1990

Performance of Western Softwood Species as Crossties in Mainline Railroad Track

D. J. Miller
Oregon State University

P. R. Houghton
Southern Pacific Transportation Co. (Retired)

In 1949, the Southern Pacific Transportation Company and Oregon State University began cooperative testing of crossties to compare the performance in mainline track of selected Oregon Wood species with that of generally-accepted Douglas-fir.

This report evaluates the findings of periodic inspections continuing through 1986–87 at 10 test sites covering a wide range of climate and track conditions in Oregon, California, and Nevada. Because of diversity of the site conditions and of the installations at various locations, each test site might best be regarded as a separate experiment.

At each inspection, track-walking inspectors visually judge the condition of each test tie and record the occurrence of checks, splits, crossgrain, decay, plate cutting, spike kill, shatter, and breakage. "Good" ties have none of those defects. Renewed ties are presumed to have failed because of defects accumulated through their final inspection.

The service life of Douglas-fir ties, the standard species in these tests, has generally been medial among the test species. Oftentimes, several species provided similarly long service at a site, thereby offering a choice, or mix, of best woods for the prevailing conditions.

The effects of tonnage and curves on tie life were not demonstrated clearly nor consistently. Sites having an adequately mild, damp climate were clearly conducive to decay, particularly in species other than incense cedar and Douglas-fir. The choice of species will be greater in climates where the decay hazard is low; resistance of the wood to wear-related defects will then be the main concern. None of the species tested was consistently superior, but incense cedar has generally been performing best.

INTRODUCTION

In 1949, the Southern Pacific Transportation Co. and Oregon State University began cooperative testing of railroad crossties made from Oregon wood species. At the time, the company was purchasing Douglas-fir and small amounts of other conifers for crossties, but it also had an interest in the utility of lesser-used woods. The primary objective of the cooperative testing was to determine the durability of the selected woods in actual use as crossties and to compare their in-track performance with that of Douglas-fir.

This report of results through the 1986–87 inspections is therefore chiefly concerned with the longevity of the Oregon woods selected for the crosstie testing project. The eight conifer species compared with Douglas-fir (*Pseudotsuga mensiesii* [Mirb.] Franco) were incense-cedar (*Libocedrus decurrens* Torr.), lodgepole pine (*Pinus contorta* Dougl. ex Loud.), mountain hemlock (*Tsuga mertensiana* [Bong.] Carr.), ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.), Shasta fir (*Abies magnifica* A. Murr.), Sitka spruce (*Picea sitchensis* [Bong.] Carr.), white fir (*Abies concolor* [Gord. & Glend.] Linda. ex Hildebr.), and west coast hemlock (*Tsuga heterophylla* [Raf.] Sarg.).

MATERIALS AND METHODS

Test tie preparation and installation

All test ties, including those of Douglas-fir, were air-seasoned, bored, incised, and pressure treated with a solution of coal-tar creosote (25%), Gasco distillate (25%), and fuel oil (50%) to a target retention of 9.5 p.c.f. as reported by Graham, 1954. Ties of white fir, west coast hemlock, Douglas-fir and lodgepole pine treated satisfactorily. Results were fairly good in Sitka spruce, but erratic in incense cedar, Shasta fir and one lot of unincised lodgepole pine ties. Later trials (Graham, 1956) suggested that mountain hemlock would be difficult to treat. Boxed heart was most prevalent in lodgepole pine ties (95%). It occurred in about half of the Sitka spruce (61%) and incense cedar (47%) ties. The other species, except mountain hemlock which lacked data, included boxed heart in one-third or fewer of their ties. The test crossties were interspersed among regular ties in mainline tracks at locations predominantly in California but also in Oregon, Nevada, and Arizona. Nine sites, judged to be the best of a total of 13, are reported here; an additional site at King City 164 has been included by request of the Association of American Railroads, to include more curved track. Usually 100 to 120 ties of each species were installed at a site.

Test site and track conditions

The sites are listed in Table 1, each with a brief description of its location, climate, and track conditions.

Climate, track conditions, and topography varied widely among test sites, ranging from hot desert to cool forested mountains having deep winter snows, and from straight, relatively flat track to the grades and curves of the Sierra Nevada and Cascade Mountains. At all sites, summers are generally quite dry and precipitation falling as rain or snow is greatest during the winter.

Features not given in Table 1 that might affect tie life are noted below:

- Marion, OR, near Salem in the Willamette Valley, has a temperate climate. Rain falls mainly during cool winter months and declines to nil during July, August. Snowfall is rare.
- Crescent Lake, OR, near the heavily forested summit of the Cascade Range east of Eugene has pleasant summer weather, but otherwise receives much rain and deep winter snows.
- Modoc Point, OR, near Klamath Falls, is considerably drier than the other sites in Oregon; some snowfall occurs with winter rains.
- Bowman, CA, northeast of Sacramento in the western foothills of the Sierra Nevada has rainy winter and spring seasons. Ties here are subjected only to slow uphill traffic.
- Soda Springs, CA, near the summit of the Sierra Nevada near Lake Tahoe, has deep winter snows and warm summers. Ties are subjected only to the same slow uphill traffic as at Bowman.
- King City, CA, about 150 miles south of San Francisco in Salinas Valley in the Coast Range,

Table 1. Location and description of test sites.

Location	Elv.	Local Climate: Total precip.	Local Climate: Avg. temp.	Track Conditions: Curvature	Track Conditions: Grade	Track Conditions: Total gross tons 1950-86	Train Speed
	Ft.	In.	°F			Millions	MPH
OREGON							
Marion	700	40	52	straight	~level	954	60
Crescent Lk.	4,800	89[1]	40[1]	curves <4°	~level	1,217	40
Modoc Pt.	4,200	14	48	straight	~level	1,383	60
CALIFORNIA							
Bowman	1,500	36	61	straight	upgrade 1.4%	597	30
Soda Springs	6,500	70	45	curves <7°	up 1.8%	597	30
King City (160)	320	10	59	straight	0 to-0.3%	521	60
King City (164)	320	10	59	curves <5°	0 to-0.3%	521	60
Palmdale	2,600	8	62	straight	0.5%	1,106	60
Loma Linda	1,000	10	63	straight	1.0%	873	50[2]
NEVADA							
Upsal	3,900	5	51	straight	level	1,785	60

[1] Estimated from nearby Santiam Pass.
[2] Many trains go much slower due to traffic.

has some winter rain. About one third of these ties have been eliminated from test.

- Palmdale, CA, in high desert about 50 miles north of Los Angeles, has some winter rain and warm to hot, dry summers.
- Loma Linda, CA, about 60 miles east of Los Angeles, has some winter rain and warm to hot, dry summers.
- Upsal, NV, in salty/alkaline desert about 60 miles east of Reno, receives a little rain and snow in winter; summers are dry and very hot.

During the ensuing years of testing, track and traffic conditions at the various sites has changed. Larger 14-inch tie plates and heavier welded rail (132 to 136 lb./yd.) were installed to carry heavier axle loadings and longer, faster trains. Traffic diminished in recent years and in 1986 many sites carried 70% to 85% of tonnages moved during the 1970's. Most tests had been ongoing for at least 33 years when last inspected in 1986.

Inspection and evaluation of test ties

At most sites the newly inserted ties were first inspected within a year or two after they were installed. Thereafter, they were inspected annually or, more recently, at intervals of several years.

At each examination, track-walking inspectors visually judge the condition of each test tie, mostly by the appearance of its upturned face; ends are examined, if necessary, to verify end splits. Inspectors may also test for decay, shatter, and spike-kill by prodding or striking suspected parts. They record the occurrence of any of the conditions defined below. The definitions serve more as a guide than as a specification to be closely adhered to by the test-tie inspector. Ties that were replaced by new ties ("renewals") are presumed to have become unserviceable from causes related to their condition at their final inspection. Ties that have been damaged abnormally, paved over by new crossings, or otherwise had their normal service disturbed were eliminated from consideration.

Definitions applying to test ties:

1. Bad check: Crack wider than 3/8 inch but usually shorter than the length of a crosstie.
2. Break: Open fracture across the width of the crosstie face.
3. Broom: Breaking down of the crosstie end into coarse, broom-like woody strands.
4. Check: Crack shorter than the length of the crosstie and not wider than 3/8 inch but not as severe as a bad check.
5. Cross grain: Wood fibers slope across the full width of the crosstie face between the rails.
6. Decay: Rot occurring in a crosstie usually at the base of a wide check or under tie plate; wood is soft, easily probed with a screwdriver, and is dull or hollow-sounding when struck.
7. Good tie: Crosstie with no defects save small checks not exceeding 1/8 inch in width.
8. Platecut: Upper surface of the tie plate lies flush with or below the face of the crosstie.
9. Renewal: Term used as a equivalent of replacement.
10. Twist: Crosstie appears twisted lengthwise with one corner of the exposed face raised above the grade.
11. Shatter: End of the crosstie is fragmented.
12. Spike-kill: Loose spike(s) in the crosstie.
13. Split: Crack continuous along the full length of the crosstie and wider than 3/8 inch.

Broom and twist, both uncommon and judged to be minor defects in these tests, have not been included in this report.

The authors inspected test ties only. The company's track inspectors periodically examine all ties in the track, including test ties, and mark for renewal any which they judge to be not functioning adequately. Ties marked for renewal usually had a combination of defects and were in poor overall condition.

RESULTS AND DISCUSSION

The tabulated results of these tests might best be viewed by regarding each site as an experiment. Irregularities between numbers of ties, and ages of ties, among various species-groups at a site cause difficulty in attempting more than general comparisons of their performance. When testing is ultimately completed, final evaluation can be made of the various species at a site and better comparisons can be made then too of performance of a particular species at different sites.

Condition of remaining ties

Most test ties that were still in track during 1986–87 inspections were at least 33 years old, and a few groups had reached 37 years.

Condition of the remaining test ties is indicated in Table 2. At sites where more than a few ties remained (Marion, Modoc Point., Bowman, King City 160, Palmdale, and Upsal), signs of wear were obvious among the aging survivors. Virtually all had become platecut, and evidence of spike kill was common. Other wear-related defects were less prevalent. Breakage was rare, but shattered ends were more common, especially so at Bowman and Upsal, and to a somewhat less degree at Palmdale. Causes

Table 2. Condition of ties in track: percent that had various defects at the last (1986–87) inspection. A tie often had more than one kind of defect.

