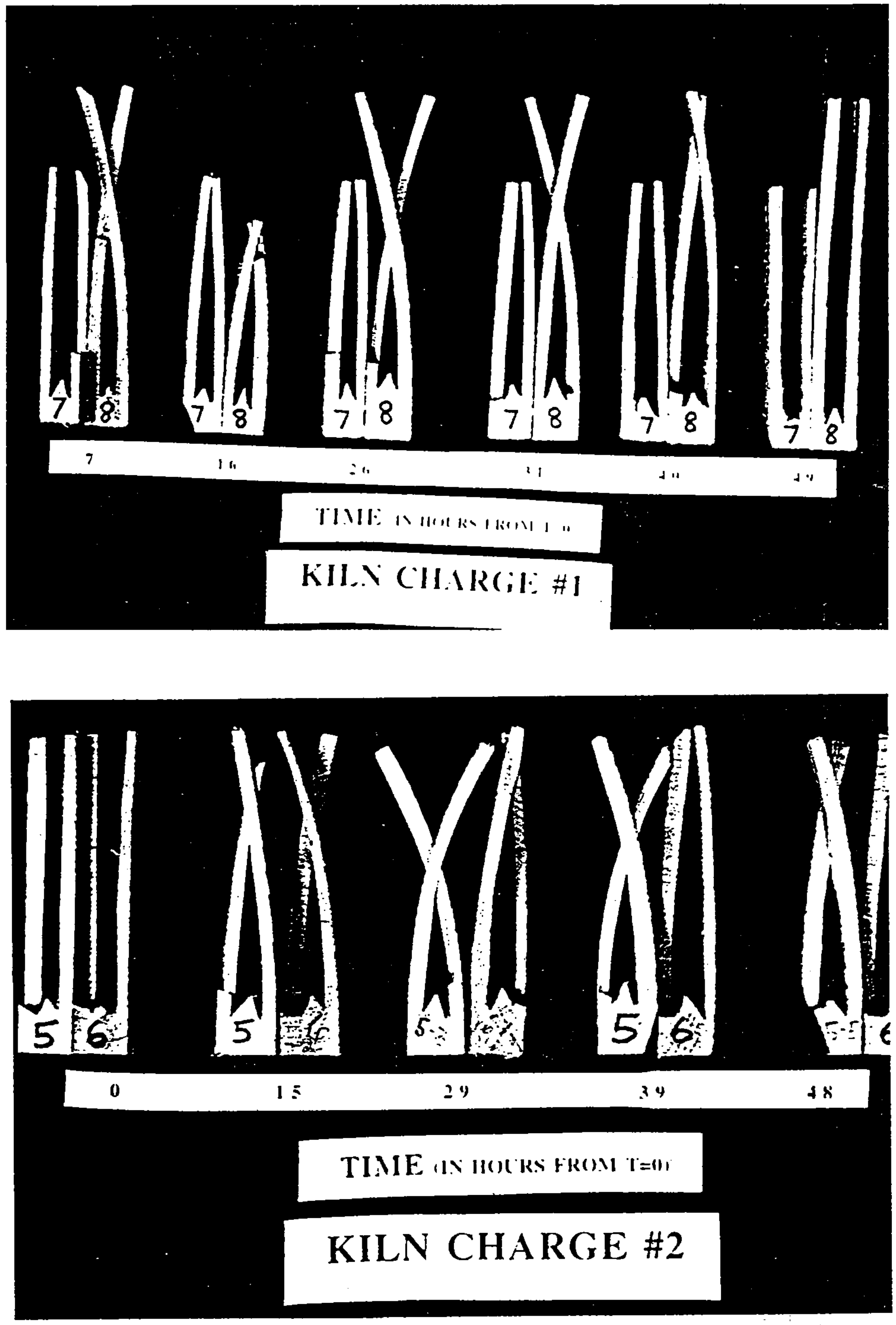


FIGURE 7. Stress samples for charges #1 and #2.

