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Investigating the Use of Small-Diameter Softwood as Guardrail Posts: Static Test Results

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Abstract

Round guardrail posts may provide an important value-added option for small-diameter thinnings. Such posts require minimum processing and have been shown to have higher strength compared to the equivalent rectangular volume. The resulting value-added product may bring a higher return compared to lumber. The obstacles to immediate utilization of ponderosa pine and Douglas-fir guardrail posts are the need for full-scale crash testing, a visual grading rule, and an installation guide. This paper reports on the static and dynamic tests performed at the USDA Forest Products Laboratory in Madison, Wisconsin, and the Midwest Roadside Safety Facility in Lincoln, Nebraska, to determine material properties for designing a new Midwest Guardrail System for round wood posts. Grading practices are recommended for round ponderosa pine, Douglas-fir, and southern yellow pine guardrail posts for the new Midwest Guardrail System.

Keywords: Round guardrail posts, small-diameter, Midwest Guardrail System, Douglas-fir, ponderosa pine, southern yellow pine.

Conversion table

To convert from	To	Multiply by
Foot (ft)	Meter (m)	0.3048
Inch (in.)	Meter (m)	0.0254

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The Forest Products Laboratory is maintained in cooperation with the University of Wisconsin.

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Introduction

For many years there has been ongoing discussion on ways to manage fuel and reduce fire control costs and damage on forested lands. This discussion has led to various strategies to prevent catastrophic fires by reducing fuel loadings (i.e., excess biomass), including prescribed burning, salvage timber operations, pruning, pre-commercial thinning, and mechanical or chemical release. In western forests, salvage timber operations and pre-commercial thinning reduce fuel loadings by removing small-diameter and low-valued material. Although these activities are believed by many to be an effective fire prevention technique, their cost effectiveness cannot be properly evaluated until all costs have been accurately determined. As more end uses for this traditionally underutilized wood become available, the overall operational costs will be reduced as a result of the financial and societal benefits that are generated. One potential use for forest thinnings is for the round guardrail posts that are used along highways for motorist safety (Paun and Jackson 2000). There are over 7,200 km of guardrail sold in the United States per year. This translates into more than 3.8 million posts (of some type) being used. A large volume of thinnings could be utilized if the thinned material is shown to perform adequately as guardrail posts. For a given volume of wood, round posts can provide twice the market value of rectangular posts and nine times the market value of chips. There are substantial opportunities for implementing round posts into W-beam guardrail systems throughout the United States, especially if it can be shown that several wood species can be acceptable for use in these crashworthy barrier systems.

Background

For more than 50 years, longitudinal barrier systems have been used to prevent errant motorists from colliding with dangerous rigid hazards along highways and roadways. Although several different longitudinal barrier systems can be found throughout the United States, W-beam guardrail systems have historically been the most common. In general, W-beam guardrail systems consist of three major components: a steel W-beam rail element, evenly spaced support posts, and guardrail blockouts. Guardrail posts are manufactured from either wood or steel. For wood guardrail systems, both 152.4- by 203.2-mm rectangular and 184.1-cm-diameter round post cross sections have been successfully utilized. They are generally manufactured from No. 1 grade southern yellow pine (SYP). Wood blockouts are usually incorporated into the design to position the W-beam rail away from the sides of the posts that face traffic. The positioning of the rail forward from the posts reduces the likelihood that a vehicle will snag on the posts as well as the potential for vehicular instability and/or rollover.

In terms of material costs to the end user (e.g., state highway agencies), typical price ranges per guardrail post for steel, rectangular wood, and round wood alternatives are $12 to $16, $11 to $19, and $11 to $13, respectively (costs were provided by a major manufacturer of roadside safety hardware). Although an SYP round post alternative has the lowest price, implementation of round-post W-beam systems has been mostly limited to the State of Texas. Funding was gathered and cooperators solicited to initiate a project to demonstrate the feasibility of using Douglas-fir (DF) and ponderosa pine (PP) in a strong-post W-beam guardrail system (strong-post means the majority of the posts in the system are meant to withstand impact with minimal dynamic deflection).

Objectives

The following objectives were identified for our guardrail post project.

1. Obtain technical data that would demonstrate whether small-diameter softwoods harvested from fuel reduction projects could be used for highway guardrail applications. Investigate the use of PP and DF, with SYP as baseline material. The test variables included post size, grade, and post embedment depth.
2. Determine reasonable grading practices for round guardrail posts manufactured from PP, DF, and SYP.
3. Investigate, design, and make recommendations for the use of round wood posts, including all these species, in the Midwest Guardrail System (MGS) or in a new strong-post, W-beam guardrail system. Utilize a proven nonlinear, dynamic vehicle-to-barrier impact analysis computer simulation program.
4. Conduct full-scale vehicle crash tests at Test Level 3 (TL-3) according to the impact safety standards of the National Cooperative Highway Research Program (NCHRP) Report No. 350 (Ross and others 1993) to demonstrate the use of wood round post alternatives in longitudinal barrier systems.
5. At the completion of the project, prepare an installation manual and standard computer-aided design (CAD) plans for round-post highway guardrail systems using PP, DF, and SYP.

Work Plan

The work plan for this research project consists of five distinct phases. Phase I includes an initial project planning period, testing component setup and preparation, and the wood materials acquisition and grading. Phase II includes static and dynamic evaluation and determination of the structural properties of the three wood post materials when subjected to a cantilevered loading. Phase III includes a dynamic evaluation of the post-soil forces for each wood species when subjected to a cantilevered loading using varying post embedment conditions. Phase IV consists of BARRIER VII computer simulation of vehicle-to-barrier impacts for the three round post wood alternatives. This computer modeling is then used to evaluate and predict dynamic barrier performance as well as to make any necessary design modifications. Phase IV also includes the final design of the barrier system as well as the preparation of an installation manual and standard CAD plans. Phase V includes full-scale vehicle crash testing conducted according to current impact safety standards and preparation of reports to summarize work completed. Appendix A shows more details and the timeline.

This report focuses on the static testing in Phase II conducted at the USDA Forest Service Forest Products Laboratory (FPL) in Madison, Wisconsin, and also includes some data from and comparisons to the dynamic test information collected at the Midwest Roadside Safety Facility (MwRSF) in Lincoln, Nebraska. A visual grading rule for round guardrail posts developed by experts from Timber Products Inspection Graders, FPL, and MwRSF is also presented.

Sampling

Three species were sampled in Phase II of the testing project: SYP, PP, and DF. The SYP material came from the following manufacturers: Arnold Forest Products in Louisiana, Interstate Timber in Tennessee, and Burke-Parsons-Bowlby in West Virginia. All of the SYP material had been treated by the suppliers to ground a contact retention level of 0.5 lb/ft^3 with chromated copper arsenate (CCA). The PP material was obtained from Hill Products Group and the posts came from both Wyoming and South Dakota. These posts were treated by Hill Products Group with CCA to a retention level of 0.5 lb/ft^3. The DF material was from two different suppliers in Oregon: Rouge Valley Fuels and Goshen Forest Products. The DF material was treated with ammoniacal copper quat type B (ACQ-B) by All-weather Wood Products or J. H. Baxter & Co. to retention levels greater than 0.5 lb/ft^3.

The test matrix for the Phase II cantilever tests is shown in Table 1. There were two rounds of testing in Phase II that were meant to provide test information to bracket the appropriate diameter for the final guardrail system design. For this research effort, it was planned that each species contain a sample of 75 pieces in order to contain a wide range of knot sizes and growth rings. To ensure proper amounts of each category, Timber Product Inspection grading supervisors assisted in identifying posts with the required diameter knots and rings per inch (1 in. = 25.4 mm) (hereafter referred to as rpi). The study was set up so that both static and dynamic tests would be performed on three knot-ring combinations (BKN LRD, SKN LRD, and SKN HRD). There were two types of knots, which varied depending on species: big (BKN) and small (SKN). There were two categories of rpi: low (LRD = ≤4 rpi) and high (HRD = ≥6 rpi). The three combinations were tested both statically and dynamically. Further, tests of a larger sample more representative of the expected global post population was also tested statically.

For each round of testing, 10 posts for each species and knot–ring category were identified to have the appropriate knot–ring combinations. An additional 45 posts were collected from the larger population of posts for static testing. At FPL, 360 static tests were planned; at MwRSF, 90 total dynamic post tests were planned.

After the samples were delivered to FPL, the knots for each post were mapped in more detail and a more rigorous measurement of rpi and percent latewood were determined from digital photographs of the ends of the posts. Appendix B contains an example data sheet for knot mapping. Each post was weighed and measured. Longitudinal stress wave modulus of elasticity (SWMOE) was determined. The posts were sorted by SWMOE and then randomly assigned to either dynamic or static testing. In Round 2 of the DF sample, five

Table 1—Number of static (ST) and dynamic (DY) tests in Rounds 1 and 2 of the Phase II cantilever beam tests [a]

	Round 1						Round 2						
	DF 184-mm		PP 216-mm		SYP 190-mm		DF 178-mm		PP 190-mm		SYP 171-mm		
Variable [b]	ST	DY	ST	DY	ST	DY	ST	DY	ST	DY	ST	DY	Total
BKN LRD	5	5	5	5	5	5	5	5	5	5	5	5	60
SKN LRD	5	5	5	5	5	5	5	5	5	5	5	5	60
SKN HRD	5	5	5	5	5	5	5	5	5	5	5	5	60
Population	45		45		45		45		45		45		270
Total tests	60	15	60	15	60	15	60	15	60	15	60	15	450

[a] Static tests were conducted at FPL, dynamic tests at MwRSF. DF, Douglas-fir; PP, ponderosa pine; SYP, southern yellow pine.
[b] BKN, big knot; SKN, small knot; LRD, ≤4 rpi; HRD, ≥6 rpi; Population, random mixture of posts.

Figure 1—Posts soaking in water before testing.

posts originally picked to be tested statically were sent to Lincoln for soil embedment testing; therefore only 40 tests of the population were conducted for Round 2 of the DF.

The static and dynamic material was stored in water tanks until testing to simulate the most severe environmental condition of being placed in wet soil (Fig. 1). As a result, the portion of the post that was to be below the ground was above the fiber saturation point and the groundline moisture conditions were typically in a range of 20% to 50% moisture content (MC) at time of test.