Site, species & insertion year		Number of ties		Condition of ties in track						
		In test	In track	No bad checks or split	Bad check or split	Plate-cut	Spike kill	Decay	Break	Shatter
				- - - - - - percent of ties in track - - - - - -						
OREGON										
MARION[1]										
Douglas-fir	'53	119	93	71	29	100	32	1	0	14
White fir	'53	120	110	48	52	99	38	18	1	1
West coast hemlock	'53	120	98	27	73	94	70	50	1	10
Shasta fir	'53	118	60	52	48	98	63	12	0	8
Sitka spruce	'53	120	87	31	69	91	76	54	0	8
Incense cedar	'53	117	104	90	10	95	58	3	1	3
Lodgepole pine	'53	116	61	54	46	100	30	16	0	3
MODOC PT.										
Douglas-fir	'53	106	61	87	13	100	30	0	0	13
White fir	'53	119	20	100	0	100	35	5	10	20
West coast hemlock	'53	92	22	86	14	100	59	9	5	27
Shasta fir	'53	112	53	91	9	100	32	2	0	8
Sitka spruce	'53	48	5	67	33	100	67	0	0	0
Sitka spruce	'54	58	8	75	25	100	75	0	0	0
Incense cedar	'53	118	68	93	7	100	26	0	1	10
Lodgepole pine	'53	119	23	65	35	100	43	4	0	4
Mt. hemlock	'54	117	20	50	50	95	45	5	0	0
CRESCENT LK.										
Douglas-fir	'53	120	18	82	18	100	33	0	0	6
White fir	'53	120	4	100	0	75	50	25	0	25
West coast hemlock	'53	120	7	100	0	100	0	0	0	29
Shasta fir	'53	120	13	85	15	100	8	0	0	0
Sitka spruce	'53	119	1	100	0	100	0	0	0	0
Incense cedar	'53	119	31	97	3	100	19	0	0	6
Lodgepole pine	'53	120	6	33	67	100	67	0	0	0
Mt. hemlock	'56	95	2	50	50	100	50	0	0	50
CALIFORNIA										
BOWMAN										
Douglas-fir	'49	50	19	79	21	100	95	42	0	21
Douglas-fir	'50	91	64	67	33	100	73	9	0	27
White fir	'50	100	93	62	38	100	66	13	1	16
White fir	'52	50	45	69	31	98	47	4	0	18
West coast hemlock	'49	50	42	64	36	100	69	14	0	5
Shasta fir	'53	46	45	62	38	100	64	18	2	16
Shasta fir	'54	50	49	65	35	100	53	8	2	16
Sitka spruce	'52	98	91	81	19	100	44	4	0	10
Incense cedar	'52	99	98	82	18	97	31	2	1	5
Lodgepole pine	'52	93	80	41	59	100	61	10	0	1
KING CITY 160										
Douglas-fir	'53	77	13	77	23	92	46	0	0	15
White fir	'53	139	35	89	11	100	17	0	0	3
Shasta fir	'53	96	32	97	3	100	16	0	0	3
Sitka spruce	'52	50	22	95	5	100	5	0	0	5
Incense cedar	'52	97	51	80	20	100	24	0	0	2

Table 2—Continued

Site, species & insertion year		Number of ties: In test	Number of ties: In track	Condition of ties in track: No bad checks or split	Bad check or split	Plate-cut	Spike kill	Decay	Break	Shatter
				----- percent of ties in track						----------
KING CITY 164										
Douglas-fir	'50	28	8	100	0	100	25	0	0	0
White fir	'50	91	5	100	0	100	40	0	0	0
West coast hemlock	'48	180	21	95	5	95	71	5	0	0
Incense cedar	'54	90	35	4	6	60	14	0	0	0
Lodgepole pine	'50	82	5	20	80	80	40	0	0	0
Mt. hemlock	'54	99	35	61	39	75	11	0	0	0
Ponderosa pine	'56	116	61	90	10	82	7	0	2	2
PALMDALE										
Douglas-fir	'49	95	26	73	27	100	42	4	0	12
White fir	'50	93	32	91	9	100	47	0	0	19
West coast hemlock	'49	78	19	79	21	100	32	5	0	5
Shasta fir	'53	94	52	90	10	98	40	0	0	27
Incense cedar	'53	86	54	76	24	100	56	0	13	4
Lodgepole pine	'50	87	17	71	29	100	29	0	0	12
Mt. hemlock	'55	84	71	66	34	96	23	0	0	6
Ponderosa pine	'56	95	83	72	28	100	23	0	2	5
LOMA LINDA										
Douglas-fir	'49	50	5	80	20	100	20	0	0	0
White fir	'49	49	0	--	--	--	--	--	--	--
West coast hemlock	'49	45	2	100	0	100	0	0	0	0
Shasta fir	'53	62	1	0	100	100	100	0	0	0
Incense cedar	'52	49	2	100	0	100	0	0	0	0
Lodgepole pine	'51	33	8	12	88	100	13	0	0	0
Mt. hemlock	'54	42	11	55	45	100	9	0	0	0
Ponderosa pine	'56	24	4	75	25	100	0	0	0	0
SODA SPRINGS										
Douglas-fir	'50	150	27	100	0	100	0	0	0	4
White fir	'50	100	20	90	10	100	0	0	0	0
West coast hemlock	'48	170	5	100	0	100	60	0	0	0
Shasta fir	'53	50	2	50	50	100	0	0	0	0
Sitka spruce	'52	46	20	85	15	100	0	0	0	0
Incense cedar	'52	99	16	100	0	100	13	0	0	0
Lodgepole pine	'50	100	9	56	44	100	0	0	0	0
Mt. hemlock	'54	100	36	86	14	100	0	0	0	0
NEVADA										
UPSAL										
Douglas-fir	'54	119	61	93	7	98	44	0	2	28
White fir	'54	70	45	93	7	100	33	0	0	24
West coast hemlock	'54	169	47	89	11	100	64	0	0	19
Shasta fir	'54	120	84	95	5	96	24	0	0	17
Sitka spruce	'54	117	11	91	9	100	82	0	0	18
Incense cedar	'54	117	70	89	11	99	61	0	0	9
Lodgepole pine	'54	119	68	44	56	100	40	0	0	10
Mt. hemlock	'54	119	63	43	57	100	43	0	3	17

1 Last reported inspection of white fir, west coast hemlock and Sitka spruce at Marion, OR in 1983.

of more shatter at these sites is not known, but locomotives pounding uphill at Bowman and high tonnage figures at Upsal (Table 1) may have contributed.

Generally, most of the remaining ties, except those at Marion, were not badly checked or split. It is presumed that because such defects are highly visible, the track inspector would have previously marked such ties for renewal - especially so if other defects were also present.

Some of the remaining ties of each species in test at Marion and Bowman were decaying. Climates at those sites would be most likely to provide prolonged periods of both moisture and the mild temperatures needed for active fungal growth (Table 1). A few ties of some species at Modoc Point also contained decay, but it was rare or absent at the other sites where climates generally are drier and/or less temperate. Incense cedar, including both remaining and renewed ties, has resisted decay at both Marion and Bowman (Table 5). Other species performed less consistently at those two high-hazard sites. For example, remaining west coast hemlock and Sitka spruce, both notably poor performers at Marion, have fared better at Bowman where differences between decay resistance of most species was less pronounced.

Service life of renewed ties

The average service life of renewed ties at each test site is listed by species in Table 3. Comparisons made between service-life figures should consider the percentages of ties renewed as well as their average years of service.

MacLean's method (MacLean, J.D. 1951) was used to predict the ultimate life of ties (Table 3), except those in small test groups of less than 50 ties, or in groups that had less than 30 percent of the ties renewed (Hunt and Garratt, 1967 suggest that at least 10 or 15 percent be renewed). It should be recognized that the predictions obtained by this method are only approximations. Those listed in Table 3 sometimes underestimate the actual life of ties if the percentage of renewals is very high, usually if above 80 to 90 percent.

Sites having numerous renewals

Renewals have been most numerous at Loma Linda, Crescent Lake, and also among most of the species tested at the Modoc Point and Soda Springs sites.

At Loma Linda, Douglas-fir ties are outlasting those of white fir and Shasta fir. Ties of west coast hemlock, incense cedar, and lodgepole pine should perform about as well as those of Douglas-fir. Mountain hemlock and ponderosa pine ties will outlast those of Douglas-fir by several years at least.

Douglas-fir ties at Crescent Lake are outlasting all other species tested there, except incense cedar and possibly lodgepole pine. White fir, west coast hemlock, Shasta fir, Sitka spruce, and mountain hemlock have been inferior to Douglas-fir. The average lives of ties of those five species are expected to be 2 to 6 years less than that of Douglas-fir ties at the site.

Differences between performance of Douglas-fir and most other species at Modoc Point were not readily discernible. Douglas-fir is outlasting mountain hemlock and may also surpass white fir and Sitka spruce. Shasta fir and perhaps west coast hemlock and lodgepole pine may ultimately perform about as well as Douglas-fir. Incense cedar ties are presently outlasting those of Douglas-fir.

Douglas-fir ties at Soda Springs are outlasting those of west coast hemlock. At the same site, lodgepole pine and perhaps Shasta fir ties may prove to be about as serviceable as those of Douglas-fir. Ties of white fir, Sitka spruce, incense cedar, and mountain hemlock are outlasting those of Douglas-fir.

At the Crescent Lake, Loma Linda, and Soda Springs sites where tests are now complete, or nearly so, some species have performed about as well as, or better than, Douglas-fir. They are indicated below by (✓ = similar to Douglas-fir) and (+ = better than Douglas-fir). Species that did not perform as well as Douglas-fir are characterized by (− = inferior to Douglas-fir).

	Crescent Lake	Loma Linda	Soda Springs
White fir	−	−	+
West coast hemlock	−	✓	−
Shasta fir	−	−	✓
Sitka spruce	−	no test	+
Incense cedar	+	✓	+
Lodgepole pine	✓	✓	✓
Mountain hemlock	−	+	+
Ponderosa pine	no test	+	no test

Sites having limited renewals

The ultimate performance of ties of different species is less predictable at sites where renewals have been less numerous, but species whose performance can be compared readily with Douglas-fir's will be commented on.

For example, renewals of Douglas-fir, Shasta fir, and lodgepole pine at Marion (Table 3) have had the same average 33-year service lives, but the more numerous renewals of Shasta fir and lodgepole pine ties (49 and 47 percent vs. 21 percent for Douglas-fir) make it likely that ties of those first two species will ultimately not last as long as those of Douglas-fir. At Marion, Douglas-fir probably will also outlast Sitka spruce and west coast hemlock, but not incense cedar. White fir ties there have had few renewals,

Table 3. Service life of renewed ties.

Site, species & insertion year.		Number of ties		Percent	Service life		Predicted ultimate life[2]
		In test	Renewed	Renewed	Average	SD	Average
					Yrs.	Yrs.	Yrs.
OREGON							
MARION[1]							
Douglas-fir	'53	119	25	21	33	3	--
White fir	'53	120	10	8	27	0	--
West coast hemlock	'53	120	2	12	25	5	--
Shasta fir	'53	118	58	49	33	3	36
Sitka spruce	'53	120	33	28	26	3	43
Incense cedar	'53	117	13	11	32	4	--
Lodgepole pine	'53	116	55	47	33	11	37
MODOC PT.							
Douglas-fir	'53	106	43	42	26	9	37
White fir	'53	119	99	83	28	7	29
West coast hemlock	'53	92	70	76	28	5	30
Shasta fir	'53	112	59	53	28	7	34
Sitka spruce	'53	48	42	88	28	6	--
Sitka spruce	'54	58	50	86	27	6	27
Incense cedar	'53	118	50	42	28	9	37
Lodgepole pine	'53	119	96	81	29	4	29
Mt. hemlock	'54	117	97	83	26	6	27
CRESCENT							
Douglas-fir	'53	120	103	85	26	8	29
White fir	'53	120	116	97	22	7	25
West coast hemlock	'53	120	113	94	23	7	26
Shasta fir	'53	120	107	89	24	7	28
Sitka spruce	'53	119	118	99	21	6	20
Incense cedar	'53	119	88	74	27	7	31
Lodgepole pine	'53	120	114	95	27	6	26
Mt. hemlock	'56	95	93	98	20	7	22
CALIFORNIA							
BOWMAN							
Douglas-fir	'49	50	31	62	22	6	36
Douglas-fir	'50	91	27	30	22	6	44
White fir	'50	100	7	7	23	5	--
White fir	'52	50	5	10	22	5	--
West coast hemlock	'49	50	8	16	27	0	--
Shasta fir	'53	46	1	2	23	0	--
Shasta fir	'54	50	1	2	22	0	--
Sitka spruce	'52	98	7	7	27	8	--
Incense cedar	'52	99	1	1	24	0	--
Lodgepole pine	'52	93	13	14	22	4	--
KING CITY 160							
Douglas-fir	'53	77	64	83	29	6	
White fir	'53	139	104	75	32	3	30
Shasta fir	'53	96	64	67	32	4	32
Sitka spruce	'52	50	28	56	33	3	35
Incense cedar	'52	97	46	47	31	7	37
KING CITY 164							
Douglas-fir	'50	28	20	71	35	3	--
White fir	'50	91	86	95	33	5	27
West coast hemlock	'48	180	159	88	33	7	31
Incense cedar	'54	90	55	61	30	5	32
Lodgepole pine	'50	82	77	94	33	5	28
Mt. hemlock	'54	99	63	64	32	1	31
Ponderosa pine	'56	116	55	47	30	0	33