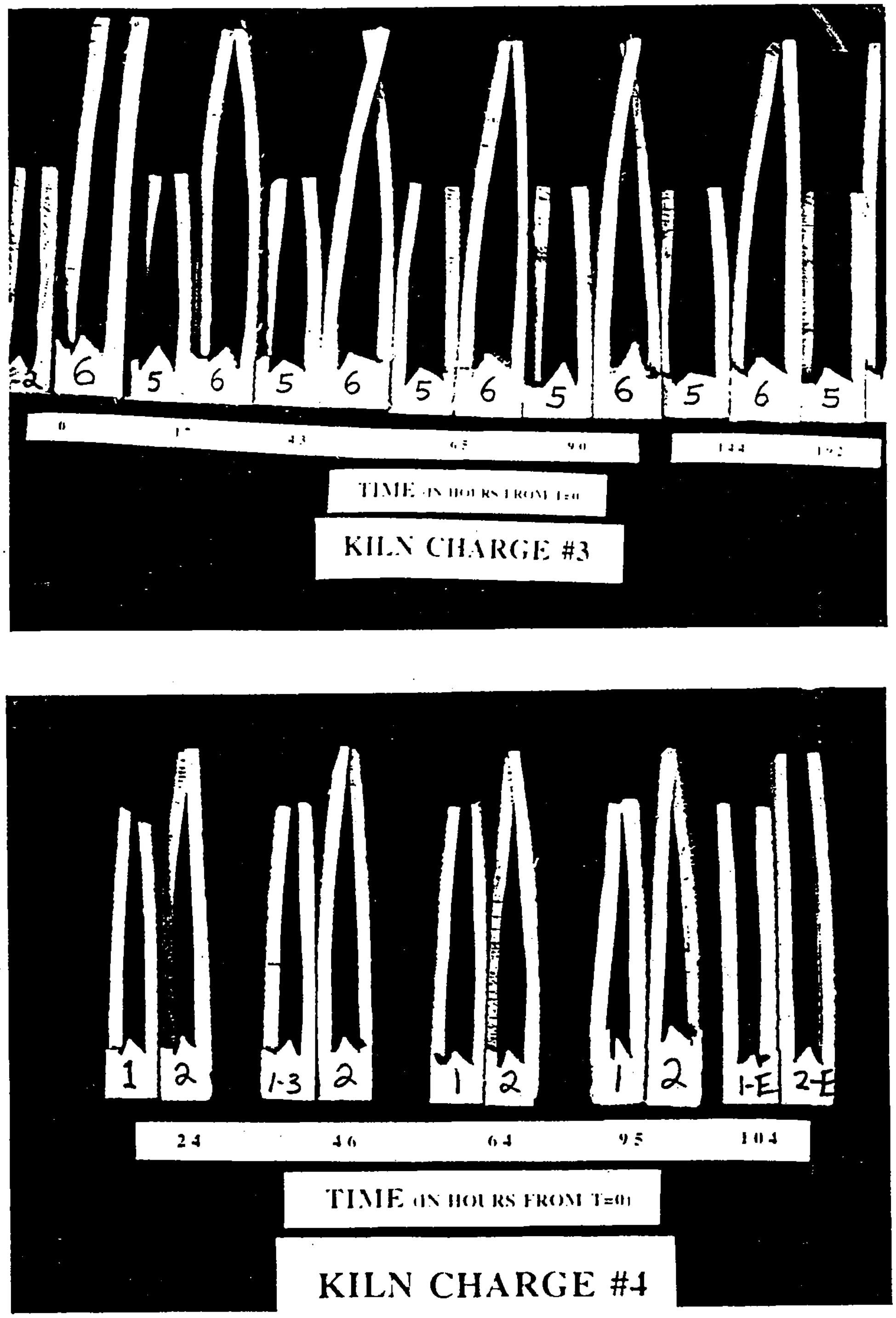


FIGURE 7 (continued). Stress samples for charges #3 and #4.