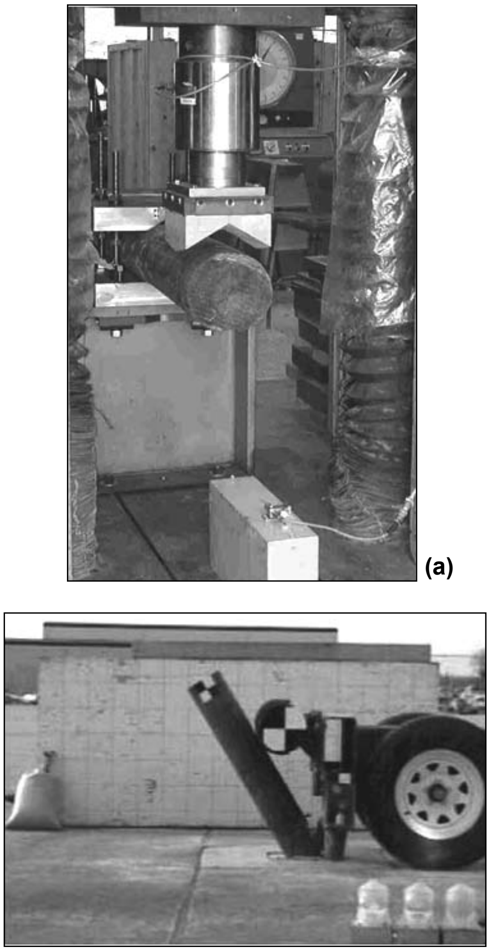
Test Methods

The static cantilever post tests were conducted using a 1-million-lb (4,448.2-kN) test frame at FPL (Fig. 2a), with a loading rate of 0.0085 m/min (0.33 in/min). Loads were recorded on a 222.4-kN (50,000-lb) load cell in Round 1 testing and a 111.2-kN (25,000-lb) load cell in Round 2. Deflections were recorded using three linear variable differential transformers (LVDTs). One LVDT was located under the concentrated load, one located at the groundline, and one located at the bottom of the post (Fig. 3). The maximum load, modulus of rupture (MOR), and time to failure were determined.

Dynamic cantilevered post tests were conducted at MwRSF using a 7.1-kN (1,605-lb) rigid-frame "bogie" (wheels mounted on a rigid steel frame) vehicle (Fig. 2b). A more complete description of the Phase II dynamic tests can be found in Hascall's thesis (Hascall 2005). In these tests, the bogie traveled at approximately 32 km/h (20 mi/h) in Round 1 and 21.7 km/h (13.5 mi/h) in Round 2. A pickup truck with a reverse tow system was used to propel the bogie. One triaxial piezoresistive accelerometer system with a range of ±200 g was mounted on the bogie near its center of gravity and used to measure acceleration in the longitudinal, lateral, and vertical directions at a sample rate of 3,200 Hz. Three pressure tape switches, spaced at 1-m intervals and placed near the end of the bogie track, were used to determine the speed of the bogie before impact. Two high-speed digital video cameras, operating at either 500 or 29.97 frames per second, were independently used to document the tests. All dynamic tests recorded the force–time profiles using accelerometer data.

Results

The following sections summarize static and dynamic test results for Round 1 and Round 2. This information was used to determine the necessary post diameter for successful performance in the MGS. A complete listing of the test results for Phase II is given in Appendix C. Selected percentiles for the population samples are shown in Appendix D.



(a)

(b)

Figure 2—Test setup for (a) static and (b) dynamic tests.

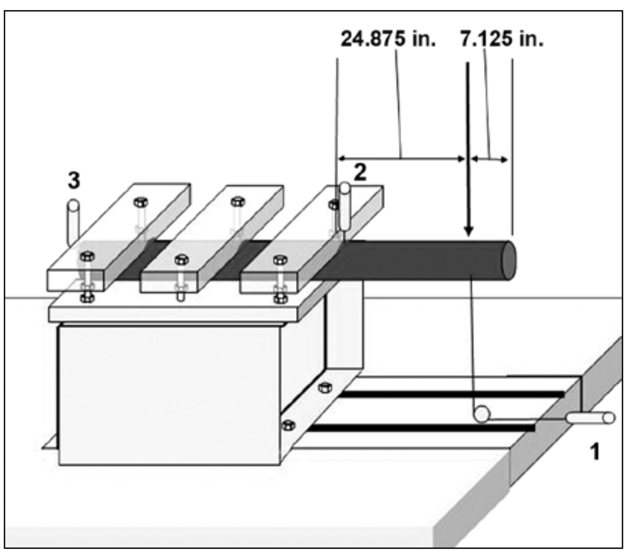


Figure 3—Static test setup showing the location of loading and LVDTs.

Static and Dynamic Tests

Both static and dynamic results for SWMOE, MOR, and peak load are presented in Table 2 for comparison.

Phase IIa (Round 1) Testing

Box plots summarizing the Round 1 test results for peak load and MOR are shown in Figures 4a and 5a, respectively. As would be expected, the most restrictive grading condition, SKN-HRD, had the highest values for all species tested. As is expected with wood, the average dynamic test results for MOR and peak load were always higher than the static. The low-grade LKN-LRD material and the SKN-LRD material were not statistically different from each other in the test for the three species groups but were consistently in the lower part of the overall populations distribution. Also, the difference in MOR between the strength of PP and the other stronger structural species DF and SYP was clearly evident.

The peak load, MOR, and material dimensions were studied to determine if any changes were required. Peak load capacity is a principal parameter for guardrail post design. Based on previous MGS post testing, a peak load of 44.5 kN (10,000 lb) was selected as the target for the round post tests. The peak load level of the PP, given its size (215.9-mm (8.5 in.) diameter top end) compared to that of DF and SYP (190 mm and 184 mm (7-1/2 in. and 7-1/4 in.), respectively), was considerably higher than the desired value. After analyzing the data, the research team decided that the SYP and DF posts could be reduced slightly in diameter and still perform adequately in the MGS. The results also suggested that a larger reduction in the PP cross section may be possible for the post to carry loads similar to those of SYP, and a slightly smaller post size for SYP should be investigated. The new sizes for Round 2 were a top-end diameter of 190.5 mm (7-1/2 in.) for PP, 171 mm (6-3/4 in.) for DF, and 177.8 mm (7-in.) for SYP.

After the first test round, important flaws were found in the standard methods used in the dynamic cantilever bogie tests. Post strength may have been overestimated by as much as 50% because of the effects of inertia, leading to inaccurate and misleading diameter calculations. An alternative procedure was investigated in a series of three additional cantilever bogie tests. These tests confirmed the problem and showed that a reduction in bogie impact speed would substantially reduce the effects of inertia, leading to a more accurate prediction of ultimate fiber stress. Unfortunately, the flaws were not identified in time to modify the original diameter calculations because the posts had already been ordered; however, the adjustments were utilized in the second round of tests.

Phase IIb (Round 2) Testing

The results of Round 2 tests for peak loads and MOR are shown in Figures 4b and 5b, respectively. The most restrictive grading condition, SKN-HRD, had values that are in

Table 2—MOE, MOR, and peak load average values for Phase II testing [a,b]

		Round 1						Round 2					
		DF		PP		SYP		DF		PP		SYP	
	Target diameter	190 mm 7-1/2 in.		216 mm 8-1/2 in.		184 mm 7-1/4 in.		171 mm 6-3/4 in.		190mm 7-1/2 in.		178 mm 7 in.	
Test mode		ST	DY	ST	DY	ST	DY	ST	DY	ST	DY	ST	DY
BKN LRD	SWMOE (GPa)	9.9	9.6	6.8	6.9	7.6	7.0	9.2	10.1	4.5	4.3	7.4	6.3
	($\times 10^6$ lb/in^2)	1.43	1.39	0.99	1.00	1.10	1.02	1.34	1.47	0.65	0.63	1.08	0.91
	MOR (MPa)	42.4	60.9	26.9	44.8	34.5	48.3	39.9	49.8	35.0	45.9	35.1	38.5
	(lb/in^2)	6160	8830	3900	6500	5000	7010	5780	7220	5070	6650	5090	5580
	Peak load (kN)	41.8	59.6	45.4	73.4	32.0	48.5	28.5	40.9	33.8	39.1	32.0	33.8
	(1,000 lb)	9.4	13.4	10.2	16.5	7.2	10.9	6.4	9.2	7.6	8.8	7.2	7.6
SKN LRD	SWMOE (GPa)	9.7	9.5	5.4	5.4	6.5	4.0	10.5	10.1	4.3	4.6	4.2	4.4
	($\times 10^6$ lb/in^2)	1.40	1.38	0.78	0.78	0.94	0.58	1.52	1.46	0.62	0.67	0.61	0.64
	MOR (MPa)	48.5	51.7	32.4	39.0	54.1	50.6	41.7	52.5	35.0	50.5	38.8	44.3
	(lb/in^2)	7040	7500	4700	5660	7850	7340	6050	7610	5070	7320	5630	6420
	Peak load (kN)	44.0	52.0	50.3	64.5	51.6	53.8	34.3	45.8	33.8	36.9	35.1	41.8
	(1,000 lb)	9.9	11.7	11.3	14.5	11.6	12.1	7.7	10.3	7.6	8.3	7.9	9.4
SKN HRD	SWMOE (GPa)	10.5	10.1	9.6	9.4	13.7	13.7	14.3	10.1	7.8	8.1	11.0	12.0
	($\times 10^6$ lb/in^2)	1.52	1.47	1.39	1.37	1.98	1.98	2.08	1.47	1.13	1.18	1.59	1.74
	MOR (MPa)	50.3	65.5	45.9	63.3	75.3	84.4	62.8	69.2	45.6	52.1	70.8	61.6
	(lb/in^2)	7290	9500	6650	9180	10920	12240	9110	10040	6610	7550	10270	8940
	Peak load (kN)	48.9	64.5	78.7	113.0	68.1	82.3	50.7	59.2	44.0	54.7	65.4	57.4
	(1,000 lb)	11.0	14.5	17.7	25.4	15.3	18.5	11.4	13.3	9.9	12.3	14.7	12.9
Pop.	SWMOE (GPa)	10.3	—	8.5	—	8.9	—	12.8	—	7.0	—	9.9	—
	($\times 10^6$ lb/in^2)	1.50		1.23		1.29		1.86		1.02		1.44	
	MOR (MPa)	52.5	—	37.5	—	51.9	—	56.3	—	41.0	—	59.1	—
	(lb/in^2)	7620		5440		7520		8160		5950		8570	
	Peak load (kN)	48.5	—	63.2	—	48.9	—	45.4	—	40.0	—	53.4	—
	(1,000 lb)	10.9		14.2		11.0		10.2		9.0		12.0	

[a] DF, Douglas-fir; PP, ponderosa pine; SYP, southern yellow pine.
[b] BKN LRD, big knots and ≤4 rpi; SKN LRD, small knots and ≤4 rpi; SKN HRD, small knots and ≥6 rpi; Pop., population, random mixture of posts.

the upper portion of the population's property distribution. Again, the low-grade LKN-LRD material and the SKN-LRD material were not consistently different from each other in the testing. But these knot–rpi conditions were consistently in the lower part of the overall population distribution. The population results suggest that the diameters of DF and SYP were close to the desired 44.5-kN (10,000-lb) peak load level. The size of the PP material, however, should be increased.