Table 3—Continued

Site, species & insertion year.		Number of ties		Percent	Service life		Predicted ultimate life[2]
		In test	Renewed	Renewed	Average	SD	Average
PALMDALE							
Douglas-fir	'49	95	69	73	27	5	34
White fir	'50	93	61	66	25	5	36
West coast hemlock	'49	78	59	76	27	5	33
Shasta fir	'53	94	42	45	25	3	36
Incense cedar	'53	86	32	37	27	1	38
Lodgepole pine	'50	87	70	80	27	5	32
Mt. hemlock	'55	84	13	15	24	2	--
Ponderosa pine	'56	95	12	13	24	0	--
LOMA LINDA							
Douglas-fir	'49	50	45	90	26	6	30
White fir	'49	49	49	100	25	5	--
West coast hemlock	'49	45	43	96	27	5	--
Shasta fir	'53	62	61	98	23	6	20
Incense cedar	'52	49	47	96	27	8	--
Lodgepole pine	'51	33	25	76	24	9	--
Mt. hemlock	'54	42	31	74	31	2	--
Ponderosa pine	'56	24	20	83	29	2	--
SODA SPRINGS							
Douglas-fir	'50	150	123	82	27	8	31
White fir	'50	100	80	80	31	6	32
West coast hemlock	'48	170	165	97	25	8	27
Shasta fir	'53	50	48	96	29	4	25
Sitka spruce	'52	46	26	57	32	2	--
Incense cedar	'52	99	83	84	31	4	29
Lodgepole pine	'50	100	91	91	31	4	29
Mt. hemlock	'54	100	64	64	29	3	31
NEVADA							
UPSAL							
Douglas-fir	'54	119	58	49	25	3	34
White fir	'54	70	25	36	24	3	37
West Coast hemlock	'54	169	122	72	24	4	30
Shasta fir	'54	120	36	30	24	4	39
Sitka spruce	'54	117	106	91	24	4	26
Incense cedar	'54	117	47	40	25	2	36
Lodgepole pine	'54	119	51	43	25	2	35
Mt. hemlock	'54	119	56	47	24	5	36

1 Last reported inspection of white fir, west coast hemlock and Sitka spruce ties at Marion, OR in 1983.

2 Predicted according to MacLean, J. D., 1951, Percentage renewals and average life of railway ties, U.S. Forest Prod. Lab. Rep. R886, Madison, WI, if tie renewal was ≥30 percent.

their performance at this time is not readily comparable with Douglas-fir.

The comparatively high percentages of renewal of Douglas-fir ties at Bowman may be influenced in some cases by their greater age. However, west coast hemlock and some white fir ties, although as old as Douglas-fir, are performing better. Other species at the site are less comparable with Douglas-fir because of tie-age differences of 3 to 5 years and few renewals.

Douglas-fir at King City, near milepost 160, is not performing as well as the other species at that site. They include white fir, Shasta fir, Sitka spruce, and incense cedar. All ties in test there are of similar age.

Douglas-fir ties at King City 164 are outlasting those of white fir, west coast hemlock, and lodgepole pine. Other species at the site are less readily comparable with Douglas-fir at this time.

Incense cedar, and possibly mountain hemlock and ponderosa pine ties are likely to outlast those of

Douglas-fir at Palmdale. West coast hemlock has performed about as well as Douglas-fir, but lodgepole pine has been slightly inferior. Other species are less readily comparable.

Ties of most species in test at Upsal are performing about as well as, or slightly better than, Douglas-fir. They include white fir, Shasta fir, and mountain hemlock; slightly better performers are of incense cedar and lodgepole pine. Ties of west coast hemlock and Sitka spruce are not lasting as long as those of Douglas-fir.

Condition of renewed ties

The condition of renewed ties is indicated in Table 4.

Bad checks and splits, prevalent in lodgepole pine with its high percentage (95%) of boxed-heart ties, and also plate cutting were the most common defects. In some cases, substantial percentages of the renewed ties were neither badly checked nor split, but they presumably suffered from plate cutting and probably other less common forms of wear as well, such as spike kill, shattered ends, and breakage. Those less common defects occurred to varying degrees, and commonly in combination, at all sites. Breakage was generally rare; it occurred most regularly in incense cedar ties.

The prevalence of wear-induced defects did not seem clearly related to tonnage alone. For example, plate cutting, spike kill, and shatter at Upsal (1,785 million gross tons) was generally less prevalent than at King City 160 (521 M.G.T.). Both sites were on straight, level track with similar train speeds but had different climates (Table 1). Nor did curved tracks at Crescent Lake, King City 164, and Soda Springs seem to induce notably greater incidence of plate cutting, as might be expected, at those sites. Percentages of plate-cut ties at Crescent Lake were, in fact, relatively low.

Decay in renewed ties has been limited mainly to the Marion and, to lesser degree, Modoc Point sites. It also occurred at both King City sites and in a few renewals at Crescent Lake. At Marion, where decay has been most prevalent, it occurred among renewed ties of all species tested, but least frequently among those of Douglas-fir and incense cedar.

Tie age when decay and wear appeared

The age of test ties, including both remaining and renewed ties, when decay and various forms of wear became apparent is noted in Table 5.

Decay, which was most prevalent at Marion, developed there mostly in ties of west coast hemlock (51%) and Sitka spruce (50%) at an average tie age of about 25 years. Fewer ties of Shasta fir (35%), lodgepole pine (32%), and white fir (23%) became decayed, and they tended to be a few years older than 25 when decay appeared. Decay was minimal in Douglas-fir (2%) and incense cedar (5%); it appeared in a few of those ties at an average age of about 30 years.

At Modoc Point and Bowman where the decay hazard was obvious, but less severe than at Marion, decayed ties occurred with erratic frequency among the various species. Douglas-fir and Shasta fir ties performed well at Modoc Point, but not at Bowman. Incense cedar ties were most consistently resistant to decay at sites where it was common. Only 5% or fewer of them had decayed at average ages of 31 years or older.

Tie age at which plate cutting developed seemed to be somewhat site specific, tending to differ more between sites than within a site. It developed most slowly at sites in Oregon, usually appearing at an average tie age of about 20 to 27 years. It was particularly slow at Marion where tonnage was least and there were no curves. High tonnage and especially curves are thought to accelerate plate cutting, and a cursory comparison of plate cutting at Crescent Lake (curves) vs. Modoc Point (straight track) tends to bear that out although smaller percentages of ties were actually cut on curved track at Crescent. However, similar comparisons at King City 164 (curves) vs. King City 160 (straight) and at Soda Springs (curves) vs. Bowman (straight and uphill) are less supportive. High tonnage in itself has not translated to rapid plate cutting. Moderate tonnage at Loma Linda (873 million gross tons) was only half of that at Upsal (1,785 M.G.T.), but cutting developed twice as rapidly at the former site. Incense cedar, a relatively soft and weak wood, generally did not become platecut any more rapidly than denser woods of other species.

Plate cutting may also be influenced by climate, although that effect has not been very obvious during our inspections. A notable exception had occurred in the past at a former site near Garnet, CA, where a desert climate and wind regularly drifted sand over the ties. Plate cutting there developed in ties at an average age of only 5 to 7 years.* The sites listed in Table 1 of this report include a wide range of climatic conditions, but tie performance at different sites may not be readily comparable because of the diversity of other characteristics, mainly curves and tonnage, that might also affect plate cutting. A comparison of two straight-track sites carrying "similar" tonnages, but having different climates, shows plate cutting to be faster at Palmdale, a high-desert site, than at Marion where the climate

*Unpublished information from 1983 inspection

Table 4. Condition of renewed ties: percent that had various defects at last inspection (1986–87). A tie often had more than one kind of defect.

Site, species & insertion year		Number of ties: In test	Number of ties: Renewed	Condition of renewed ties: No bad checks or split	Bad check or split	Plate-cut	Spike kill	Decay	Break	Shatter
				percent of renewed ties						
OREGON										
MARION[1]										
Douglas-fir	'53	119	25	24	76	80	60	4	0	16
White fir	'53	120	10	30	70	40	0	80	10	20
West coast hemlock	'53	120	22	23	77	23	0	55	5	18
Shasta fir	'53	118	58	28	72	90	57	48	3	25
Sitka spruce	'53	120	33	9	91	52	0	39	0	30
Incense cedar	'53	117	13	62	38	85	62	23	8	8
Lodgepole pine	'53	116	55	11	89	87	40	49	9	16
MODOC PT.										
Douglas-fir	'53	106	45	44	56	78	27	0	4	13
White fir	'53	119	99	33	67	89	30	14	5	13
West coast hemlock	'53	92	70	21	79	66	24	21	6	16
Shasta fir	'53	112	59	42	58	88	24	5	2	10
Sitka spruce	'53	48	42	17	83	81	31	12	0	21
Sitka spruce	'54	58	50	18	82	92	68	52	2	10
Incense cedar	'53	118	50	60	40	88	34	0	16	2
Lodgepole pine	'53	119	96	17	83	92	19	4	7	8
Mt. hemlock	'54	117	97	8	92	86	41	14	2	7
CRESCENT LK.										
Douglas-fir	'53	120	102	50	50	55	14	0	0	12
White fir	'53	120	116	38	62	42	8	3	2	6
West coast hemlock	'53	120	113	32	68	43	9	2	0	10
Shasta fir	'53	120	107	37	63	56	7	0	0	5
Sitka spruce	'53	119	118	11	89	57	4	1	2	6
Incense cedar	'53	119	88	56	44	77	20	0	2	16
Lodgepole pine	'53	120	114	15	85	70	16	2	2	7
Mt. hemlock	'56	95	93	2	98	46	8	0	1	2
CALIFORNIA										
BOWMAN										
Douglas-fir	'49	50	31	32	68	65	3	0	0	13
Douglas-fir	'50	91	27	22	78	63	0	0	4	4
White fir	'50	100	7	14	86	71	0	0	14	0
White fir	'52	50	5	0	100	60	0	0	0	20
West coast hemlock	'49	50	8	12	88	100	0	0	0	0
Shasta fir	'53	46	1	0	100	100	0	0	0	0
Shasta fir	'54	50	1	0	100	0	0	0	0	0
Sitka spruce	'52	98	7	29	71	57	43	0	57	57
Incense cedar	'52	99	1	100	0	100	0	0	0	0
Lodgepole pine	'52	93	13	0	100	77	0	0	0	0
KING CITY 160										
Douglas-fir	'53	77	64	36	64	94	56	2	0	38
White fir	'53	139	104	72	28	99	46	1	0	13
Shasta fir	'53	96	64	64	36	100	45	2	0	11
Sitka spruce	'52	50	28	79	21	100	39	0	0	14
Incense cedar	'52	97	46	61	39	91	52	0	17	9