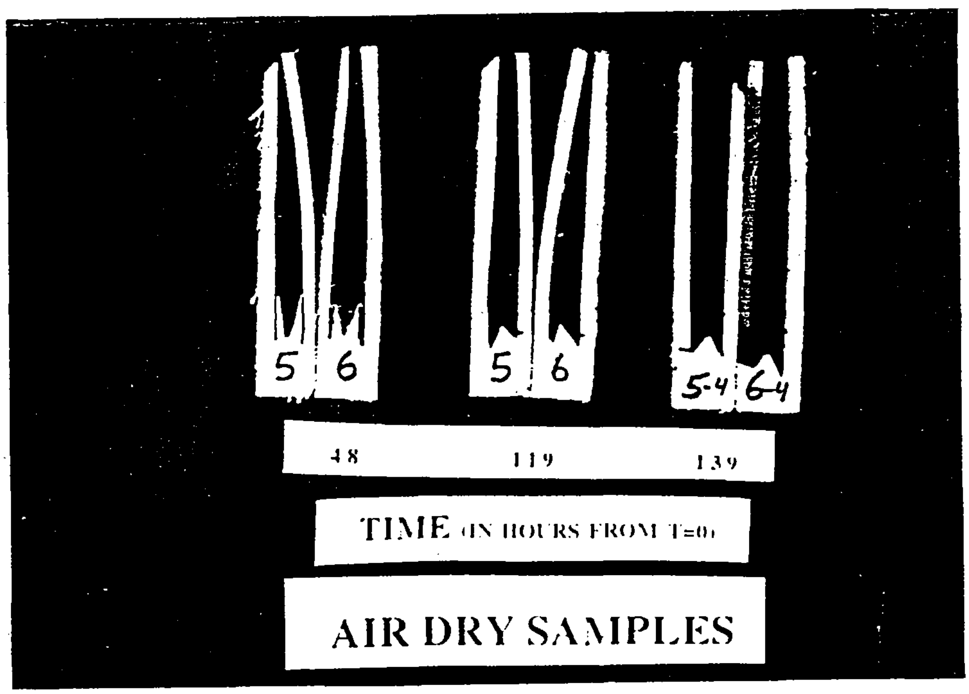


FIGURE 7 (continued). Stress samples for air drying.

TABLE 5. Tally of defects.

RUN	Pieces	Surface Checks		Through Checks		End Splits		Defective	
#	#	#	%	#	%	#	%	#	%
1	254	14	5.5	23	9.1	36	14.2	73	28.7
2	220	20	9.1	23	10.5	9	4.1	52	23.6
3	220	51	23.1	17	7.7	6	2.7	74	33.6
4	258	14	5.4	11	4.2	11	4.3	36	14.0

Plots of meter reading versus oven-dry moisture content are shown in Figures 8 and 9. Some low MC pieces are not represented on the graph because the readings were off the meters' scale. The correction factors for the resistance- and capacitance-type meters are shown in Table 6.

Panel Fabrication

When the panels were received they had many end checks up to 1/8" in width. These went into the piece for as much as a foot. Some of these resulted from snipe on the boards before they were glued. The narrow end on a sniped board resulted in a poor or nonexistent glue joint.

Comments were obtained from Ron Turner, Larry Oldaker, and Lance from Rainier Wood Products regarding the breakdown of the juniper lumber and assembly of the panels. As recorded by Scott Leavengood, these are given below.

- Cupping of panels was common after lay-up. The panels then "relaxed" after some time.

- Warpage was a severe problem with most dried juniper boards, particularly when ripping the boards. It was felt that dried juniper lumber contains a great deal of longitudinal stresses. This behavior is also common with maple.

- Board widths used in the study were too narrow to "rip the bow out" of the boards.

- They felt that music boxes, cabinet parts, and furniture were good uses for juniper.