Other Observations From Phase II Testing

Knot size did not seem to have a consistent impact on load capacity of the round posts. The knots and rpi data indicated that the most substantial gains in post strength were obtained by raising the rpi value. A higher rpi count increased the average MOR and peak loads for all species by 40% and consistently placed the material tested into the upper part of the population distribution. The comparison of the results from Rounds 1 and 2 dynamic and static testing suggested a dynamic magnification factor of 20% to 30%.

A 3% failure rate was established as an acceptable level of risk for the system to fail; system failure was defined as the failure of four consecutive posts when the system was subjected to NCHRP Report No. 350 test level-3 (TL-3) criteria. The proper minimum size was determined using elastic bending equations and estimated MOR. Sixty percent of the posts needed to withstand an impact force of 42.3 kN (9,500 lb) at a height of 632 mm (24.875 in.) or a bending moment of 26.7 kN-m (236.3×10^3 lb-in.). A detailed description of the sizing criteria can be found in Hascall's thesis (Hascall 2005). The resulting target sizes were 165 mm (6-1/2 in.) for DF, 184 mm (7-1/4 in.) for PP, and 177.8 mm (7 in.) for SYP. These sizes were investigated in the Phase III soil embedment testing.

Discussion

The major purpose of the small-diameter round guardrail post project was to develop a new MGS that could utilize round posts from DF, SYP, and PP. This research paper documents the test results for Phase II of the small-diameter round guardrail post project. The test results summarized here and the Phase III soil embedment tests have provided enough information for the development of a full-size guardrail system. BARRIER VII computer simulations,

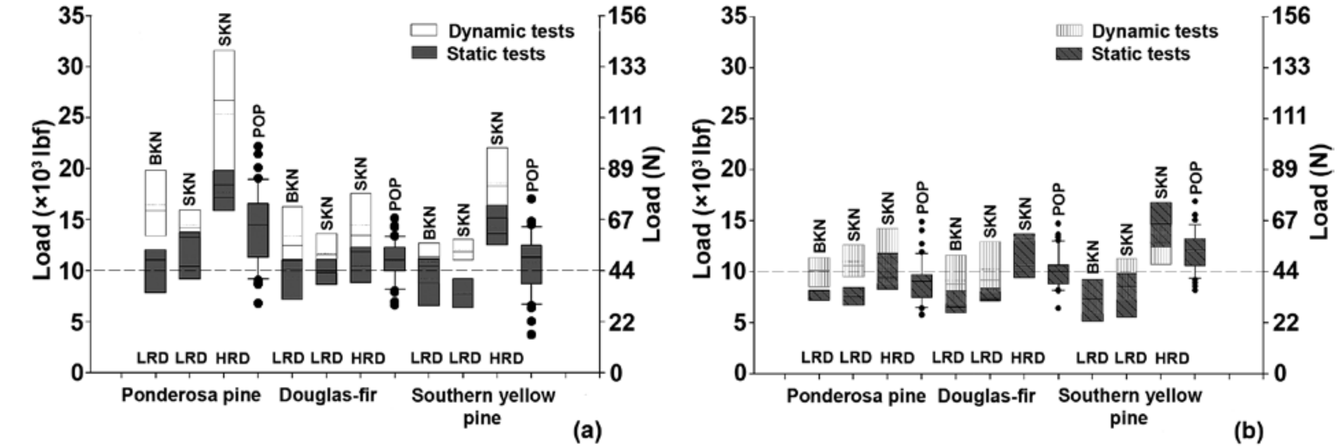


Figure 4—Box plots for peak load for Round 1 (a) and Round 2 (b) dynamic and static tests. Where appropriate, box plots show 5th, 25th, 50th, 75th, and 95th percentiles and extreme points. Dashed lines represent mean values. BKN, big knots; SKN, small knots; LRD, low rpi; HRD, high rpi; POP, population.

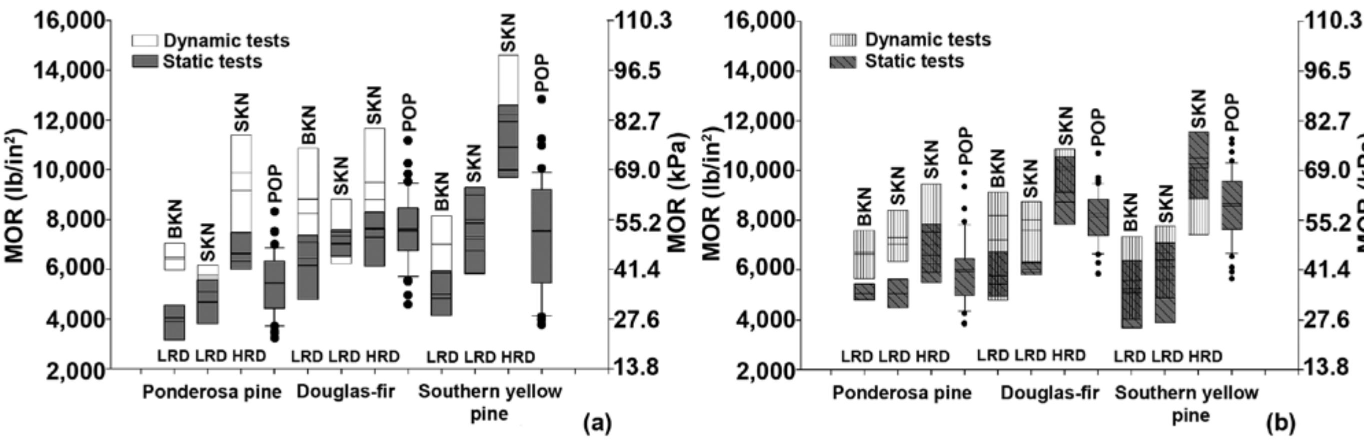


Figure 5—Box plots for MOR for Round 1 (a) and Round 2 (b) dynamic and static tests. Where appropriate, box plots show 5th, 25th, 50th, 75th, and 95th percentiles and extreme points. Dashed lines represent mean values. BKN, big knots; SKN, small knots; LRD, low rpi; HRD, high rpi; POP, population.

based on work by Powell (1973), have been used to estimate the sizes required for the round PP, DF, and SYP guardrail posts to perform effectively in the MGS. More information on the methodology to determine post size and embedment depth can be found in other publications (Hascall 2005, Kretschmann and others 2006, Haskell and others 2007).

Recommended Grading Criteria

The complete size and grading criteria are given in Appendix E. These criteria were developed after reviewing the static and dynamic test data, the population distribution of knots and ring density, and simulation results. The criteria were chosen to be restrictive enough to reduce the diameter of the posts as much as possible, but relaxed enough to allow a high percentage of the posts to qualify. The grading criteria that were developed for the full-size MGS crash test systems are given in Table 3. For the grading criteria, the diameter at groundline (0.914 m from base) rather than the top-end diameter was specified.

The results and computer simulations indicated that the following posts should perform successfully in the MGS design: 184-mm-diameter DF posts with ≤38-mm knots and ≥6 rpi, 203-mm-diameter PP posts with ≤89-mm knots and ≥6 rpi, and 190-mm-diameter SYP posts with ≤64-mm knots and ≥4 rpi, each with a 1:10 slope of grain.

Conclusions

The static and dynamic component testing conducted at FPL and MwRSF provided sufficient information to allow for the following conclusions:

- Properties can be fine tuned for DF and PP by adjusting size and grading criteria to allow substitution for SYP in round strong-post W-beam guardrail systems.
- For a given diameter, rpi had more impact on the properties of the post than did knots.

Table 3—Criteria for Midwest Guardrail System posts

Species	Diameter at groundline	Knot size	Ring density (rpi)	Slope of grain
Douglas-fir	184 mm 7-1/4 in.	≤38 mm ≤1-1/2 in.	≥6	1:10
Ponderosa pine	203 mm 8 in.	≤89 mm ≤3-1/2 in.	≥6	1:10
Southern yellow pine	190 mm 7-1/2 in.	≤64 mm ≤2-1/2 in.	≥4	1:10

- Round guardrail posts represent a feasible use for forest thinnings generated by fuel loading management programs.

Future Work

Final full-scale crash testing results for DF and PP will be documented in a future MwSRF research report. Detailed drawings of the MGS for round PP, DF, and SYP posts will be published at a future date. Finally, an installation guide will be produced to assist in assembly of the system.