Table 4—Continued

Site, species & insertion year		Number of ties: In test	Number of ties: Renewed	Condition of renewed ties: No bad checks or split	Bad check or split	Plate-cut	Spike kill	Decay	Break	Shatter
				- - - - - - - - percent of renewed ties - - - - - - - -						
CALIFORNIA (cont'd)										
KING CITY 164										
Douglas-fir	'50	28	20	75	25	100	70	5	0	25
White fir	'50	91	86	60	40	98	43	3	0	9
West coast hemlock	'48	180	159	34	66	96	58	29	0	6
Incense cedar	'54	90	55	65	35	82	64	2	25	11
Lodgepole pine	'50	82	77	5	95	97	48	3	0	4
Mt. hemlock	'54	99	63	19	81	95	41	2	0	3
Ponderosa pine	'56	116	55	36	64	98	36	5	4	0
PALMDALE										
Douglas-fir	'49	95	69	51	49	96	0	0	0	7
White fir	'50	93	61	59	41	97	2	0	0	13
West coast hemlock	'49	78	59	53	47	97	0	0	0	3
Shasta fir	'53	94	42	52	48	93	0	0	2	19
Incense cedar	'53	86	32	41	59	100	0	0	3	0
Lodgepole pine	'50	87	70	14	86	100	0	0	0	1
Mt. hemlock	'55	84	13	31	69	92	8	0	0	8
Ponderosa pine	'56	95	12	25	75	100	0	0	0	0
LOMA LINDA										
Douglas-fir	'49	50	45	36	64	100	2	0	0	2
White fir	'49	49	49	39	61	100	0	0	0	6
West coast hemlock	'49	45	43	30	70	100	7	0	0	2
Shasta fir	'53	62	61	51	49	98	5	0	3	8
Incense cedar	'52	49	47	66	34	100	9	0	2	4
Lodgepole pine	'51	33	25	36	64	80	12	0	0	4
Mt. hemlock	'54	42	31	68	32	100	0	0	0	0
Ponderosa pine	'56	24	20	70	30	100	15	0	0	0
SODA SPRINGS										
Douglas-fir	'50	150	123	49	51	74	6	0	2	15
White fir	'50	100	80	63	37	94	6	0	0	11
West coast hemlock	'48	170	165	22	78	66	8	0	2	5
Shasta fir	'53	50	48	81	19	98	0	0	2	6
Sitka spruce	'52	46	26	88	12	100	4	0	0	4
Incense cedar	'52	99	83	69	31	98	11	0	2	4
Lodgepole pine	'50	100	91	18	82	98	5	0	1	5
Mt. hemlock	'54	100	64	69	31	98	5	0	0	2
NEVADA										
UPSAL										
Douglas-fir	'54	119	58	84	16	78	0	0	2	10
White fir	'54	70	25	56	44	92	0	0	0	0
West coast hemlock	'54	169	122	37	63	84	0	0	2	20
Shasta fir	'54	120	36	69	31	83	0	0	0	6
Sitka spruce	'54	117	106	39	61	89	0	0	3	27
Incense cedar	'54	117	47	85	15	89	0	0	15	2
Lodgepole pine	'54	119	51	10	90	96	0	0	4	2
Mt. hemlock	'54	119	56	11	89	66	0	0	2	4

[1] Last reported inspection of white fir, west coast hemlock and Sitka spruce ties at Marion, OR in 1983.

Table 5. Average age of ties when decay and various forms of wear became apparent and percent of ties in test that were affected.

Site, species & insertion year		Ties in test	Decay			Plate-cut			Spike kill			Shatter		
			Ave.	SD		Ave.	SD		Ave.	SD		Ave.	SD	
		No.	Yrs.	----	(%)	Yrs.	----	(%)	Yrs.	----	(%)	Yrs.	----	(%)
OREGON														
MARION[1]														
Douglas-fir	'53	119	29	2	(2)	27	2	(96)	32	1	(38)	28	2	(14)
White fir	'53	120	25	4	(23)	27	2	(94)	28	1	(35)	24	2	(2)
West coast hemlock	'53	120	24	3	(51)	27	1	(81)	28	1	(57)	26	2	(12)
Shasta fir	'53	118	30	4	(35)	27	2	(94)	31	2	(60)	27	4	(17)
Sitka spruce	'53	120	25	3	(50)	26	3	(80)	29	2	(55)	25	3	(14)
Incense cedar	'53	117	31	3	(5)	28	3	(94)	32	2	(58)	28	4	(3)
Lodgepole pine	'53	116	29	3	(32)	25	2	(91)	32	2	(34)	28	4	(9)
MODOC PT.														
Douglas-fir	'53	106	--	-	(0)	23	4	(91)	29	4	(4)	28	7	(13)
White fir	'53	119	25	4	(13)	21	5	(91)	28	1	(31)	27	5	(14)
West coast hemlock	'53	92	25	5	(13)	25	2	(74)	28	2	(33)	24	8	(18)
Shasta fir	'53	112	27	4	(4)	23	4	(94)	29	2	(28)	27	3	(9)
Sitka spruce	'53	48	28	1	(10)	23	5	(83)	27	2	(35)	22	6	(19)
Sitka spruce	'54	58	23	4	(45)	20	3	(93)	26	2	(69)	25	2	(9)
Incense cedar	'53	118	--	-	(0)	22	5	(95)	29	2	(30)	31	2	(7)
Lodgepole pine	'53	119	27	3	(4)	22	3	(93)	28	1	(24)	26	4	(8)
Mt. hemlock	'54	117	26	3	(13)	20	5	(87)	27	2	(42)	25	2	(6)
CRESCENT LK.														
Douglas-fir	'53	120	--	-	(0)	21	4	(65)	30	3	(17)	22	6	(11)
White fir	'53	120	31	2	(4)	19	6	(43)	30	2	(9)	20	10	(7)
West coast hemlock	'53	120	20	0	(2)	21	5	(47)	27	8	(8)	23	7	(11)
Shasta fir	'53	120	--	-	(0)	22	4	(61)	30	3	(7)	15	6	(4)
Sitka spruce	'53	119	30	0	(1)	16	6	(57)	19	9	(4)	16	5	(6)
Incense cedar	'53	119	--	-	(0)	22	4	(83)	32	2	(20)	24	6	(13)
Lodgepole pine	'53	120	30	3	(2)	21	4	(72)	30	3	(18)	27	4	(7)
Mt. hemlock	'56	95	--	-	(0)	18	2	(47)	27	3	(8)	20	9	(3)
CALIFORNIA														
BOWMAN														
Douglas-fir	'49	50	35	2	(16)	16	2	(78)	31	2	(38)	26	7	(16)
Douglas-fir	'50	91	35	2	(7)	16	3	(89)	32	2	(52)	30	4	(20)
White fir	'50	100	33	3	(12)	16	3	(98)	33	3	(61)	30	4	(15)
White fir	'52	50	31	0	(4)	25	4	(94)	30	2	(42)	28	2	(18)
West coast hemlock	'49	50	34	2	(12)	16	2	(100)	33	2	(58)	37	0	(4)
Shasta fir	'53	46	30	0	(19)	21	3	(100)	29	2	(63)	30	3	(15)
Shasta fir	'54	50	28	1	(8)	24	5	(98)	29	2	(52)	28	4	(16)
Sitka spruce	'52	98	34	0	(4)	26	4	(97)	31	2	(44)	27	6	(13)
Incense cedar	'52	99	33	2	(2)	25	4	(97)	31	3	(30)	30	3	(5)
Lodgepole pine	'52	93	32	1	(9)	17	4	(97)	30	2	(53)	34	0	(1)
KING CITY 160														
Douglas-fir	'53	77	30	0	(1)	18	6	(94)	30	2	(55)	29	4	(34)
White fir	'53	139	20	0	(1)	17	7	(99)	31	2	(39)	29	3	(11)
Shasta fir	'53	96	33	0	(1)	16	8	(100)	30	2	(35)	31	3	(8)
Sitka spruce	'52	50	--	-	(0)	20	6	(100)	32	2	(24)	33	1	(10)
Incense cedar	'52	97	--	-	(0)	14	6	(96)	31	2	(37)	28	5	(5)

Table 5—Continued

Site, species & insertion year		Ties in test	Decay Ave.	Decay SD		Plate-cut Ave.	Plate-cut SD		Spike kill Ave.	Spike kill SD		Shatter Ave.	Shatter SD	
		No.	Yrs.	----	(%)	Yrs.	----	(%)	Yrs.	----	(%)	Yrs.	----	(%)
CALIFORNIA (cont'd)														
KING CITY 164														
Douglas-fir	'50	28	30	0	(4)	25	7	(100)	33	2	(57)	33	3	(18)
White fir	'50	91	30	5	(3)	11	4	(98)	32	2	(43)	30	3	(9)
West coast hemlock	'48	180	35	2	(26)	23	3	(96)	34	2	(59)	32	3	(6)
Incense cedar	'54	90	29	0	(1)	21	7	(73)	29	4	(44)	29	2	(7)
Lodgepole pine	'50	82	33	0	(2)	18	4	(96)	34	2	(48)	32	4	(4)
Mt. hemlock	'54	99	26	0	(1)	22	7	(87)	30	2	(30)	29	3	(2)
Ponderosa pine	'56	116	27	2	(3)	18	6	(90)	27	2	(21)	27	0	(1)
PALMDALE														
Douglas-fir	'49	95	37	0	(1)	14	6	(97)	33	2	(12)	28	7	(8)
White fir	'50	93	--	-	(0)	11	5	(98)	34	3	(17)	26	7	(15)
West coast hemlock	'49	78	37	0	(1)	12	4	(97)	34	1	(8)	25	6	(4)
Shasta fir	'53	94	--	-	(0)	16	5	(96)	30	2	(22)	26	5	(23)
Incense cedar	'53	86	--	-	(0)	15	6	(100)	31	2	(35)	30	3	(2)
Lodgepole pine	'50	87	--	-	(0)	11	5	(100)	34	2	(6)	29	5	(3)
Mt. hemlock	'55	84	--	-	(0)	14	6	(95)	28	3	(20)	25	2	(6)
Ponderosa pine	'56	95	--	-	(0)	17	6	(100)	28	1	(20)	27	3	(4)
LOMA LINDA														
Douglas-fir	'49	50	--	-	(0)	9	3	(100)	26	8	(4)	15	0	(1)
White fir	'49	49	--	-	(0)	8	1	(100)	--	-	(0)	16	1	(6)
West coast hemlock	'49	45	--	-	(0)	9	3	(100)	33	1	(7)	15	0	(1)
Shasta fir	'53	62	--	-	(0)	6	3	(98)	21	8	(6)	20	6	(8)
Incense cedar	'52	49	--	-	(0)	6	2	(100)	27	4	(8)	31	0	(4)
Lodgepole pine	'51	33	--	-	(0)	8	4	(85)	31	3	(12)	25	0	(3)
Mt. hemlock	'54	42	--	-	(0)	12	5	(100)	32	0	(2)	--	-	(0)
Ponderosa pine	'56	24	--	-	(0)	9	6	(100)	22	8	(12)	--	-	(0)
SODA SPRINGS														
Douglas-fir	'50	150	--	-	(0)	16	1	(79)	33	0	(5)	25	7	(13)
White fir	'50	100	--	-	(0)	18	5	(95)	33	0	(5)	25	5	(9)
West coast hemlock	'48	170	--	-	(0)	17	2	(67)	34	2	(10)	28	5	(5)
Shasta fir	'53	50	--	-	(0)	14	4	(98)	--	-	(0)	25	5	(6)
Sitka spruce	'52	46	--	-	(0)	14	2	(100)	28	0	(2)	28	0	(2)
Incense cedar	'52	99	--	-	(0)	14	1	(98)	30	2	(11)	28	0	(3)
Lodgepole pine	'50	100	--	-	(0)	22	4	(98)	32	1	(5)	23	9	(5)
Mt. hemlock	'54	100	--	-	(0)	12	1	(99)	29	0	(3)	26	0	(1)
NEVADA														
UPSAL														
Douglas-fir	'54	119	--	-	(0)	21	4	(88)	29	3	(23)	25	6	(19)
White fir	'54	70	--	-	(0)	17	4	(97)	29	2	(21)	29	3	(16)
West coast hemlock	'54	169	--	-	(0)	18	5	(89)	28	2	(18)	21	6	(20)
Shasta fir	'54	120	--	-	(0)	18	5	(92)	30	2	(17)	27	6	(13)
Sitka spruce	'54	117	--	-	(0)	16	3	(90)	30	2	(8)	19	5	(26)
Incense cedar	'54	117	--	-	(0)	18	4	(95)	29	3	(37)	28	4	(6)
Lodgepole pine	'54	119	--	-	(0)	19	5	(98)	29	2	(23)	26	6	(7)
Mt. hemlock	'54	119	--	-	(0)	20	5	(84)	29	3	(23)	26	7	(11)

[1]Last reported inspection of white fir, west coast hemlock and Sitka spruce ties at Marion, OR in 1983.

is temperate and annual rainfall averages ~40 inches (Tables 1, 5). Conversely, at two similar low-rainfall desert sites having different total gross tonnages (Palmdale, 8 inches of rain and 1,106 million GT *vs.* Upsal, 5 inches and 1,785 million GT), plate cutting was again most rapid at Palmdale (Table 5), despite having less tonnage carried there. This Palmdale *vs.* Upsal comparison contradicts the reasonable expectation that plate cutting and tonnage should be directly related.