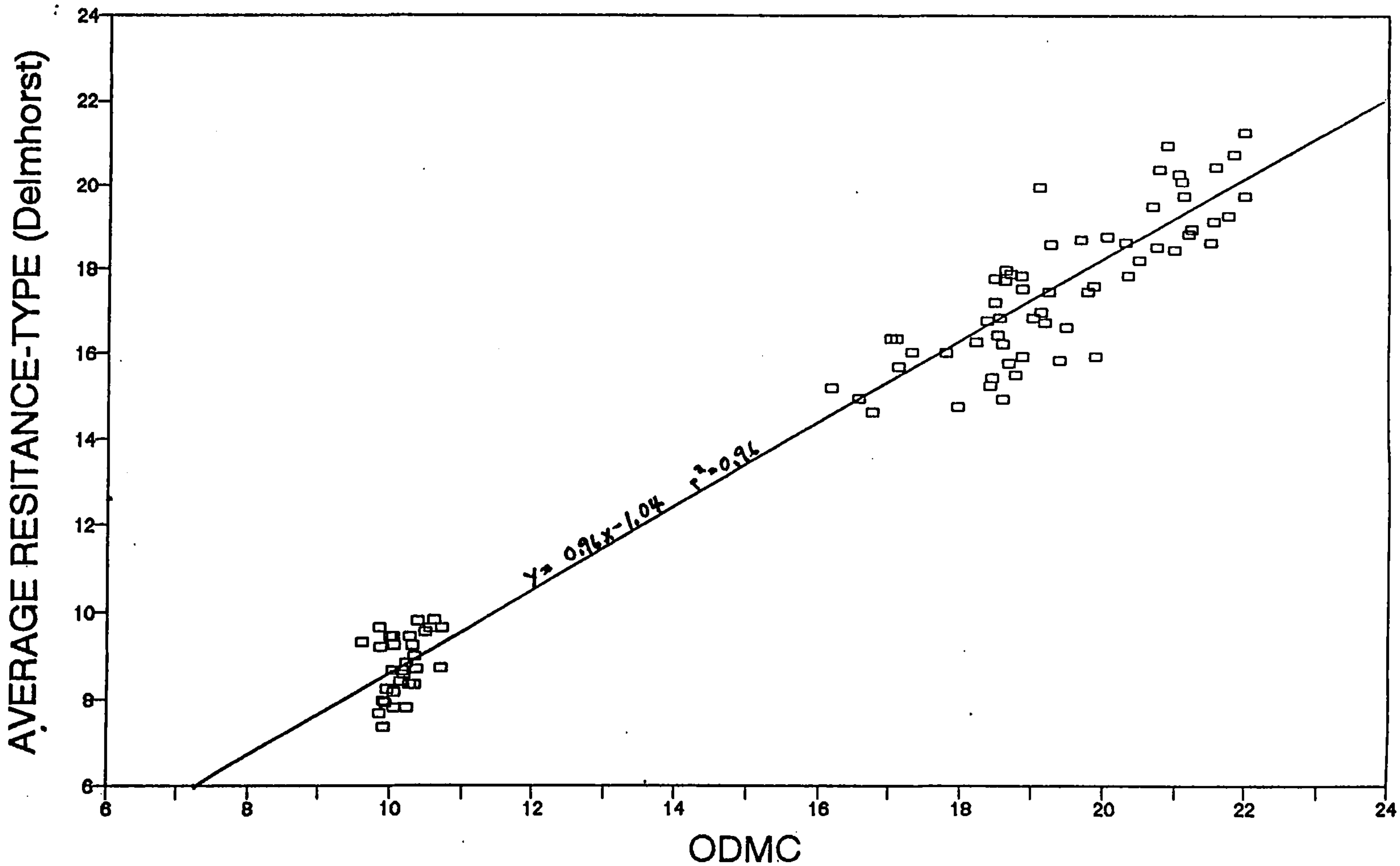


FIGURE 8. Meter reading versus true moisture content for resistance-type meter.