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Appendix A—Detailed Work Schedule

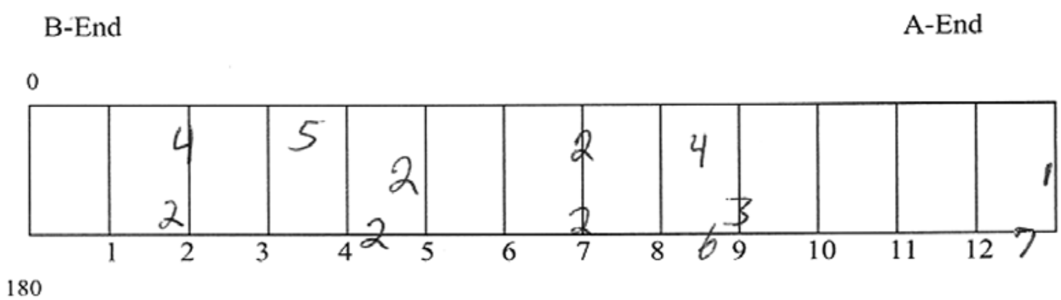
Phase	Step	Work task	Completion date
I	1	Study begins	September 2003
	2	Detailed planning, acquisition of wood post materials and preliminary grading	Spring 2004
IIa	3	Static testing, dynamic bogie testing - cantilevered sleeve	Fall 2004
II b	4	Static testing, dynamic bogie testing – cantilevered sleeve	Summer 2005
III	5	Dynamic bogie testing – soil embedment	Summer 2005
II and III	6	Special progress report	Summer 2005
IV	7	BARRIER VII simulation	Fall 2005
	8	Preliminary guardrail system design	Fall 2005
	9	Special progress report	December 2005
	10	Preliminary installation manual and standard CAD plans	Spring 2006
V	11	Full-scale crash testing	Spring 2006
	12	Special progress report	Fall 2006
	13	Final installation manual and standard CAD plans	Fall 2006
	14	Final post grading specification	December 2006
	15	Final report	Spring 2007
	16	Close out research project	Spring 2007

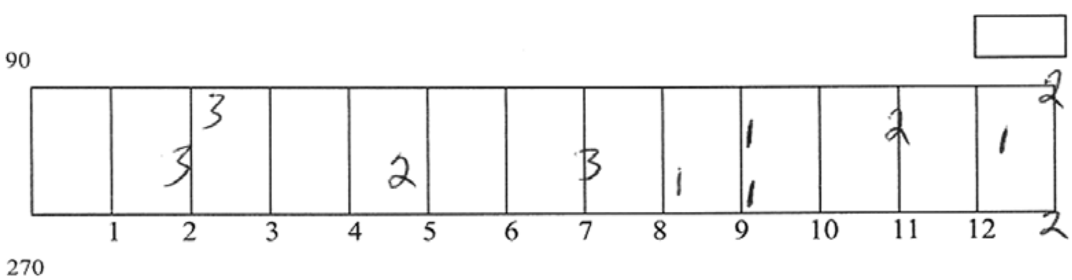
Appendix B—Example Data Sheet

Knot Map – guardrail testing

Sample # __________

Sample ID 763





1 – ½"	7- 4"
2 – 11/2"	
3 – 2"	9 - other
4 – 21/2"	
5 – 3"	M.D. – Machine Damage
6 – 31/2"	

Appendix C—Phase II Data

Column Heading Definitions

ID	Post identification number
Circum	Circumference of post at groundline (in.)
L	Length of post (in.)
Stresswave E	Modulus of elasticity determined by stress wave testing ($\times 10^6$ lb/in^2)
Test location	Where post was to be tested: F = FPL; L = Lincoln
I	Moment of inertia for post (in^4)
A	Cross-sectional area of post (in^2)
P Max	Maximum load on post (thousands of pounds)
Tip Deflection at Pmax	Deflection of tip at the maximum load (in.)
MOR	Modulus of rupture (lb/in^2)
KN1	Number of 1/2-inch knots
KN2	Number of 1-inch knots
KN3	Number of 1-1/2-inch knots
KN4	Number of 2-inch knots
KN5	Number of 2- 1/2-inch knots
KN6	Number of 3-inch knots
KN7	Number of 3-1/2-inch knots
KN8	Number of 4-inch knots
KN9	Number of other type defect
Density	Estimated density of post (lb/ft^3)
Ring per inch	Number of rings per inch determined from portion of post to be in ground
Latewood content	Percentage of latewood determined from digitized photos of bottom
Sp Gr	Specific gravity of post determined by ovendried weight and green volume
MC	Moisture content near the point of failure (%)
Category	Knot category: baseline, high ring density, large knot, or general population
Species	Wood species: ponderosa pine, Douglas-fir, or southern yellow pine

Phase IIa (Round 1) data

ID	Circum (in)	L (in)	Stresswave E ($\times 10^6$ lbs/in^2)	Test location	I (in^4)	A (in^2)	P Max ($\times 10^3$ lb)	Tip deflection at Pmax (in)	MOR (lb/in^2)	KN1	KN2	KN3	KN4	KN5	KN6	KN7	KN9	Density (lb/ft^3)	Ring density (rpi)	Percent latewood	Sp Gr	MC (%)	Category	Species
101	25.96	77.99	0.885	L			12.80	1.90	5770	0	4	3	1	1	0	0	0	32.408	8.2	26		43	Baseline	Ponderosa Pine
102	27.50	77.95	0.795	F	288.20	60.18	10.40	1.06	3927	3	2	1	1	0	1	0	1	54.156	7.0	20	0.33	57	Baseline	Ponderosa Pine
103	27.50	77.95	1.025	F	288.20	60.18	16.12	1.83	6090	0	6	5	0	0	0	0	0	39.448	7.9	27	0.43	26	Baseline	Ponderosa Pine
104	28.25	78.03	0.719	L			15.00	2.00	5210	2	6	1	0	0	1	0	0	52.86	6.9	23		26	Baseline	Ponderosa Pine
105	27.70	78.03	0.924	L			16.90	2.00	6240	1	1	3	1	1	0	0	1	55.139	7.6	21		31	Baseline	Ponderosa Pine
106	27.91	77.99	0.769	L			13.80	1.90	4990	3	4	1	0	0	0	0	0	37.75	7.6	14		38	Baseline	Ponderosa Pine
107	26.00	77.95	0.918	F	230.28	53.79	11.39	1.27	5091	1	3	5	0	0	0	0	0	43.627	7.8	22	0.40	20.9	Baseline	Ponderosa Pine
108	26.25	77.99	0.645	F	239.27	54.83	8.55	1.53	3712	0	0	2	5	0	0	0	0	51.908	5.6	26	0.40	42.6	Baseline	Ponderosa Pine
109	26.33	78.03	0.55	L			14.20	4.30	6110	0	3	9	0	0	0	0	0	37.624	6.2	33		38	Baseline	Ponderosa Pine
110	25.50	78.07	0.498	F	213.07	51.75	9.86	2.91	4671	1	6	1	2	0	0	0	0	45.541	6.5	24	0.42	21.1	Baseline	Ponderosa Pine
111	27.80	77.95	1.54	L			30.80	4.50	11280	3	3	1	0	0	0	0	0	44.319	10.3	12		38	HRD	Ponderosa Pine
112	28.01	77.95	1.87	L			32.40	4.40	11510	9	0	0	0	0	0	0	0	53.816	14.9	9		27	HRD	Ponderosa Pine
113	28.00	78.03	1.59	F	309.74	62.39	16.81	0.90	6017	1	0	0	0	0	0	0	0	50.031	12.1	1	0.40	29	HRD	Ponderosa Pine
114	27.00	77.95	1.058	F	267.81	58.01	14.94	1.06	5961	6	2	0	0	0	0	0	0	44.624	11.0	10	0.42	39.3	HRD	Ponderosa Pine
115	27.75	78.23	1.527	F	298.83	61.28	19.83	0.77	7292	2	3	0	0	0	0	0	0	32.365	8.7	8	0.41	18	HRD	Ponderosa Pine
116	27.25	77.99	1.612	F	277.87	59.09	19.75	1.46	7667	11	2	0	0	0	0	0	0	30.591	11.7	15	0.36	15.9	HRD	Ponderosa Pine
117	27.92	78.15	1.14	L			21.70	4.40	7850	3	7	0	0	0	0	0	0	34.714	14.2	17		38	HRD	Ponderosa Pine
118	28.13	77.95	1.039	L			15.20	2.00	5380	1	4	3	0	0	0	0	0	47.265	8.3	18		36	HRD	Ponderosa Pine
119	27.75	77.99	1.159	F	298.83	61.28	17.23	1.41	6333	4	6	1	0	0	0	0	0	43.181	10.6	19	0.39	31.4	HRD	Ponderosa Pine
120	27.71	77.99	1.283	L			26.70	4.00	9870	6	4	0	0	0	0	0	0	56.905	14.8	14		30	HRD	Ponderosa Pine
121	27.00	78.11	1.03	F	267.81	58.01	11.69	0.70	4665	2	1	2	2	0	0	0	0	44.14	7.6	18	0.38	25.3	Knot	Ponderosa Pine
122	28.42	78.03	1.041	L			18.80	2.40	6420	2	2	4	2	0	0	0	0	41.457	8.5	26		49	Knot	Ponderosa Pine
123	25.33	77.91	0.999	L			12.80	2.00	6170	5	4	4	0	0	0	0	0	41.916	10.2	25		41	Knot	Ponderosa Pine
124	27.83	78.03	1.089	L			15.90	2.10	5790	7	2	2	1	0	0	0	0	45.283	10.2	21		52	Knot	Ponderosa Pine
125	28.50	77.95	0.676	F	332.47	64.64	11.06	1.70	3753	7	1	0	0	0	1	0	1	51.097	9.1	15	0.46	37.4	Knot	Ponderosa Pine
126	27.25	77.91	0.858	F	277.87	59.09	6.66	0.38	2587	5	3	4	2	0	0	0	0	39.329	8.5	31	0.32	34.7	Knot	Ponderosa Pine
127	27.75	77.99	1.137	L			20.90	4.50	7680	1	4	3	0	0	0	0	0	52.52	9.0	18		36	Knot	Ponderosa Pine
128	25.83	78.03	0.741	L			14.10	1.80	6440	1	3	4	4	0	0	0	0	35.043	8.4	35		47	Knot	Ponderosa Pine
129	28.00	77.99	1.125	F	309.74	62.39	12.38	0.61	4429	1	2	5	1	0	0	0	0	49.764	10.0	24	0.36	44.4	Knot	Ponderosa Pine
130	26.00	77.87	1.052	F	230.28	53.79	9.07	0.53	4062	0	5	2	2	0	0	0	0	39.466	7.2	24	0.39	18.5	Knot	Ponderosa Pine
131	28.00	78.27	1.796	F	309.74	62.39	18.89	0.90	6759	11	1	0	0	0	0	0	0	34.488	9.6	13	0.44	18.2	Population	Ponderosa Pine
132	26.00	78.19	1.978	F	230.28	53.79	15.17	0.80	6780	2	0	0	0	0	0	0	0	35.922	10.3	2	0.46	17.2	Population	Ponderosa Pine
133	26.75	78.03	1.624	F	258.03	56.94	18.28	1.05	7504	20	5	0	0	0	0	0	0	33.198	8.1	30	0.39	40.6	Population	Ponderosa Pine
134	28.50	77.95	1.63	F	332.47	64.64	22.19	1.20	7531	6	4	1	0	0	0	0	0	34.018	10.6	17	0.48	17.2	Population	Ponderosa Pine
135	28.25	78.03	2.191	F	320.96	63.51	20.11	0.71	7007	2	2	0	0	0	0	0	0	46.467	10.7	6	0.47	38.3	Population	Ponderosa Pine
136	27.25	78.11	1.612	F	277.87	59.09	21.43	1.19	8322	10	0	0	0	0	0	0	0	33.049	10.2	10	0.39	15.7	Population	Ponderosa Pine
137	23.50	77.99	0.983	F	153.69	43.95	9.56	0.70	5787	6	7	2	1	0	0	0	0	45.254	8.6	30	0.35	35.4	Population	Ponderosa Pine
138	27.50	77.95	1.225	F	288.20	60.18	11.74	0.66	4436	6	6	0	0	0	0	0	0	41.72	11.3	18	0.36	58.2	Population	Ponderosa Pine
139	26.75	77.91	1.199	F	258.03	56.94	15.57	1.15	6388	3	3	2	0	0	0	0	0	43.55	10.9	15	0.39	23.7	Population	Ponderosa Pine
140	28.50	77.91	1.196	F	332.47	64.64	16.17	0.96	5489	3	4	3	0	0	0	0	0	46.515	11.3	20	0.40	102.5	Population	Ponderosa Pine
141	27.00	78.07	1.192	F	267.81	58.01	14.79	0.94	5904	6	6	2	0	0	0	0	0	38.894	11.4	24	0.33	73.8	Population	Ponderosa Pine
142	27.25	77.99	1.141	F	277.87	59.09	14.07	2.22	5463	6	5	1	0	0	0	0	0	50.447	9.7	19			Population	Ponderosa Pine
143	27.25	77.99	1.086	F	298.83	61.28	9.51	0.58	3497	2	4	4	1	0	0	0	0	44.299	9.1	26	0.33	129.1	Population	Ponderosa Pine
144	28.25	77.99	1.383	F	320.96	63.51	14.71	1.10	5126	2	5	2	0	0	0	0	0	50.141	11.0	18	0.38	40.8	Population	Ponderosa Pine
145	26.25	77.99	1.382	F	258.03	56.94	13.57	0.77	5568	11	4	1	0	0	0	0	0	43.049	11.6	22	0.45	45.4	Population	Ponderosa Pine
146	27.25	77.99	1.295	F	277.87	59.09	14.24	1.34	5529	5	3	1	0	0	0	0	0	46.126	12.2	14	0.41	34.5	Population	Ponderosa Pine
147	28.00	77.95	1.281	F	309.74	62.39	15.10	1.27	5404	7	2	0	0	0	0	0	0	51.316	13.5	11	0.41	47.5	Population	Ponderosa Pine
148	28.25	77.95	1.291	F	320.96	63.51	18.58	1.09	6473	3	5	0	0	0	0	0	0	42.855	11.8	13	0.40	29.7	Population	Ponderosa Pine
149	28.50	77.95	1.153	F	332.47	64.64	15.59	1.23	5289	3	4	1	0	0	0	0	0	46.339	9.2	14	0.41	72.2	Population	Ponderosa Pine