Spike kill developed in ties more slowly than plate cutting. It appeared among ties that usually had an average age of at least 20 years, and averages exceeding 30 years were common. At sites where it was most prevalent it occurred in more than half of the ties of most species. At other sites, it seldom occurred in more than 10 percent of the ties of any species. Neither tonnage, track curvature, nor species had consistent effects on the prevalence or rapidity of spike killing. During in-track tie inspections, it was seen to be associated with decay pockets in the tie-plate area. That observation apparently was not frequent enough to be clearly reflected in data in Table 5 on spike kill in decay-susceptible species at Marion. Spike kill and decay were mutually prevalent in one group of Sitka spruce ties at Modoc Point, but otherwise the analogy was not generally evident there, nor at other sites where both defects occurred.

Density is the most important wood property affecting withdrawal of a spike (U.S.D.A. Wood Handbook, 1974). Ties of incense cedar (least dense wood tested) and Douglas-fir (most dense) usually were at about the same age when they became spike killed, but at most sites spike kill was more prevalent in the cedar ties.

Shatter has generally been less prevalent than spike kill and has tended to develop sooner. The average age of ties found to be shattered has usually been about 20 to 30 years. Fewer than 20 percent of the ties of a species have been shattered at most sites, and figures below 10 percent were common. The generally low incidence of shattered ties makes comparisons between species questionable, but percentages of incense cedar, lodge pole pine and west coast hemlock ties that shattered were no more than that of Douglas-fir at most sites (80%) where those species were tested. Mountain hemlock and ponderosa pine ties also have performed well, but they sometimes had 6 or 7 fewer years in track.

Effect of initial condition of ties on their service life

The average service lives of renewed ties that were judged to have been in good condition, or to have had serious seasoning defects when newly inserted into track are listed in Table 6. Judgment was based on the condition of ties when first inspected in track, usually within one year after insertion. Ties at the King City 160 and 164 sites and at Bowman have been deleted. The first inspection at King City in 1959 was 3 to 11 years after insertion, and may not represent the initial condition of those ties. Also, renewals of most species at Bowman have been too scanty (Table 4) to provide useful information.

At sites where more numerous renewals provided larger samples, most of the renewed ties had originally been in good condition or were merely checked when inserted. That bias sometimes severely limited the sample size of those other ties that were badly checked or split when new, but it did indicate, in a reassuring way, that the newly installed ties were generally of good quality. However, renewals among lodgepole pine and mountain hemlock ties usually did include relatively high percentages (not necessarily high counts) of failed ties that had been badly checked or split when new.

New ties that were in good condition or were merely checked when inserted into track tended to have a somewhat longer average service life than those that were badly checked or split when installed. In cases where both categories of tie quality were reasonably well represented in a species, the difference often amounted to only 1 to 3 more years for the better ties. Greater differences did occur, particularly at Loma Linda where bad checks and splits in new ties have reduced their average life, in most species, by 3 to 8 years.

There were relatively few crossgrained ties, and their performance as judged by their service life, was erratic. Some lasted at least as long as their straight-grained counterparts; others were renewed in 20 years or less, but drastic reductions of tie life, to about 10 years, were uncommon.

SUMMARY AND CONCLUSIONS

The service life of Douglas-fir ties, the standard species used in these tests, has generally been medial among the included species. They have not clearly provided the longest service at any of the test sites; at Bowman and King City 160 they are failing faster than other species (Table 3). Oftentimes, there has been no singularly long-lasting species at a site. Rather, two or more species may provide similarly long life and thereby would allow a choice, or mix, of suitable species at a site.

The effects of tonnage and curves on tie longevity could not be clearly nor consistently demonstrated. An obvious site effect was the prevalence of decay in ties at Marion, Modoc Point, and Bowman. Some species that have been vulnerable to decay at those

Table 6. Average service life of renewed ties that were in good condition or merely checked, or had defective bad checks or split, or were cross grained when inserted into track - (n) = count of affected ties.

Site, species & insertion year		Number of ties renewed	Good or checked			Badly checked or split			Cross grained		
			Ave.	SD		Ave.	SD		Ave.	SD	
			Yrs.	----	(n)	Yrs.	----	(n)	Yrs.	----	(n)
OREGON											
MARION[1]											
Douglas-fir	'53	25	33	3	(21)	32	3	(4)	--	--	(0)
White fir	'53	10	27	0	(10)	--	--	(0)	--	--	(0)
West coast hemlock	'53	22	25	4	(19)	27	0	(1)	21	6	(3)
Shasta fir	'53	58	33	2	(38)	32	3	(20)	--	--	(0)
Sitka spruce	'53	33	26	4	(25)	27	0	(8)	--	--	(0)
Incense cedar	'53	13	32	3	(12)	27	0	(1)	--	--	(0)
Lodgepole pine	'53	55	32	3	(44)	38	24	(11)	--	--	(0)
MODOC PT.											
Douglas-fir	'53	43	27	8	(41)	16	7	(2)	16	12	(3)
White fir	'53	99	28	7	(90)	26	7	(9)	--	--	(0)
West coast hemlock	'53	70	28	5	(61)	23	8	(4)	28	2	(6)
Shasta fir	'53	59	29	6	(56)	18	9	(2)	9	0	(1)
Sitka spruce	'53	42	29	5	(34)	23	8	(4)	24	9	(4)
Sitka spruce	'54	50	28	5	(43)	21	9	(7)	--	--	(0)
Incense cedar	'53	50	28	9	(48)	27	0	(2)	--	--	(0)
Lodgepole pine	'53	96	29	4	(71)	27	5	(24)	27	0	(1)
Mt. hemlock	'54	97	28	5	(47)	27	5	(39)	17	8	(12)
CRESCENT											
Douglas-fir	'53	103	26	8	(86)	21	5	(5)	17	0	(1)
White fir	'53	116	22	7	(113)	--	--	(0)	14	4	(3)
West coast hemlock	'53	113	23	7	(118)	--	--	(0)	17	0	(1)
Shasta fir	'53	107	24	7	(102)	22	5	(2)	19	2	(2)
Sitka spruce	'53	118	21	6	(113)	25	4	(4)	22	5	(2)
Incense cedar	'53	88	28	7	(86)	15	3	(2)	--	--	(0)
Lodgepole pine	'53	114	28	6	(102)	22	6	(7)	24	4	(5)
Mt. hemlock	'56	93	23	6	(39)	17	6	(51)	12	2	(3)
CALIFORNIA											
PALMDALE											
Douglas-fir	'49	69	27	5	(62)	23	4	(2)	23	6	(3)
White fir	'50	61	26	5	(50)	25	3	(11)	--	--	(0)
West coast hemlock	'49	59	27	5	(57)	27	0	(1)	19	0	(1)
Shasta fir	'53	42	25	3	(31)	25	4	(10)	27	0	(1)
Incense cedar	'53	32	27	1	(18)	26	1	(14)	--	--	(0)
Lodgepole pine	'50	70	28	4	(27)	27	5	(42)	30	0	(1)
Mt. hemlock	'55	13	24	1	(7)	23	3	(6)	--	--	(0)
Ponderosa pine	'56	12	24	0	(7)	24	0	(5)	--	--	(0)
LOMA LINDA											
Douglas-fir	'49	45	29	5	(27)	22	5	(16)	11	0	(1)
White fir	'49	49	27	5	(34)	22	4	(14)	23	0	(1)
West coast hemlock	'49	43	29	6	(24)	26	3	(19)	--	--	(0)
Shasta fir	'53	61	24	5	(47)	19	8	(13)	--	--	(0)
Incense cedar	'52	47	28	7	(42)	29	6	(3)	--	--	(0)
Lodgepole pine	'51	25	29	7	(9)	21	9	(14)	21	0	(2)
Mt. hemlock	'54	31	31	0	(22)	31	0	(1)	29	4	(5)
Ponderosa pine	'56	20	29	0	(13)	28	3	(7)	--	--	(0)

Table 6—Continued

Site, species & insertion year		Number of ties renewed	Good or checked Ave.	SD		Badly checked or split Ave.	SD		Cross grained Ave.	SD	
			Yrs.	----	(n)	Yrs.	----	(n)	Yrs.	----	(n)
SODA SPRINGS											
Douglas-fir	'50	123	29	7	(77)	25	9	(36)	18	8	(7)
White fir	'50	80	31	5	(63)	29	7	(17)	--	--	(0)
West coast hemlock	'48	165	33	4	(46)	22	7	(106)	22	7	(11)
Shasta fir	'53	48	30	3	(46)	23	0	(1)	8	0	(1)
Sitka spruce	'52	26	32	0	(16)	31	2	(10)	--	--	(0)
Incense cedar	'52	83	31	3	(48)	30	5	(35)	--	--	(0)
Lodgepole pine	'50	91	33	3	(31)	30	4	(59)	--	--	(0)
Mt. hemlock	'54	64	29	4	(38)	30	2	(24)	30	0	(2)
NEVADA											
UPSAL											
Douglas-fir	'54	58	26	2	(54)	17	0	(1)	17	0	(1)
White fir	'54	25	25	3	(21)	23	4	(3)	17	0	(1)
West coast hemlock	'54	122	24	4	(101)	23	5	(16)	17	0	(4)
Shasta fir	'54	36	24	4	(28)	23	4	(8)	--	--	(0)
Sitka spruce	'54	106	24	4	(84)	23	4	(19)	20	4	(3)
Incense cedar	'54	47	25	2	(46)	26	0	(1)	--	--	(0)
Lodgepole pine	'54	51	26	2	(22)	26	2	(24)	24	4	(4)
Mt. hemlock	'54	56	26	1	(24)	23	6	(30)	17	7	(3)

[1] Last reported inspection of white fir, west coast hemlock and Sitka spruce ties at Marion, OR in 1983.

sites performed well elsewhere. Hence, the choice of species should be broader in dry, less temperate climates where the decay hazard is low. Under such conditions, the resistance of wood to defective wear, seasoning splits, spike kill, and breakage is paramount. None of the species tested seems outstandingly resistant to all of the various defects that cause ties to fail, but incense cedar generally seems to be providing the longest service.