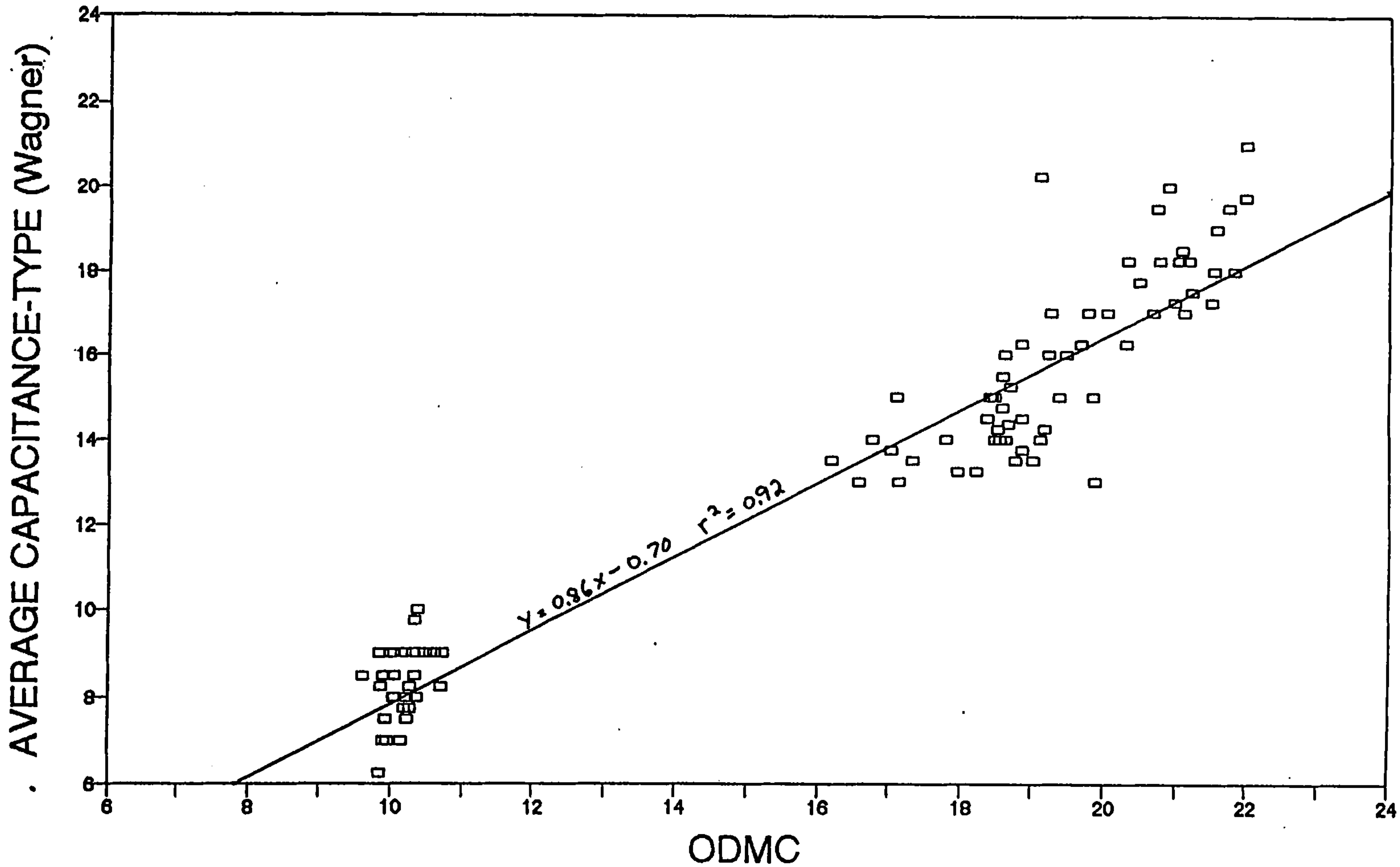


FIGURE 9. Meter reading versus true moisture content for capacitance-type meter.

TABLE 6. Correction factors for the two types of moisture meters. Add the factor given to the meter reading to get the true moisture content. All values in percent.

Meter Reading	Resistance-type meter	Capacitance-type meter
6	1.3	1.8
8	1.4	2.1
10	1.5	2.4
12	1.6	2.4
14	1.7	3.0
16	1.7	3.3
18	1.8	3.6
20	1.9	3.9
22	2.0	4.3
24	2.1	4.6
26	2.1	4.9
28	2.2	5.2

- Juniper machines well and is easy to work with
- Fingerjointing shorter, more defect-free pieces would be preferred to edge-gluing longer boards into panel. They felt that 8 inches should be the minimum length for fingerjoint pieces. Shorter pieces aren't desirable because small amounts of warpage in many short pieces becomes magnified when the pieces are used to create a long panel. They felt that chip-out may be a problem when fingerjointing juniper due to grain deviations.
- Grade recovery from logs appears to be very poor. When told that the material they worked with represented the top 20% of the grade recovery, they wondered how bad the other 80% must have been.

- The minimum panel width Rainier Wood Products can produce is 17-18 inches, and the maximum width is 46-52 inches.

- When asked to characterize what distinguished the waste material from the material they were able to use for panels, they cited: loose knots, warp, and Larry Swan's stipulation against using any pieces under 3 inches in width. They said they could have used a lot more of the material if not for the "nothing under 3 inches in width" stipulation.

- They had a problem with delaminations at the end of panels due to sniped boards. This problem is not unique to juniper.