ID	Circum (in)	L (in)	Stresswave E ($\times 10^6$ lbs/in^2)	Test location	I (in^4)	A (in^2)	P Max ($\times 10^3$ lb)	Tip deflection at Pmax (in)	MOR (lb/in^2)	KN1	KN2	KN3	KN4	KN5	KN6	KN7	KN9	Density (lb/ft^3)	Ring density (rpi)	Percent latewood	Sp Gr	MC (%)	Category	Species
150	27.75	77.95	1.077	F	298.83	61.28	13.56	0.83	4987	3	6	1	0	0	0	0	0	46.608	7.9	18	0.35	31.9	Population	Ponderosa Pine
151	26.75	78.11	1.027	F	258.03	56.94	11.45	1.16	4700	2	7	0	0	0	0	0	0	40.429	10.2	16	0.36	40.7	Population	Ponderosa Pine
152	28.00	77.91	0.789	F	309.74	62.39	11.25	1.44	4027	1	6	4	0	0	0	0	0	40.563	11.0	25	0.34	38	Population	Ponderosa Pine
153	27.50	77.99	1.368	F	288.20	60.18	16.91	1.22	6388	6	3	2	0	0	0	0	0	46.193	10.8	18	0.43	27.4	Population	Ponderosa Pine
154	28.00	77.99	1.264	F	309.74	62.39	13.21	1.04	4728	3	1	1	1	0	0	0	0	46.158	15.2	12	0.35	35.4	Population	Ponderosa Pine
155	27.75	77.95	1.294	F	298.83	61.28	16.49	1.00	6064	2	3	0	0	0	0	0	0	40.045	15.8	8	0.40	21.9	Population	Ponderosa Pine
156	28.50	78.03	1.493	F	332.47	64.64	19.07	1.15	6472	6	2	0	0	0	0	0	0	43.535	17.1	10	0.41	36.1	Population	Ponderosa Pine
157	27.75	77.99	1.328	F	298.83	61.28	16.99	1.15	6245	7	2	0	0	0	0	0	0	45.661	19.2	11	0.39	40	Population	Ponderosa Pine
158	27.50	78.03	1.123	F	288.20	60.18	16.42	0.86	6202	4	3	1	1	0	0	0	0	36.989	13.4	17	0.46	21.4	Population	Ponderosa Pine
159	28.00	77.95	1.46	F	309.74	62.39	16.42	1.03	5876	1	6	1	0	0	0	0	0	42.329	13.1	16	0.41	22.7	Population	Ponderosa Pine
160	27.50	77.91	1.393	F	288.20	60.18	16.69	1.47	6306	4	0	1	0	0	0	0	0	46.976	17.4	7	0.42	32.4	Population	Ponderosa Pine
161	27.25	78.03	0.926	F	277.87	59.09	11.40	0.90	4425	1	5	2	0	0	0	0	0	41.629	10.2	17	0.42	21.4	Population	Ponderosa Pine
162	25.25	77.91	1.089	F	204.84	50.74	9.56	0.74	4667	2	5	3	0	0	0	0	0	36.734	13.4	21	0.42	22.8	Population	Ponderosa Pine
163	25.50	77.95	0.933	F	213.07	51.75	6.81	0.38	3228	2	2	1	1	1	0	0	1	36.735	10.6	18	0.37	23.6	Population	Ponderosa Pine
164	26.75	77.95	1.111	F	258.03	56.94	9.05	1.36	3716	5	1	1	1	0	0	0	0	45.658	12.2	14	0.31	94.4	Population	Ponderosa Pine
165	26.50	77.91	0.708	F	248.52	55.88	8.82	0.61	3725	0	1	4	1	0	0	0	0	38.002	11.3	18	0.39	22.3	Population	Ponderosa Pine
166	25.50	77.99	0.739	F	213.07	51.75	9.33	0.66	4420	3	1	2	3	1	0	0	0	39.265	11.8	28	0.42	19.4	Population	Ponderosa Pine
167	27.75	77.91	1.061	F	298.83	61.28	11.50	0.59	4229	1	1	5	0	0	0	0	0	41.97	12.9	18	0.42	22.8	Population	Ponderosa Pine
168	26.50	77.99	0.862	F	248.52	55.88	9.74	0.63	4110	5	0	3	2	0	0	0	0	39.06	10.2	22	0.39	34.4	Population	Ponderosa Pine
169	25.50	77.95	0.882	F	213.07	51.75	8.67	0.58	4110	3	5	4	0	0	0	0	0	37.115	9.2	25	0.39	16.5	Population	Ponderosa Pine
170	27.50	78.03	1.334	F	288.20	60.18	16.04	1.04	6061	2	10	0	0	0	0	0	0	42.288	12.7	22	0.43	31	Population	Ponderosa Pine
171	27.75	77.95	1.364	F	298.83	61.28	18.09	0.99	6649	2	6	0	0	0	0	0	0	35.228	13.7	14	0.37	19.8	Population	Ponderosa Pine
172	28.25	77.95	1.297	F	320.96	63.51	14.53	1.29	5064	1	8	3	0	0	0	0	0	54.188	9.2	26	0.39	66.4	Population	Ponderosa Pine
173	27.75	77.83	0.933	F	298.83	61.28	9.36	0.61	3442	4	5	1	1	0	0	0	0	44.887	10.8	21	0.41	24.5	Population	Ponderosa Pine
174	27.25	78.03	0.968	F	277.87	59.09	13.62	0.81	5289	3	3	1	0	0	0	0	0	47.058	12.9	12	0.41	33	Population	Ponderosa Pine
175	27.75	77.99	1.085	F	298.83	61.28	14.46	1.58	5316	6	2	2	1	0	0	0	0	49.029	10.6	20	0.41	53.6	Population	Ponderosa Pine
201	22.75	78.11	1.898	F	134.99	41.19	12.82	1.37	8554	10	2	0	0	0	0	0	0	35.557	10.2	14	0.41	19.1	HRD	Douglas Fir
202	23.08	78.11	1.397	L			16.40	4.20	10500	1	4	4	1	0	0	0	0	40.193	11.5	25		59	HRD	Douglas Fir
203	22.54	77.91	2.058	L			18.80	4.40	12870	1	0	0	0	0	0	0	0	44.175	17.6	1		58	HRD	Douglas Fir
204	22.25	77.80	1.3	F	123.51	39.40	9.08	0.97	6475	9	3	10	0	0	0	0	0	33.003	6.4	45	0.38	19.7	Population	Douglas Fir
205	22.75	78.19	1.419	F	134.99	41.19	8.59	0.67	5729	5	8	1	0	0	0	0	0	45.312	9.6	24	0.42	20	HRD	Douglas Fir
206	22.92	77.09	1.159	L			13.50	4.30	8750	1	7	0	0	0	0	0	0	33.718	8.8	15		65	HRD	Douglas Fir
207	23.25	77.95	1.155	F	147.25	43.02	10.46	0.84	6537	5	4	1	0	0	0	0	0	36.973	10.7	16	0.42	18.8	HRD	Douglas Fir
208	23.00	77.72	1.496	F	141.02	42.10	11.79	1.75	7615	2	5	1	0	0	0	0	0	33.602	7.5	15	0.41	20.8	HRD	Douglas Fir
209	22.92	77.99	1.262	L			13.50	4.10	8810	4	3	3	0	0	0	0	0	31.221	13.7	19		64	HRD	Douglas Fir
210	23.04	78.03	1.495	L			10.30	2.00	6590	9	7	0	0	0	0	0	0	33.604	7.1	23		64	HRD	Douglas Fir
211	23.08	77.99	1.497	L			12.10	4.30	7730	7	4	2	4	0	0	0	0	39.413	18.6	37		63	Knot	Douglas Fir
212	22.00	78.15	1.379	F	118.05	38.52	6.27	0.81	4624	5	3	2	2	0	0	0	0	37.042	9.7	25	0.48	18.7	Knot	Douglas Fir
213	22.96	77.48	1.051	L			9.90	1.90	6440	4	4	10	1	0	0	0	0	37.148	8.3	46		59	Knot	Douglas Fir
214	23.50	77.68	1.353	F	153.69	43.95	8.19	1.21	4959	1	7	4	1	0	0	0	0	40.452	7.4	31	0.40	38.9	Knot	Douglas Fir
215	22.83	77.99	1.58	L			17.30	3.90	11420	1	6	4	2	0	0	0	0	43.655	10.8	33		59	Knot	Douglas Fir
216	23.00	77.17	1.287	F	141.02	42.10	10.17	1.15	6569	4	0	1	2	3	0	0	0	35.032	5.9	30	0.41	20.3	Knot	Douglas Fir
217	22.50	77.95	1.757	F	129.15	40.29	11.87	0.84	8185	3	3	1	3	0	0	0	0	40.451	12.2	24	0.55	18.1	Knot	Douglas Fir
218	22.67	78.03	1.504	L			15.30	4.30	10320	2	1	4	0	0	0	0	0	37.012	9.9	16		61	Knot	Douglas Fir
219	23.25	77.91	1.379	F	147.25	43.02	10.30	0.81	6438	0	2	0	0	1	0	0	0	38.557	11.7	9	0.44	19.2	Knot	Douglas Fir
220	22.83	77.95	1.324	L			12.50	4.40	8260	8	0	3	2	0	0	0	0	38.107	11.3	25		57	Knot	Douglas Fir
221	21.75	78.11	1.234	F	112.77	37.65	6.78	0.85	6705	3	7	5	1	0	0	0	0	35.098	7.9	36	0.45	16.9	Baseline	Douglas Fir
222	23.21	77.87	1.203	L			9.00	1.80	5630	7	6	0	0	0	0	0	0	30.877	4.9	19		37	Baseline	Douglas Fir
223	22.50	77.95	1.411	F	129.15	40.29	10.18	1.16	7020	5	11	4	0	0	0	0	0	35.099	5.7	39	0.39	20	Baseline	Douglas Fir