A suggested approach toward using this information to predict life of these test species in tracks elsewhere would be:

a. Choose from our test sites those, if any, that best simulate the climate and track conditions in question. Preferably, use sites where renewals have been numerous and testing is most nearly complete.

b. Select species having best track records; consider both percentage of renewals and their average life. Differences of only 1 or 2 years between probable average life may be disregarded.

Conclusions based on the results of our periodic inspections of the test ties, most recently in 1986–87, are:

- Ties of some of the test species can perform at least as well as those of Douglas-fir, particularly so in areas where decay is not a hazard.

- The comparative performance of the different test species varies inconsistently among sites, but incense cedar is likely to be a top performer.
- The widest choice of serviceable species is possible at sites where the decay hazard is negligible.
- Bad checks and splits in new ties generally tend to reduce their ultimate service life. When reductions occur, they often amount to a few years or less. Reductions of the life of crossgrained ties are erratic and may occasionally be drastic.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the financial support provided by the Association of American Railroads for compiling and reporting this information.

The authors also wish to acknowledge the initiative and effort of R. M. Alpen, Southern Pacific Transportation Co., and R. D. Graham, Oregon State University, both retired, who implemented and monitored these tests many years ago. We appreciate the assistance of V. Shafarenko, formerly with the Assoc. of American Railroads and now with Gross & Janes Co., and of R. G. Gourley, Oregon State University, for his patience and effort in processing the data.

LITERATURE CITED

Graham, R. D. 1954. The air-seasoning and preservative treatment of crossties from eight Oregon conifers. Proc. of the American Wood Preservers' Assoc. 50:175–184.

Graham R.D. 1956. the preservative treatment of eight Oregon conifers by pressure processes. Proc. of the American Wood Preservers' Assoc. 53:118–138.

Hunt, G. M. and G. A. Garratt. 1967. Wood Preservation, 3rd Ed., pg. 278. McGraw-Hill. N.Y., N.Y.

MacLean, J. D. 1951. Percentage renewals and average life of railway ties. USDA Forest serv., Forest Prod. Lab., Report R-886, Madison, WI.

USDA Forest Products Laboratory. 1974. Wood Handbook, Agric. Handbook, No. 72. Washington, D.C.

The Air Seasoning and Preservative Treatment of Crossties from Eight Oregon Conifers[1]

Robert D. Graham

In Charge, Wood Preservation, Oregon Forest Products Laboratory, Corvallis, Oregon

Data are presented on (1) the change in weight, and grade of ties during air seasoning, and (2) the penetration and retentions obtained in this material at a commercial plant. The data indicate that all of the species can be air seasoned in less than one year without the development of serious defects and that most can be treated with good results.

This co-operative project was undertaken to determine the suitability of various Oregon woods for use as crossties and to obtain information on their air seasoning and preservative treating characteristics. The species used included incense cedar, Douglas fir, Shasta red fir, white fir, western hemlock, lodgepole pine, ponderosa pine and Sitka spruce. Ties from all of these species except ponderosa pine are being installed in test tracks in several western states.

Although Douglas fir undoubtedly will continue to be the primary crosstie species on the West Coast, there is every reason to expect other so-called secondary species to be used to supplement the crosstie supply. Their utilization is essential to good forest management practices if a well-balanced forest economy is to be maintained. A number of these species are available in comparatively large volumes and many will comprise an increasing portion of the remaining timber supply as the preferred species are harvested.

Since the strength properties of all of these species are lower than those of Douglas fir, the resulting service life also may be somewhat lower than the present 15–20 year average service life for Douglas fir in mainline track (the total average useful service life is about 30 years). However, their serviceability may be sufficient to warrant their use in certain proportions in mainline track and to a much greater extent in secondary track. Information on the seasoning and treating characteristics of these species will be useful in their utilization for many other purposes.

GENERAL PROCEDURE

The different species were obtained from areas that were considered representative of future sources of supply. Some were from young-growth stands while others were from old-growth material. The ties were graded at the loading point, shipped to Eugene, Oregon, for seasoning, regraded after seasoning as they were loaded onto trams, bored and incised, then treated. A number of ties from each species were weighed monthly during seasoning. Ties, selected at random, were weighed before and after treatment.

Grading

All species were graded by regular tie inspectors of the Southern Pacific Company to the specifications for Douglas fir railroad ties contained in paragraphs 405, 406 and 407 of the Standard Grading and Dressing Rules for West Coast Lumber, No. 14, published by the West Coast Lumbermen's Association. The grades were tallied as the ties were loaded for shipment. When the ties were regraded after seasoning, an additional ¼ inch was allowed for shrinkage during seasoning.

Seasoning

The ties were piled by species in 10 stacks of about 100 ties each. Each seasoning pile (Figure 1) was 2 stacks wide and 5 stacks deep. A ten-foot clearance was left between seasoning piles for the removal of ties. From 17 to 25 ties, well distributed throughout each seasoning pile,

[1] A co-operative project of the Oregon Forest Products Laboratory and the Southern Pacific Company.

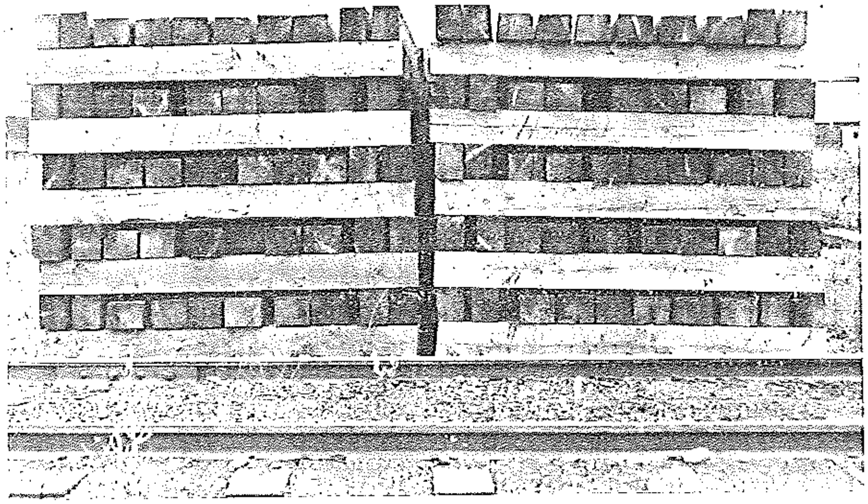

Figure 1.—Method of piling crossties for air seasoning.

were tagged and weighed monthly. Each tie was inserted in its original position after each weighing by means of a metal slide. Occasionally, groups of ties were chosen at random and weighed to check the validity of the original selection.

Specific Gravity and Moisture Content Determinations

Cross sections were cut from a number of ties of each species for specific gravity and moisture content measurements. The specific gravity was determined by water immersion and the moisture content by oven drying. Additional determinations will be made when ties from these species are treated in an experimental plant.

Preparation of Crossties for Treatment

The grade was marked with crayon on the end of each tie as it was loaded onto the tram. A lead-headed nail was driven into each tie and stamped with the grade. The position of the nail, as shown in the following, also indicated the grade.

Grade	Stamp	Position of Nail
Select	S	In center of tie
No. 1	1	Mid-way between center and edge
No. 2	2	Near edge

As the ties were unloaded at the boring mill a number of ties were pulled from each tram and weighed. Rings per inch and percent summerwood measurements were made on ties in each loaded tram after the ties had been bored for spike holes and incised. All ties but those in lodgepole pine group 1 were incised. Due to a mechanical failure of the horizontal borer, the ties treated during May and June of 1952 could not be bored for anti-split bolts. The letters and year LM 52 were stamped on the line end of each tie and the species letters and year were stamped on the other end.

Treating of Crossties

All ties described in this report were treated in the Southern Pacific Plant at Eugene, Oregon. The treating cylinder, which is 8 feet in diameter and 132 feet long, holds 960 ties loaded on 16 trams. The retort and Rueping tank are equipped with steam coils. The preservative is weighed into and out of the system in the scale tank.

The schedules employed (Table 4) were based largely on data developed by the Southern Pacific Company at their experimental plant in Oakland, California.

Weighing and Tagging Ties After Treatment

A number of ties from different trams in each charge were weighed after treatment to determine the retention. Borings were made to measure the penetration.

The ties were stored by species. All boxed-heart ties and badly checked free-of-heart-center ties were bored and anti-split bolts were inserted. A copper tag bearing the species letter and tie number was placed on the upper face about 8 inches from the line end of each tie. The number, grade and type of tie, and presence or absence of anti-split bolts was recorded for each tie.

DESCRIPTION OF MATERIAL

Crossties

All of the sawn, 7- by 9-inch by 8-foot ties were obtained in Oregon. Generally, the tie species were slightly lower in ring count, percent summerwood, and specific gravity (Table 1) than is considered average for the species. Douglas fir was average in these characteristics and lodgepole pine was above average. The percentage of boxed-heart ties in each species as shown below is indicative of the material from which the ties were cut.

Species	Boxed-heart ties (Percent)
Cedar, incense	47
Douglas fir	32
Fir, Shasta red	34
Fir, white	32
Hemlock, western	22
Pine, lodgepole	95
Spruce, Sitka	61

Preservative

The following composition and weight of the coal-tar creosote-petroleum solution (at 100 deg. F.) was typical of the preservative used:

Fraction	Specific gravity	Weight per gal. (Pounds)	Weight (Percent)	Volume (Percent)
Coal-tar creosote	1.080	9.00	25.0	23.2
Gasco distillate	0.987	8.22	25.0	25.5
Fuel oil	0.990	8.25	50.0	51.3

SEASONING RESULTS

The species included in this study either were seasoned or could be seasoned to a moisture content of 30 percent without the development of serious defects before fall if they were placed in the seasoning yard by early spring. Decay did develop in ponderosa pine ties brought into the seasoning yard during July and left over winter.

Changes in Weight and Moisture Content

During the two-year period in which the ties were weighed (Figures 2 and 3), they lost weight during the spring and summer months, but either lost very little or gained weight during the fall and winter months. In each of these years the first fall rains fell on September 15. Ties that were placed in the seasoning yard during the fall, winter and early spring months lost weight at an increasing rate from March through June, then at a decreasing rate through September. These ties usually dried to an average moisture content of less than 30 percent. Although ties brought in during the summer lost weight rapidly until September, their moisture content remained high over winter.

The winter of 1947–48, which was nearly normal in both precipitation and temperature, probably is typical of winter seasoning conditions in western Oregon. The cold, wet climatic conditions of the winter of 1948–49 are reflected in the sustained increased weight of the ties during that period.

The change in weight of the lightest tie, heaviest tie, and group average for each species are shown in Figure 3.

Condition of Ties

The condition of all ties after seasoning was good. The ends of ties contained end checks, but most of these checks were narrow and extended for only a short distance from the ends. Ties in the top layer of the seasoning piles were more prone to contain long checks. The Sitka spruce ties that had been in the yard for 43 months contained the most checks, but very few of these ties were severely checked. The end-checking of Shasta red fir ties was quite peculiar; the checks were irregular, and appeared to follow the rays for a short distance, then the annual rings for a short distance.