- I asked if the radial splits in the boards might be due to feed roll pressure on cupped panels during surfacing. They said this was not the case because the panels were sanded before cupping. One gentleman suggested that the radially-oriented splits may be due to end-checking in logs left sitting too long. He wondered if the split would propagate if the panel were trimmed beyond the split.

- Warpage was more of a problem with clear lumber than knotty lumber. One gentleman theorized that compression wood was more prevalent in the clear lumber, thus causing the warpage problem.

- Feed rate was 90-100 feet per minute.

- Rainier is currently fingerjointing and edge-gluing western redcedar and cottonwood. They mentioned no difficulties with western redcedar, however they were experiencing difficulties with "fuzzing" with cottonwood.

Panel Evaluation

The split data for the panels are given in Table 7. Split frequency is given both by number in the charge and average number by panel. The "sums" represent the length of all splits added together for panels from a charge or the average for the 12 panels from the charge panel. The mean split length as well as the maximum are also shown.

There are no clear trends by kiln charge. An analysis of variance on sum of splits in the final condition showed no differences among panels from the four kiln charges but significant differences among the coated, uncoated, and middle splits. A paired t-test between the coated and uncoated ends showed statistically significant differences for both the frequency of splitting as well as the sum of the split lengths. The numbers in both columns indicate that the coated ends of the panels performed better than the uncoated ends. One might expect charge #4 (air dried, then kiln dried at 130°F) to be different from charges 1 and 2 (kiln dried); however, this was not the case. The defects did tend to increase with time.

		Uncoated End						Coated End						Checks in Middle					
	Charge	Initial	12%	7%	14%	7%	Mean	Initial	12%	7%	14%	7%	Mean	Initial	12%	7%	14%	7%	Mean
# Splits by charge, #	1	48	38	69	72	79	61	34	46	41	50	58	46	1	3	3	5	6	3.6
	2	37	51	42	66	61	51	45	35	48	42	44	43	2	2	4	4	4	3.2
	3	55	58	60	47	82	60	54	54	66	67	61	60	3	1	5	1	5	3.0
	4	56	57	70	69	85	67	49	50	56	56	72	57	1	1	1	5	2	2.0
	Mean	49.0	51.0	60.3	63.5	76.8	60	45.5	46.3	52.8	53.8	58.8	51	1.8	1.8	3.3	3.8	4.3	3.0
Sum of length by charge, inches	1	239	220	398	255	450	312	99	218	133	251	285	197	64	122	115	244	260	161
	2	204	251	266	310	381	282	211	103	227	147	176	173	88	88	171	171	180	140
	3	213	205	267	339	352	276	140	143	212	214	226	187	122	64	245	56	245	147
	4	195	221	242	411	283	270	161	169	189	190	242	190	56	56	56	245	125	108
	Mean	213	224	293	329	367	285	153	158	190	200	232	187	83	83	147	179	203	139
Avg. # splits by panel, #	1	4.0	3.2	5.8	6.0	6.6	5.1	2.8	3.8	3.4	4.2	4.8	3.8	0.1	0.3	0.3	0.4	0.5	0.3
	2	3.1	4.3	3.5	5.5	5.1	4.3	3.8	2.9	4.0	3.5	3.7	3.6	0.2	0.2	0.3	0.3	0.3	0.3
	3	4.6	4.8	5.0	3.9	6.8	5.0	4.5	4.5	5.5	5.6	5.1	5.0	0.3	0.1	0.4	0.1	0.4	0.3
	4	4.7	4.8	5.8	5.8	7.1	5.6	4.1	4.2	4.7	4.7	6.0	4.7	0.1	0.1	0.1	0.4	0.2	0.2
	Mean	4.1	4.3	5.0	5.3	6.4	5.0	3.8	3.9	4.4	4.5	4.9	4.3	0.1	0.1	0.3	0.3	0.4	0.2
Avg. sum of length by panel, inches	1	19.9	18.4	33.1	21.2	37.5	26.0	8.3	18.2	11.1	20.9	23.7	16.4	5.3	10.2	9.6	20.3	21.6	13.4
	2	17.0	20.9	22.2	25.8	31.8	23.5	17.6	8.6	18.9	12.2	14.7	14.4	7.3	7.3	14.3	14.3	15.0	11.6
	3	17.8	17.1	22.3	28.2	29.4	23.0	11.7	11.9	17.6	17.8	18.8	15.6	10.2	5.3	20.5	4.7	20.5	12.2
	4	16.2	18.4	20.1	34.2	23.6	22.5	13.5	14.1	15.8	15.8	20.2	15.9	4.7	4.7	4.7	20.5	10.4	9.0
	Mean	17.7	18.7	24.4	27.4	30.6	23.8	12.8	13.2	15.9	16.7	19.3	15.6	6.9	6.9	12.2	14.9	16.9	11.6
Mean split length, inches	1	5.0	5.8	5.8	3.5	5.7	5.2	2.9	4.7	3.2	5.0	4.9	4.2	64.0	40.6	38.3	48.8	43.3	47.0
	2	5.5	4.9	6.3	4.7	6.2	5.5	4.7	2.9	4.7	3.5	4.0	4.0	44.1	44.1	42.8	42.8	45.0	43.7
	3	3.9	3.5	4.5	7.2	4.3	4.7	2.6	2.6	3.2	3.2	3.7	3.1	40.6	64.0	49.1	56.3	49.1	51.8
	4	3.5	3.9	3.5	6.0	3.3	4.0	3.3	3.4	3.4	3.4	3.4	3.4	56.3	56.3	56.3	49.1	62.6	56.1
	Mean	4.5	4.5	5.0	5.3	4.9	4.8	3.4	3.4	3.6	3.8	4.0	3.6	51.2	51.2	46.6	49.2	50.0	49.7
Max. split length in in charge, inches	1	48	33	48	14	48	38	7	11	9	22	22	14	64	58	64	64	64	63
	2	32	48	34	40	52	41	11	7	11	13	24	13	83	83	83	83	91	85
	3	40	13	40	52	40	37	16	16	24	24	27	21	58	64	78	56	78	67
	4	13	40	14	48	14	26	14	14	14	14	27	17	56	56	56	78	69	63
	Mean	33	34	34	38	38	36	12	12	14	18	25	16	65	65	70	70	75	69