ID	Circum (in)	L (in)	Stresswave E (x10^6 lbs/in^2)	Test location	I (in^4)	A (in^2)	P Max (x10^3 lb)	Tip deflection at Pmax (in)	MOR (lb/in^2)	KN1	KN2	KN3	KN4	KN5	KN6	KN7	KN9	Density (lb/ft^3)	Ring density (rpi)	Percent late-wood	Sp Gr	MC (%)	Category	Species
224	22.54	77.36	1.425	L			14.60	4.50	10040	3	4	3	0	0	0	0	0	37.968	5.3	20		31	Baseline	Douglas Fir
225	23.58	77.72	1.361	L			12.70	2.00	7620	5	5	5	1	0	0	0	0	45.123	7.7	34		32	Baseline	Douglas Fir
226	23.00	77.32	1.628	L			10.60	4.20	6840	5	2	3	1	0	0	0	0	40.458	6.7	22		45	Baseline	Douglas Fir
227	23.13	77.48	1.266	L			11.60	4.10	7360	3	10	0	0	0	0	0	0	33.903	6.3	23		61	Baseline	Douglas Fir
228	22.00	78.07	1.246	F	118.05	38.52	8.56	0.89	6319	6	4	1	0	0	0	0	0	31.03	7.5	17	0.42	18.3	Baseline	Douglas Fir
229	23.00	78.11	1.65	F	141.02	42.10	12.01	1.67	7755	4	4	2	0	0	0	0	0	40.706	7.2	18	0.44	20.3	Baseline	Douglas Fir
230	22.00	77.48	1.496	F	118.05	38.52	10.03	1.63	7402	3	1	6	3	0	0	0	0	39.574	9.8	35	0.44	20.9	Baseline	Douglas Fir
231	22.75	76.73	1.533	F	134.99	41.19	13.41	1.21	8950	3	4	4	0	0	0	0	0	38.684	8.6	23	0.51	18.5	Population	Douglas Fir
232	23.50	77.95	1.7	F	153.69	43.95	11.99	1.93	7258	6	3	1	0	0	0	0	0	48.732	13.2	15	0.40	76.6	Population	Douglas Fir
233	22.00	77.95	1.756	F	118.05	38.52	12.79	1.07	9438	4	0	0	1	0	0	0	0	37.317	15.4	8	0.46	19.8	Population	Douglas Fir
234	22.00	77.68	1.163	F	118.05	38.52	8.63	0.94	6365	4	4	7	0	0	0	0	0	32.665	6.7	33	0.46	22.9	Population	Douglas Fir
235	23.00	77.95	1.355	F	141.02	42.10	8.62	1.06	5563	7	3	2	0	0	0	0	0	34.132	7.2	19	0.39	20.6	Population	Douglas Fir
236	23.25	77.99	1.459	F	147.25	43.02	11.59	1.26	7244	5	4	1	0	0	0	0	0	36.108	7.6	16	0.40	21.1	Population	Douglas Fir
237	22.25	77.72	1.624	F	123.51	39.40	14.39	1.77	10263	3	4	0	0	0	0	0	0	35.876	10.9	11	0.41	20.6	Population	Douglas Fir
238	23.50	77.95	1.316	F	153.69	43.95	9.61	1.47	5937	2	2	5	0	0	0	0	0	45.634	11.2	21	0.45	37.9	Population	Douglas Fir
239	22.25	76.69	1.712	F	123.51	39.40	10.21	1.36	7283	5	7	4	0	0	0	0	0	44.875	12.1	31	0.50	22.4	Population	Douglas Fir
240	22.50	77.99	1.261	F	129.15	40.29	6.65	0.68	4588	4	7	6	0	0	0	0	0	43.05	7.1	36	0.41	30.8	Population	Douglas Fir
241	22.50	77.60	1.489	F	129.15	40.29	12.23	1.22	8436	6	1	5	0	0	0	0	0	36.893	7.8	23	0.44	20.8	Population	Douglas Fir
242	22.25	78.15	1.089	F	123.51	39.40	6.96	0.64	4963	3	3	3	0	0	0	0	0	34.436	9.7	18	0.39	21.2	Population	Douglas Fir
243	22.00	77.76	1.494	F	118.05	38.52	10.20	1.14	7525	5	1	1	0	0	0	0	0	37.822	7.8	10	0.43	24.2	Population	Douglas Fir
244	22.25	77.17	1.633	F	123.51	39.40	11.23	0.99	8009	5	5	1	0	0	0	0	0	38.031	10.4	18	0.46	19	HRD	Douglas Fir
245	22.00	77.68	1.477	F	118.05	38.52	10.92	0.99	8053	4	0	4	0	0	0	0	0	38.405	10.4	16	0.44	22.4	Population	Douglas Fir
246	22.50	77.48	1.761	F	129.15	40.29	12.32	1.11	8494	7	3	2	0	1	0	0	0	37.191	16.6	24	0.49	19.1	Population	Douglas Fir
247	22.50	77.52	1.252	F	129.15	40.29	8.00	0.91	5517	4	3	9	0	0	0	0	0	34.749	7.2	37	0.37	18.5	Population	Douglas Fir
248	22.50	77.40	1.573	F	129.15	40.29	11.38	1.25	7847	3	3	6	0	0	0	0	0	37.382	8.4	27	0.46	17.6	Population	Douglas Fir
249	23.00	77.09	1.395	F	141.02	42.10	10.32	0.82	6666	3	3	4	0	0	0	0	0	35.328	10.5	21	0.41	20	Population	Douglas Fir
250	23.00	77.60	1.265	F	141.02	42.10	9.00	1.03	5811	1	8	7	0	0	0	0	0	36.172	7.9	38	0.42	21.1	Population	Douglas Fir
251	22.00	77.60	1.675	F	118.05	38.52	10.20	1.35	7529	4	2	6	0	0	0	0	0	36.572	10.7	26	0.45	19.7	Population	Douglas Fir
252	22.25	77.36	1.73	F	123.51	39.40	11.62	1.52	8288	2	4	1	0	0	0	0	0	38.001	8.2	13	0.41	20.9	Population	Douglas Fir
253	22.75	77.63	1.111	F	134.99	41.19	10.50	1.47	7002	5	4	2	0	0	0	0	1	37.815	6.8	19	0.43	28.4	Population	Douglas Fir
254	22.25	77.99	1.475	F	123.51	39.40	11.08	0.98	7902	1	5	5	0	0	0	0	0	34.076	10.4	26	0.44	17.1	Population	Douglas Fir
255	23.00	77.52	1.327	F	141.02	42.10	12.78	1.83	8249	2	4	4	1	1	0	0	0	38.17	15.0	31	0.47	22.9	Population	Douglas Fir
256	23.50	77.99	1.518	F	153.69	43.95	12.70	1.47	7688	7	3	6	1	0	0	0	0	36.926	11.6	35	0.41	20.3	Population	Douglas Fir
257	22.50	77.68	1.437	F	129.15	40.29	11.06	1.40	7627	9	8	1	1	0	0	0	1	37.378	9.2	32	0.42	20.6	Population	Douglas Fir
258	22.50	77.56	1.535	F	129.15	40.29	13.35	1.40	9210	4	2	4	0	0	0	0	0	35.548	7.6	20	0.44	19.4	Population	Douglas Fir
259	22.00	77.87	1.546	F	118.05	38.52	11.57	1.60	8537	6	6	0	0	0	0	0	0	32.317	6.5	18	0.38	19	Population	Douglas Fir
260	22.25	77.87	1.267	F	123.51	39.40	9.71	0.98	6928	7	3	4	0	0	0	0	0	35.251	7.1	25	0.40	20.6	Population	Douglas Fir
261	22.00	77.72	2.209	F	118.05	38.52	15.14	1.39	11173	11	3	0	0	0	0	0	0	43.03	15.3	17	0.50	20.2	Population	Douglas Fir
262	22.25	77.83	1.149	F	123.51	39.40	10.15	1.18	7241	13	1	0	0	0	0	0	0	37.436	8.8	15	0.46	20.8	Population	Douglas Fir
263	22.50	77.87	1.954	F	129.15	40.29	14.27	1.16	9840	1	5	3	0	0	0	0	0	37.546	9.3	20	0.46	20	Population	Douglas Fir
264	22.50	77.48	1.968	F	129.15	40.29	11.90	1.18	8210	1	5	5	0	0	0	0	0	41.371	11.3	26	0.48	19.6	Population	Douglas Fir
265	22.25	77.95	1.711	F	123.51	39.40	11.45	1.06	8167	4	3	1	0	0	0	0	0	37.198	8.6	13	0.42	20	Population	Douglas Fir
266	22.00	76.97	1.227	F	118.05	38.52	7.90	0.68	5826	3	3	3	1	0	0	0	0	35.939	7.1	22	0.45	21.7	Population	Douglas Fir
267	22.50	77.99	1.472	F	129.15	40.29	10.69	0.90	7372	2	4	6	0	0	0	0	0	37.202	8.2	28	0.44	20.3	Population	Douglas Fir
268	22.75	77.17	1.681	F	134.99	41.19	10.91	1.59	7279	6	2	3	0	0	0	0	1	35.628	8.7	19	0.45	17.5	Population	Douglas Fir
269	22.25	77.91	1.758	F	123.51	39.40	13.35	1.72	9521	17	3	0	0	0	0	0	0	38.949	10.8	23	0.47	20	Population	Douglas Fir
270	22.25	77.95	1.641	F	123.51	39.40	12.93	1.37	9220	3	4	0	0	0	0	0	0	35.039	15.2	11	0.43	18.7	Population	Douglas Fir
271	22.00	77.80	1.534	F	118.05	38.52	8.25	0.84	6087	2	3	5	0	0	0	0	0	39.116	9.7	23	0.46	22.1	Population	Douglas Fir
272	21.50	77.95	1.479	F	107.68	36.78	11.45	1.42	9049	5	2	4	0	0	0	0	0	37.255	12.1	21	0.45	19.7	Population	Douglas Fir