The change in grade during seasoning (Table 3) appeared to be a fair indication as to the condition of the ties. There was a marked decrease in the percentage of select ties, a marked increase in the percentage of number 1 ties, and a slight increase in the percentage of num-

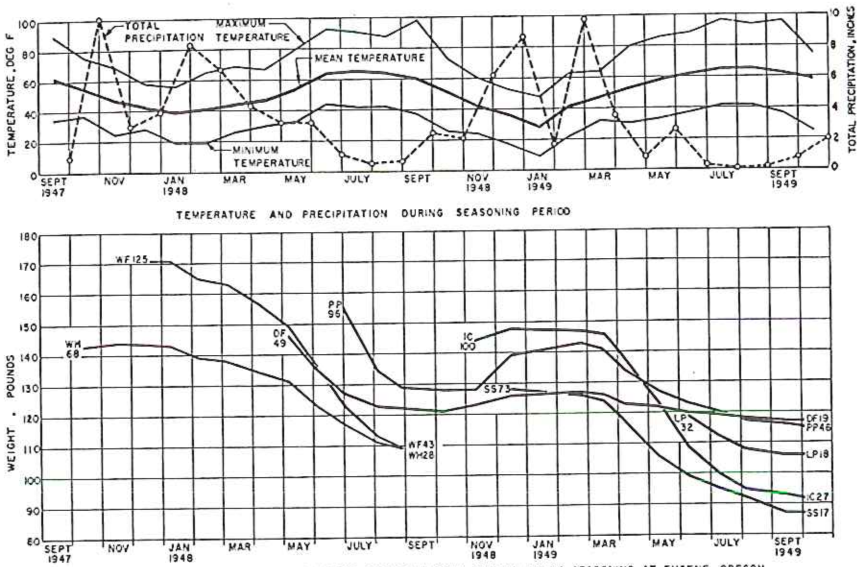

FIGURE 2. CHANGE IN WEIGHT OF 7 BY 9 INCH CROSS TIES OF VARIOUS SPECIES DURING SEASONING AT EUGENE OREGON
WH-WESTERN HEMLOCK WF-WHITE FIR DF-DOUGLAS-FIR PP-PONDEROSA PINE, IC-INCENSE CEDAR
SS-SITKA SPRUCE LP-LODGEPOLE PINE (PER CENT MOISTURE CONTENT FOLLOWS SPECIES LETTERS)

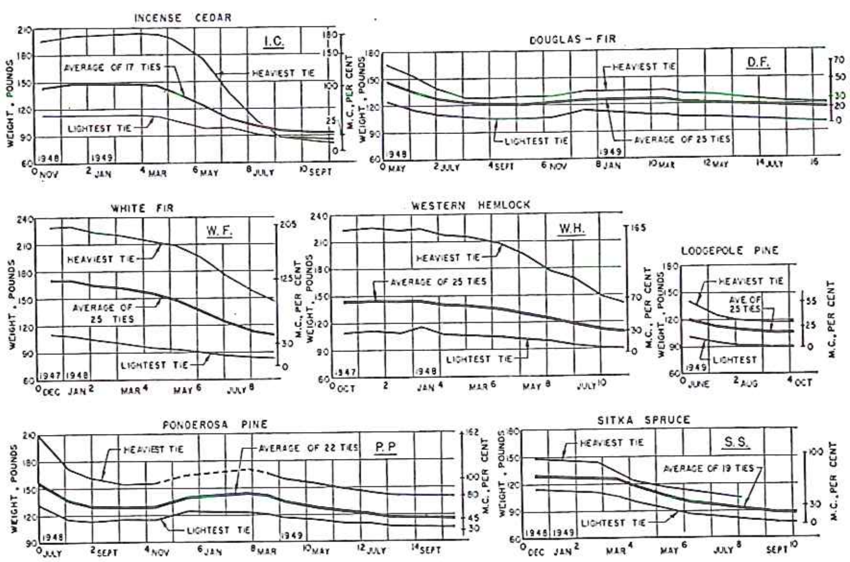

FIGURE 3. CHANGE IN WEIGHT OF TIES OF EACH SPECIES DURING AIR SEASONING AT EUGENE OREGON

ber 2 ties in all species except Shasta red fir (this species had a moisture content of 41 percent when treated). Although seasoning did result in the development of defects, few of these defects were serious enough to warrant the ties being reduced to number 2 grade.

Decay was found only in the ponderosa pine ties. These ties, which had been brought into the yard during the summer, seasoned to an average moisture content of about 65 percent and remained above this moisture content until the following spring. The decay organism was identified as *Schizophyllum commune.* This common virulent slash destroyer had attacked the sapwood and produced sporophores within one year. No decay was found in any of the other species, two of which had been in the seasoning yard for 43 months. Apparently, if the ties can be seasoned to an average moisture content of 30 percent before fall, the possibility of attack is reduced greatly.

Damp-wood termites were found attacking the surfaces of two western hemlock ties where they had been in contact with an infected foundation member. The damage was insignificant, being limited to an area several inches in length. Both damp-wood and subterranean termites were found in old creosoted ties being used as foundation members.

Seasoning Conclusions

1. The effective air seasoning period at Eugene, Oregon, begins in March and ends in September. Little or no loss in weight occurs during the months of October through February. These conditions probably are typical for that portion of Oregon west of the Cascade range.

2. Ties of these species, and probably all native conifers, can be air seasoned to a moisture content of 30 percent before fall, if they are placed in the seasoning yard by early spring.

3. Tie-size material of these species can be air seasoned without the development of serious defects.

4. Fungi may attack ties that are not seasoned sufficiently before fall.

TREATING RESULTS

The treating schedules used (Table 4) resulted in generally satisfactory treatments (Tables 5 and 6) and had no visible adverse effect on any of the species. Penetration usually was good, but retentions frequently were lower than the 9.5 pounds per cubic foot desired.

Incense Cedar *(Libocedrus decurrens)*

Deeper and more uniform penetration in incense cedar was obtained with the Rueping process (Charge 199) than with the Lowry process (Charge 200). The average retentions in Rueping charge 199 were 7.4 and 9.5 lb., whereas those in Lowry charge 200 were 13 and 15 lb. Short pressure periods of 120 and 50 minutes were used.

The ties from Rueping charge 199 bled so severely after treatment that pools of preservative formed under the trams after they were pulled from the retort. The lower moisture content ties (22 percent), which had a 2-lb. higher retention, bled more than the ties with higher moisture content (46 percent). The Lowry-treated ties did not bleed.

Incense cedar can be readily penetrated with preservative, but higher initial air pressures should be employed to obtain deeper penetration with lower net retentions. An expansion bath and longer final vacuum may reduce greatly the amount of bleeding after treatment.

Douglas Fir *(Pseudotsuga taxifolia)*

The typical Rueping treatment used for this species resulted in good penetration (0.70 in.) and a fairly high retention (8.5 lb.). The ties did not bleed and were in good condition. The penetration did not extend much below the depth of the incisions.

Shasta Red Fir *(Abies magnifica var. shastensis)*

The Shasta red fir ties, which were treated to a retention of 7.4 lb., were quite oily and continued to bleed long after treatment. Penetration was extremely erratic, ranging from less than 0.1 in. to 2 in. Borings taken from opposite faces of a tie frequently showed this great variation, which probably was due to differences in sapwood thickness. The sapwood could not be identified by visual observation.

White Fir *(Abies concolor and Abies grandis)*

The penetration in white fir, usually solid black, was uniformly good. The average penetration values in the three charges were 1.01, 0.77, and 0.99 in. The highest retention of 13.8 lb. and deepest penetration were obtained by the Lowry process (Charge 200). Retentions of 6.6 and 9.4 lb. were obtained in Rueping charges 202 and 255. Penetration varied directly as the retention. Some bleeding did occur.

It should be possible to obtain good penetration in white fir with a wide range of retentions by varying the initial air pressure and the gross injection. The penetration data indicate that there is little or no difference in the treatability of the heartwood and sapwood.

Western Hemlock *(Tsuga heterophylla)*

Retentions and penetrations in the three western hemlock charges, all treated by the Rueping process were: charge 254—7.7 lb. and 0.70 in., charge 202—6.2 lb. and 0.72 in., charge 203—8.5 lb. and 0.94 in. Penetration was largely solid black and uniformly satisfactory. The treated ties did not bleed excessively.

The uniform penetration indicates that with incised material there is little or no difference in the treatability of the heartwood or sapwood. Like white fir, it should respond well to differences in initial air and gross injections if various retentions with good penetration are desired.

Lodgepole Pine *(Pinus contorta var. latifolia)*

A much better treatment was obtained with incised lodgepole pine treated by the Lowry process than with unincised pine treated by the Rueping process. The retentions and penetrations obtained in these charges were: Lowry charge 200, 7.5 lb. and 0.73 in.; Rueping charge 301, 6.0 lb. and 0.30 in. The higher net retention is attributed to the Lowry process, but the deeper penetration is attributed to the incising of the ties in charge 200. As shown in the following table, deep ringed penetration was associated with shallow solid black penetration. The total penetration was about equal to the depth of the incisions, except where deep solid black penetration was obtained.

Percentage of 26 borings	Average penetrations in incised ties		
Percent	Solid black Inch	Ringed Inch	Total Inch
35	0.86	0.00	0.86
65	0.21	0.45	0.67
100	0.43	0.30	0.73

Deep solid black penetration undoubtedly was associated with the sapwood whereas ringed penetration was associated with the heartwood. Many of the unincised ties in charge 301 had virtually no penetration in the center of the faces where the sapwood would be the thinnest (95 percent of these ties were boxed heart). It definitely appears that incising aided penetration in the summerwood bands of the heartwood.

Sitka Spruce *(Picea sitchensis)*

Both charges of Sitka spruce were characterized by part solid black and part ringed penetration. The average total penetration was 0.84 in. and the average ringed penetration was 0.45 in. The net retentions ranged from 6.3 to 10.0 lb. per cubic foot. The highest retention and deepest penetration were obtained in the ties that had been seasoned to an average moisture content of 19 percent; the ringed penetration in these ties was twice as great as the solid black penetration.

The penetration measurements indicate that there is little or no difference in the treatability of the heartwood and sapwood which could not be differentiated visually. The spruce ties did bleed to some extent.

Treating Conclusions

1. The treating conditions employed had no influence on the visible physical characteristics of the ties. The maximum pressures employed for the different species were as follows:

Species	Pressure Psi
Incense cedar	120
Douglas fir	150
Shasta red fir	135
White fir	100–120
Western hemlock	108–140
Lodgepole pine	100–120
Sitka spruce	140

2. Incense cedar ties (incised) can be treated successfully. However, higher initial air pressures than were used in this investigation will be required to obtain deeper penetration with lower net retentions. An expansion bath and longer than usual final vacuum may be required to prevent bleeding.

3. Douglas fir ties (incised) were treated satisfactorily with a standard Rueping treatment.

4. Although Shasta red fir ties (incised) received a fair treatment, additional work is required to explain the erratic penetration in the incised surfaces and to develop a more satisfactory treating schedule.

5. White fir and western hemlock ties (both incised) can be treated so as to obtain deep penetration with a considerable range in retentions by varying the initial air pressure and gross injection. There appears to be no difference in the treatability of the heartwood and sapwood. Neither species tends to bleed excessively after treatment.

6. Lodgepole pine ties should be incised to insure adequate penetration in the heartwood. Heartwood penetration is limited to the summerwood bands. A Rueping process should be used to limit the retention in the sapwood, which is very easily treated.

7. Sitka spruce ties (incised) can be treated satisfactorily, but the penetration will be part solid black and part ringed. There appears to be no difference in the treatability of the heartwood and sapwood.

SUMMARY

Crossties of incense cedar, Douglas fir, Shasta red fir, white fir, western hemlock, lodgepole pine, ponderosa pine, and Sitka spruce were obtained from areas of possible future sources of supply, air seasoned, and then treated with a creosote-petroleum solution in preparation for test track installations.