TABLE 7. Summary of panel evaluation separated by splits on the coated and uncoated ends and splits that did not reach the end of the panel. Sums of lengths are the length of all checks added together for panels from a charge or the average sum for the 12 panels tested from a charge.

The panel characteristics associated with splits are given in Table 8. At the end of the moisture cycling there were 559 splits, the average length of these being 4 inches. Knots greater than 0.5" in diameter nearly always resulted in a split while knots smaller than this generally were not associated with splits. Splits associated with knots were the most common type of split. Failure along the glueline (not including snipe) was the next most common mode followed by radial or tangential splits in the wood. Any of these could result from warping of the panel.

The maximum split length on each panel is shown in Table 9. This would be the amount that would have to be trimmed out of the panel if the full width of the panel were to be used. Considering that the moisture cycling was relatively mild, losses were significant. The splits associated with the presence of pith tended to be long, and therefore are associate with many of the values in Table 9.

CONCLUSIONS

The method of drying had little or no effect on the panel performance. The splitting appears to be related to the wood characteristics such as knots, grain, and the presence of pith.

Knots large that 0.5 inches in diameter and pith should be avoided when processing juniper.

The moisture meter correction factors are small but significant for juniper.

TABLE 8. Causes of defects in panels after moisture cycling.

FAILURE	FREQUENCY	PERCENT
In Glueline	118	21.1
Originated at Knot	215	38.5
Along Pith	19	3.4
Along Ray	79	14.1
Along Ring	81	14.5
Snipe (manufacturing)	44	7.9
Other	3	0.6
TOTAL SPLITS	559	100

TABLE 9. Maximum length of split in each of the 48 panels. Values are in inches. Total panel length was 96 inches.

	CHARGE			
PANEL	1	2	3	4
1	73.4	15.1	29.0	7.5
2	22.0	68.7	43.5	8.0
3	36.6	91.0	59.9	12.5
4	10.9	8.0	6.0	4.7
5	53.8	12.2	29.5	9.0
6	22.1	51.6	77.5	14.3
7	64.0	13.0	15.5	6.7
8	48.0	34.0	13.7	7.5
9	29.1	7.6	8.5	8.1
10	59.75	36.9	40.2	69.0
11	14.25	8.6	4.9	13.0
12	38.8	7.0	26.7	56.3