ID	Circum (in)	L (in)	Stresswave E ($\times 10^6$ lbs/in^2)	Test location	I (in^4)	A (in^2)	P Max ($\times 10^3$ lb)	Tip deflection at Pmax (in)	MOR (lb/in^2)	KN1	KN2	KN3	KN4	KN5	KN6	KN7	KN9	Density (lb/ft^3)	Ring density (rpi)	Percent latewood	Sp Gr	MC (%)	Category	Species
273	22.00	77.96	1.404	F	118.05	38.52	10.08	1.22	7436	5	4	5	0	0	0	0	0	41.196	11.4	28	0.47	24.3	Population	Douglas Fir
274	22.50	77.95	1.396	F	129.15	40.29	9.93	1.04	6847	2	5	4	0	0	0	0	0	34.868	13.1	24	0.46	21.4	Population	Douglas Fir
275	22.00	77.80	1.44	F	118.05	38.52	10.69	1.14	7889	3	1	2	0	0	0	0	0	37.02	11.8	11	0.45	19.5	Population	Douglas Fir
301	22.00	77.75	1.043	F	118.05	38.52	6.09	0.67	4496	3	2	5	2	1	0	0	0	31.15	5.4	35	0.50	17	Knot	Southern Pine
302	22.75	78.25	1.131	F	134.99	41.19	7.49	1.11	4995	0	2	3	2	0	0	0	0	32.21	4.4	21	0.41	18.9	Knot	Southern Pine
303	23.38	77.25	0.846	L			11.80	1.80	7230									40.7	2.6			50	Knot	Southern Pine
304	22.29	77.25	1.148	L			8.80	4.10	6250									38.86	2.5			41	Knot	Southern Pine
305	23.25	77.50	0.792	L			8.70	1.80	5440									25.09	6.0			68	Knot	Southern Pine
306	22.79	77.25	1.325	L			13.70	4.30	9080									35.3	6.3			43	Knot	Southern Pine
307	22.50	77.30	1.319	F	129.15	40.29	7.00	0.61	4828	1	0	5	0	0	0	0	0	35.38	4.1	16	0.43	21.1	Knot	Southern Pine
308	22.25	77.75	1.287	F	123.51	39.40	5.31	0.49	3787	3	1	3	1	0	0	0	0	39.16	2.4	18	0.47	28.6	Knot	Southern Pine
309	23.38	78.15	1.24	L			11.40	4.10	7030									42.64	3.3			31	Knot	Southern Pine
310	22.75	77.30	0.459	F	134.99	41.19	10.30	3.35	6871	1	4	2	2	0	0	0	0	33.83	2.8	23	0.46	20.2	Knot	Southern Pine
311	22.25	74.00	0.984	F	123.51	39.40	12.58	1.86	8969	5	0	0	0	0	0	0	0	38.55	2.5	5	0.48	20.7	Baseline	Southern Pine
312	22.75	74.00	0.454	F	134.99	41.19	9.78	3.15	6527	5	1	0	0	0	0	0	0	46.85	3.4	7	0.41	26	Baseline	Southern Pine
313	22.50	74.00	0.797	F	129.15	40.29	13.03	2.56	8988	1	0	0	0	0	0	0	0	46.8	3.8	1	0.52	22.6	Baseline	Southern Pine
314	23.29	78.50	0.696	L			10.70	1.90	6650									40.84	3.0			37	Baseline	Southern Pine
315	22.75	78.25	0.567	F	134.99	41.19	7.72	1.35	5154	6	0	0	0	0	0	0	0	43.54	3.2	6	0.42	34.6	Baseline	Southern Pine
316	23.50	77.00	1.43	L			11.90	2.10	7230									40.73	3.0			32	Baseline	Southern Pine
317	23.58	77.00	0.709	L			12.20	4.40	7320									35.86	3.0			40	Baseline	Southern Pine
318	23.63	77.88	0.739	L			11.50	1.90	6850									37.5	3.0			35	Baseline	Southern Pine
319	23.00	77.70	0.729	F	141.02	42.10	14.85	3.11	9586	8	0	0	0	0	0	0	0	38.24	2.2	8	0.48	22.4	Baseline	Southern Pine
320	23.33	77.88	0.466	L			14.00	4.50	8670									40.04	2.3			31	Baseline	Southern Pine
321	22.50	73.00	1.784	F	129.15	40.29	13.97	1.40	9635	0	0	0	0	0	0	0	0	39.98	7.8	0	0.47	24.3	HRD	Southern Pine
322	22.88	73.00	2.315	L			23.10	3.80	15140									50.18	7.3			25	HRD	Southern Pine
323	22.92	73.00	1.993	L			18.30	4.00	11940									45.32	4.7			27	HRD	Southern Pine
324	21.25	78.00	1.991	F	102.76	35.93	15.37	1.72	12581	6	0	0	0	0	0	0	0	37.8	9.9	6	0.50	19	HRD	Southern Pine
325	22.00	77.25	2.233	F	118.05	38.52	17.10	1.58	12618	9	3	0	0	0	0	0	0	45.32	8.2	15	0.56	19.6	HRD	Southern Pine
326	23.25	78.25	1.905	F	147.25	43.02	15.95	1.42	9972	1	0	0	0	0	0	0	0	40.02	11.0	1	0.49	20.8	HRD	Southern Pine
327	22.38	78.50	1.92	L			16.50	4.10	11560									34.79	9.5			27	HRD	Southern Pine
328	23.46	77.60	1.704	L			13.90	3.80	8480									37.24	8.0			31	HRD	Southern Pine
329	22.50	77.75	2.004	F	129.15	40.29	14.17	1.96	9771	0	5	0	0	0	0	0	0	39.4	9.9	10	0.47	19.2	HRD	Southern Pine
330	22.71	77.50	1.986	L			21.00	4.10	14070									39.86	11.0			27	HRD	Southern Pine
331	23.00	77.99	1.454	F	141.02	42.10	12.55	1.19	8106	3	7	0	0	0	0	0	0	31.75	10.3	17	0.43	16.1	Population	Southern Pine
332	23.25	76.93	1.078	F	147.25	43.02	6.55	0.61	4097	0	3	1	0	0	0	0	0	30.38	3.7	9	0.34	23.9	Population	Southern Pine
333	23.50	78.15	0.973	F	153.69	43.95	6.60	0.67	3994	0	1	3	0	0	0	0	0	40.23	3.2	11	0.41	47.1	Population	Southern Pine
334	22.75	77.83	1.367	F	134.99	41.19	13.12	1.19	8751	1	6	1	0	0	0	0	0	36.02	8.3	16	0.52	18.4	Population	Southern Pine
335	23.25	77.60	0.626	F	147.25	43.02	8.14	1.48	5091	10	1	1	0	0	0	0	0	33.44	2.5	15	0.42	19.3	Population	Southern Pine
336	23.00	77.56	0.835	F	141.02	42.10	8.65	0.79	5586	1	0	0	0	0	0	0	0	40.36	4.0	1	0.45	24.5	Population	Southern Pine
337	23.00	77.56	1.276	F	141.02	42.10	6.14	0.61	3967	0	4	4	1	0	0	0	0	38.29	3.1	24	0.36	37.1	Population	Southern Pine
338	23.25	78.07	1.336	F	147.25	43.02	6.04	0.50	3777	3	1	4	0	0	0	0	0	36.28	4.1	17	0.39	27.5	Population	Southern Pine
339	23.25	77.72	1.475	F	147.25	43.02	12.11	1.11	7570	4	4	1	0	0	0	0	0	39.78	4.9	15	0.45	30	Population	Southern Pine
340	23.00	77.72	1.139	F	141.02	42.10	8.07	0.83	5213	0	3	5	0	0	0	0	0	30.35	4.1	21	0.35	21.4	Population	Southern Pine
341	23.00	78.03	2.092	F	141.02	42.10	19.88	1.75	12834	6	0	0	0	0	0	0	0	42.01	9.0	6	0.55	18.8	Population	Southern Pine
342	22.75	76.38	1.306	F	134.99	41.19	9.83	0.79	6561	3	7	5	1	0	0	0	0	39.1	8.4	36	0.49	16.9	Population	Southern Pine
343	22.50	77.99	1.639	F	129.15	40.29	11.74	1.10	8099	3	2	2	6	0	0	0	0	40.09	7.0	37	0.45	22.6	Population	Southern Pine
344	23.00	77.01	0.54	F	141.02	42.10	8.17	1.46	5275	10	2	1	0	0	0	0	0	43.18	3.2	17	0.40	55	Population	Southern Pine
345	23.25	77.48	0.823	F	147.25	43.02	8.05	1.10	5031	4	1	3	1	0	0	0	0	33.16	2.9	19	0.38	19.7	Population	Southern Pine
346	23.00	76.65	1.741	F	141.02	42.10	13.63	1.64	8798	2	3	5	0	0	0	0	0	39	10.8	23	0.49	19.3	Population	Southern Pine