All of the species were seasoned without the development of serious defects. There was a marked decrease in the number of select ties but only a slight increase in the amount of No. 2 ties as a result of seasoning. The effective seasoning period at Eugene, Oregon, was found to begin in March and to end in September. Ties that were in the yard during the full period seasoned to a moisture content of 30 percent. Decay developed in ponderosa pine ties that were placed in the yard during the late summer and remained at a high moisture content over winter. Their moisture content remained high during the following summer.

The treating schedules, with maximum pressures of 100 to 140 psi, had no visible adverse effect on the various species. All ties, except for one charge of lodgepole pine, were incised. The penetration-retention results were fairly satisfactory.

The penetration in incense cedar was very erratic. Penetration was better in ties treated by the Rueping process, while retention was much higher with the Lowry process. However, the Rueping-treated ties bled severely whereas the Lowry-treated ties bled very little.

Douglas fir was treated satisfactorily with a standard Rueping process.

The treatment of the Shasta red fir ties was not satisfactory; retention was low and penetration was extremely erratic.

White fir and western hemlock ties received a deep, uniform penetration with a wide range of retentions and did not bleed excessively.

Incised lodgepole pine ties received a satisfactory treatment whereas unincised ties did not. Penetration in pine heartwood was limited to the summerwood.

Sitka spruce treated fairly well. The penetration was solid black near the surface with ringed penetration beneath.

Acknowledgements

The author wishes to express his sincere appreciation for the fine co-operation that was received from all departments of the Southern Pacific Company. It was through their combined efforts that this phase of the project was completed. Particular recognition should be paid to Mr. E. H. Polk, Purchasing Agent, and his assistant Mr. T. Kachin who were instrumental in initiating the project and obtaining ties of the different species; to Mr. R. M. Alpen, Manager Treating Plant, for developing the schedules used and for his guidance throughout the investigation; to Mr. Chas. Adams (retired) and Mr. V. M. Kysh, Superintendents, and Mr. Robert Alloway, Treating Plant, Eugene, Oregon, for providing the labor and facilities required; and to the other members of the company who have assumed the responsibility for installing the ties in test tracks.

Table 1.—Source and Description of Crossties

Species	Oregon county where cut	Group	Growth rate: Average	Growth rate: Range	Summerwood: Average	Summerwood: Range	Specific Gravity: OD / G*	Specific Gravity: OD / OD**	Boxed-heart ties
			Rings per inch	Rings per inch	Percent	Percent			Percent
Cedar, incense	Douglas	1	6	4–10	15	15-20	0.33	0.35 }	
	Douglas	2	12	4–25	20	15-30	0.33	0.35 }	47
Douglas fir	Coos	1	6	3–10	35	15–50	0.45	0.50	32
Fir, Shasta red	Jackson	1	14	4–30	20	15–60	0.34	0.39	34
Fir, white	Jackson	1	11	5–30	20	15–30	0.35	0.41	32
	Jackson	2	4	3–11	20	15–35			32
Hemlock, western	Lincoln	1	6	4–11	20	10–35	0.39	0.43 }	
	Lincoln	2	6	2–12	25	15–40		}	22
Pine, lodgepole	Klamath	1	9	3–20	25	15–60		}	
	Klamath	2	8	5–14	20	15–40	0.41	0.45 }	95
Pine, ponderosa	Lane	1	Decay developed in ties over winter						
Spruce, Sitka	Coos	1	5	3– 9	20	10–50	0.32	0.34 }	
	Curry	2	3	2– 4	20	15-20	0.35	0.37 }	61

*Oven-dry weight, green volume.
**Oven-dry weight, oven-dry volume.

Table 2.—Summary of Seasoning Data; by Species

Species	Group	Date in yard	Seasoning Period: Period of weighing Months	Seasoning Period: Until treated Months	Avg. Weight: Initial Lb./cu. ft.	Avg. Weight: Final* Lb./cu. ft.	Avg. M. C.: Initial Percent	Avg. M. C.: Final* Percent
Cedar, incense	1	10-48	11	43	41.1	26.3	100	27
	2	9-51		10		30.0		46
Douglas fir	1	4-48	17	17	41.7	33.4	49	19
Fir, Shasta red	1	7-51		11		29.7		41
Fir, white	1	11-47	9	9	48.9	31.1	125	43
	2	3-51		15		29.1		4
Hemlock, western	1	9-47	11	13	40.9	31.1	68	28
	2	1,6-51		11-17		30.9		27
Pine, lodgepole	1	5-49	4	4	34.0	30.3	32	18
	2	7-51		10		31.1		22
Pine, ponderosa	1	6-48	15		44.3	32.9	96	46
Spruce, Sitka	1	12-48	10	43	36.6	24.8	73	17
	2	8,11-51		9		28.3		33

*Weight and moisture content at end of periodic weighings.

Table 3.—Percentages of Ties by Grade Before and After Seasoning

Species	Group	Seasoning period Months	Seasoning condition	Tie grade*: Select FOHC** Percent	Select BH† Percent	No. 1 FOHC Percent	No. 1 BH Percent	No. 2 FOHC Percent	No. 2 BH Percent	Ties in-spected Basis	All grades boxed-heart Percent
Cedar, incense	1, 2	10, 43	Before	42.5	42.5	6.0	6.0	2.0	0.5	1363	49
			After	31	27	16	18	6	2	1225	47
Douglas fir	1	17	Before	74	14	8	2	2	0	1529	16
			After	43	16.5	16.5	16	—— 8 ——		962	32
Fir, Shasta red	1	11	Before	53	27	9	4	4	2	1307	33
			After	48	21	9	8	9	5	928	34
Fir, white	2	15	Before	54	15	18	9	—— 3 ——		588	24
			After	17	11	39	17	12	4	566	32
Hemlock, western	2	11, 17	Before	69	14	9	4	—— 4 ——		1218	18
			After	33	8	35	12	10	2	1205	22
Pine, lodgepole	1	4	Before	1	84	0	10	0	4	960	98
			After	3	52	3	36	0	6	960	96
	2	10	Before	2	62	2	25	0	9	593	96
			After	2	33	3	45	1	16	582	94
Spruce, Sitka	2	9	Before	10	5	23	56	2	3	818	64
			After	1	0	36	58	2	3	772	61

*Standard Grading and Dressing Rules for West Coast Lumber, No. 14. West Coast Bureau of Lumber Grades and Inspection. Select, par. 405; No. 1, par. 406; No. 2, par. 407.
**FOHC—free-of-heart-center, pith absent or near one edge.
†BH—boxed-heart, containing pith of tree.

Table 4.—Treating Schedules

Charge and Species*	Conditioning Period		Initial Air		Pressure Period				Final Vacuum		
	Average temp. °F	Duration Hr.:Min.	Pressure Psi	Duration Hr.:Min.	Average temp. °F	Duration Hr.:Min.	Max. pressure Psi	Time to max. press. Hr.:Min.	Max. vac. In.Hg.	Duration Hr.:Min.	Total time Hr.:Min.
199 IC			30	1:00	200	2:00	120	0:30	20	1:00	4:30
200 LP, IC, WF	180	3:20			200	0:50	120	0:40	24	1:55	6:40
202 WH, WF			30	0:50	200	2:00	108	0:45	24	2:00	5:25
203 WH, SS			30	0:45	200	2:45	140	0:30	24	2:00	6:15
211 SS	185	5:20	20	0:45	200	1:50	140	1:35	24	1:15	9:40
212 SF	185	2:15	30	1:15	200	2:15	135	0:15	24	1:30	7:40
254 WH			40	0:15	200	2:15	140		24	2:30	6:00
255 WF	210	4:00	30	0:15	200	2:55	100		24	2:00	10:25
300 DF	200	5:00	40	0:45	200	3:20	150		24	2:00	12:00
301 LP			20	0:45	200	6:45	100		24	2:00	10:30

*IC, Incense cedar; LP, Lodgepole pine; WF, White fir; WH, Western hemlock; SS, Sitka spruce; SF, Shasta red fir; DF, Douglas fir.

Table 5.—Summary of Treating Data; by Species

Species	Group	Charge	Date of treatment	Moisture content Percent	Weight, initial Lb. per cu. ft.	Retention Lb. per cu. ft.	Penetration: Solid black Inches	Penetration: Ringed Inches	Penetration: Total Inches
Cedar, incense	1	199				9.5	0.68	0.08	0.76
	1	200	5-52	22	25.1	14.9	0.37	0.17	0.54
	2	199				7.4	0.45	0.20	0.65
	2	200	5-52	46	30.0	12.9	0.41	0.26	0.67
Douglas fir	1	300	10-49	19	33.4	8.5	----	----	0.70
Fir, Shasta red	1	212	6-52	41	29.7	7.4	0.46	0.13	0.59
Fir, white	1	255	9-48	31	28.6	9.4	----	----	0.99
	2	200				13.8	0.89	0.12	1.01
	2	202	5-52	34	29.1	6.6	0.72	0.05	0.77
Hemlock, western	1	254	9-48	22	29.7	7.7	----	----	0.70
	2	202				6.2	0.64	0.08	0.72
	2	203	5-52	27	30.9	8.5	0.91	0.03	0.94
Pine, lodgepole	1*	301	10-49	18	30.3	6.0	----	----	0.30
	2	200	5-52	22	31.1	7.5	0.43	0.30	0.73
Spruce, Sitka	1	211	5-52	19	25.2	10.0	0.32	0.60	0.92
	2	211				8.8	0.36	0.39	0.75
	2	203	5-52	33	28.3	6.3	0.49	0.37	0.86

*Not incised.

Table 6.—Summary of Treating Results; by Charges

Charge and Species*		Pieces	Group	Moisture content Percent	Gross injection	Net Retention by plant	Net Retention by weighing	Penetration Inches	Borings Basis	Pieces weighed: Before treat. Basis	Pieces weighed: After treat. Basis
					Pounds per cubic foot						
199	IC	960	1	22	12.8	11.6	9.5	0.76	20	41	35
	IC	960	2	46	12.8	11.6	7.4	0.65	27	44	35
200	IC	303	1	22	11.9	9.4	14.9	0.54	8	--	10
	IC	303	2	46	11.9	9.4	12.9	0.67	8	--	10
	LP	593	2	22	11.9	9.4	7.5	0.73	26	50	40
	WF	64	2	34	11.9	9.4	13.8	1.01	14	50	10
202	WF	524	2	34	11.9	8.9	6.6	0.77	26	--	19
	WH	436	2	27	11.9	8.9	6.2	0.72	28	63	28
203	WH	782	2	27	12.2	8.9	8.5	0.94	29	--	17
	SS	178	2	33	12.2	8.9	6.3	0.86	25	25	10
211	SS	960	1	19	13.7	10.0	10.0	0.92	12	25	19
	SS	960	2	33	13.7	10.0	8.8	0.75	30	32	20
212	SF	960	1	40	11.6	9.0	7.4	0.59	32	50	34
254	WH	960	1	22	11.9	9.5	7.7	0.70	20	48	25
255	WF	960	1	31	11.3	9.5	9.4	0.99	18	39	30
300	DF	960	1	19	10.7	9.5	8.5	0.70	20	24	20
301	LP†	960	1	18	8.5	----	6.0	0.30	25	25	25

*IC, Incense cedar; LP, Lodgepole pine; WF, White fir; WH, Western hemlock; SS, Sitka spruce; SF, Shasta red fir; DF Douglas fir.

†Not incised.

Session Chairman Kittell: Thank you, Mr. Graham.

That completes the program for this morning. I will turn the session back to our President, Mr. Brentlinger.

President Brentlinger: Thank you, Mr. Kittell. The meeting will now recess until two o'clock this afternoon.