ID	Circum (in)	L (in)	Stresswave E ($\times 10^6$ lbs/in^2)	Test location	I (in^4)	A (in^2)	P Max ($\times 10^3$ lb)	Tip deflection at Pmax (in)	MOR (lb/in^2)	KN1	KN2	KN3	KN4	KN5	KN6	KN7	KN9	Density (lb/ft^3)	Ring density (rpi)	Percent latewood	Sp Gr	MC (%)	Category	Species
347	22.25	77.20	1.191	F	123.51	39.40	10.76	1.01	7671	10	3	1	0	0	0	0	0	33.62	6.9	19	0.45	16.7	Population	Southern Pine
348	22.00	78.15	1.155	F	118.05	38.52	13.26	2.00	9786	0	0	0	0	0	0	0	0	40.31	4.3	0	0.52	19.8	Population	Southern Pine
349	22.00	78.11	1.595	F	118.05	38.52	13.21	1.42	9749	6	3	2	0	0	0	0	0	33.01	10.8	18	0.42	19.2	Population	Southern Pine
360	21.25	77.99	1.461	F	102.76	35.93	10.84	1.33	9871	4	1	2	1	0	0	0	0	33.05	9.6	16	0.46	17.1	Population	Southern Pine
351	22.50	77.17	1.206	F	129.15	40.29	10.28	1.04	7087	4	0	0	0	0	0	0	0	34.62	3.5	4	0.44	21.5	Population	Southern Pine
352	22.50	73.50	1.342	F	129.15	40.29	13.34	2.05	9199	0	0	0	0	0	0	0	0	40.63	6.0	0	0.49	20.7	Population	Southern Pine
353	22.75	77.56	1.213	F	134.99	41.19	13.99	3.03	9336	0	0	0	0	0	0	0	0	40.71	11.4	0	0.48	26.7	Population	Southern Pine
354	22.50	77.95	0.995	F	129.15	40.29	10.82	2.23	7464	3	0	0	0	0	0	0	0	36.77	3.2	3	0.45	24.7	Population	Southern Pine
355	22.50	77.36	0.822	F	129.15	40.29	10.91	2.24	7525	0	0	0	0	0	0	0	0	33.33	3.6	0	0.44	23.1	Population	Southern Pine
356	22.50	77.95	0.762	F	129.15	40.29	11.99	2.80	8270	0	0	0	0	0	0	0	0	38.01	3.8	0	0.45	24.1	Population	Southern Pine
357	22.75	74.41	2.127	F	134.99	41.19	14.51	1.72	9678	1	0	0	0	0	0	0	0	45.88	5.1	1	0.52	27.9	Population	Southern Pine
358	22.75	77.56	1.095	F	134.99	41.19	10.03	1.30	6691	0	0	0	0	0	0	0	0	36.5	3.2	0	0.41	23.2	Population	Southern Pine
359	22.00	77.36	2.198	F	118.05	38.52	15.25	1.64	11249	0	0	0	0	0	0	0	0	42.43	9.5	0	0.54	22	Population	Southern Pine
360	22.50	77.24	2.266	F	129.15	40.29	14.58	1.17	10054	0	0	0	0	0	0	0	0	41.99	11.2	0	0.54	22.2	Population	Southern Pine
361	22.50	77.17	1.634	F	129.15	40.29	15.93	1.97	10986	0	0	0	0	0	0	0	0	43.62	4.4	0	0.55	24.1	Population	Southern Pine
362	22.25	78.15	0.889	F	123.51	39.40	10.01	1.52	7139	6	0	0	0	0	0	0	0	32.67	3.1	6	0.43	20.7	Population	Southern Pine
363	22.50	77.76	1.91	F	129.15	40.29	13.39	1.38	9232	0	0	0	0	0	0	0	0	43.48	6.2	0	0.49	23.2	Population	Southern Pine
364	22.00	77.36	0.773	F	118.05	38.52	8.78	1.71	6478	0	0	0	0	0	0	0	0	39.38	3.2	0	0.49	21.7	Population	Southern Pine
365	22.00	77.56	0.714	F	118.05	38.52	7.21	1.25	5320	3	1	0	0	0	0	0	0	35.24	2.7	5	0.41	23.3	Population	Southern Pine
366	21.50	77.52	1.044	F	107.68	36.78	9.46	1.36	7475	3	1	3	0	0	0	0	0	32.46	7.2	14	0.44	19	Population	Southern Pine
367	23.00	77.01	1.617	F	141.02	42.10	12.75	1.75	8230	1	0	1	2	0	0	0	0	41.77	8.3	12	0.44	26.8	Population	Southern Pine
368	22.75	77.13	0.768	F	134.99	41.19	9.72	1.48	6483	4	0	0	0	0	0	0	0	45.57	2.5	4	0.44	43.6	Population	Southern Pine
369	22.75	76.97	1.837	F	134.99	41.19	13.80	1.91	9208	2	0	0	0	0	0	0	1	40.26	11.2	2	0.53	19.2	Population	Southern Pine
370	22.25	77.09	1.401	F	123.51	39.40	12.61	1.25	8994	3	6	2	0	0	0	0	0	36.26	8.7	21	0.50	17.6	Population	Southern Pine
371	23.25	77.60	1.006	F	147.25	43.02	6.63	0.68	4143	1	2	2	0	0	0	0	0	33.6	3.0	11	0.46	20.2	Population	Southern Pine
372	23.00	77.68	1.314	F	141.02	42.10	7.42	0.69	4791	1	4	4	0	0	0	0	0	32.67	12.8	21	0.40	20	Population	Southern Pine
373	22.75	77.80	1.301	F	134.99	41.19	13.46	1.92	8978	3	8	1	0	0	0	0	0	35.45	6.5	22	0.42	21.1	Population	Southern Pine
374	22.00	77.48	1.343	F	118.05	38.52	7.83	0.87	5776	2	3	3	0	0	0	0	0	36.51	3.9	17	0.37	33.8	Population	Southern Pine
375	23.00	77.76	1.536	F	141.02	42.10	15.00	1.44	9685	2	1	1	0	0	0	0	1	31.65	9.0	7	0.39	18.4	Population	Southern Pine

Phase IIb (Round 2) data

ID	Circum (in)	L (in)	Stresswave E (x10^6 lb/in^2)	Test location	I (in^4)	A (in^2)	P Max (x10^3 lb)	Tip Deflection at Pmax (in)	Pmax adj 7.25 (x10^3 lb)	MOR (lb/in^2)	KN1	KN2	KN3	KN4	KN5	KN6	KN7	KN8	KN9	MD	SUMKN	Density (lb/ft^3)	Ring density (rpi)	Percent latewood	Sp Gr	MC (%)	Category	Species
401	19.92	78.13	1.354	L			8.80	2.90		8700													3.7			70	Knot	Douglas Fir
402	20.75	78.13	1.539	F	93.42	34.26	8.12	1.24	10.74	7144	10	8	1	0	0	0	0	0	0	1	29	35.8	4.0	20	0.44	24	Knot	Douglas Fir
403	22.54	78.13	1.176	L			5.40	3.10		3690													4.3			61	Knot	Douglas Fir
404	22.08	78.13	1.990	L			13.10	3.30		9580													4.3			54	Knot	Douglas Fir
405	21.38	78.13	1.502	L			10.20	3.30		8200													4.0			70	Knot	Douglas Fir
406	20.00	78.13	1.421	F	80.63	31.83	8.47	1.64	9.56	6355	10	5	1	1	0	0	0	0	0	0	27	39.2	4.0	18	0.50	27	Knot	Douglas Fir
407	22.00	78.13	1.496	F	118.05	38.52	6.59	1.32	7.31	4860	9	9	1	2	0	0	0	0	0	0	38	45.1	4.0	17	0.44	44	Knot	Douglas Fir
408	20.50	78.13	1.297	F	89	33.44	5.55	1.44	7.62	5063	9	6	7	3	2	0	0	0	0	0	64	50.9	9.0	26	0.48	48	Knot	Douglas Fir
409	22.75	78.13	0.921	F	134.99	41.19	8.17	1.68	8.20	5453	8	10	2	1	0	0	0	0	0	0	38	54.3	5.0	20	0.46	86	Knot	Douglas Fir
410	22.29	78.13	1.331	L			8.30	2.90		5910													3.7			66	Knot	Douglas Fir
411	20.75	78.13	1.239	F	93.42	34.26	7.32	1.63	9.68	6437	5	9	0	0	0	0	0	0	0	0	23	38.2	4.0	19	0.37	20	Baseline	Douglas Fir
412	21.00	78.13	1.496	F	98	35.09	7.00	1.39	8.94	5941	16	8	0	0	0	0	0	0	0	0	32	40.6	5.0	34	0.45	46	Baseline	Douglas Fir
413	23.00	78.13	1.602	F	141.02	42.1	8.97	1.47	8.71	5793	10	12	2	0	0	0	0	0	0	0	40	44.1	3.0	20	0.48	29	Baseline	Douglas Fir
414	21.63	78.13	1.476	L			9.20	3.00		7120													4.0			65	Baseline	Douglas Fir
415	21.79	78.13	1.145	L			7.10	3.10		5380													3.7			72	Baseline	Douglas Fir
416	21.50	78.13	1.475	F	107.68	36.78	7.39	1.39	8.78	5839	9	5	4	0	0	0	0	0	0	1	31	45.6	4.0	17	0.38	27	Baseline	Douglas Fir
417	20.75	78.13	1.300	L			9.10	3.00		8020													3.7			64	Baseline	Douglas Fir
418	23.08	78.13	1.589	L			13.60	3.50		8680													5.7			61	Baseline	Douglas Fir
419	22.21	78.13	1.769	L			12.30	3.10		8830													5.7			63	Baseline	Douglas Fir
420	21.50	78.13	1.804	F	107.68	36.78	7.88	2.30	9.37	6227	5	9	0	0	0	0	0	0	0	0	23	48.4	4.0	20	0.44	37	Baseline	Douglas Fir
421	21.92	78.13	2.321	L			13.60	4.60		10130													12.3			60	HRD	Douglas Fir
422	21.46	78.13	1.931	L			13.30	4.80		10600													7.7			60	HRD	Douglas Fir
423	21.00	78.13	2.540	F	98	35.09	13.92	1.68	17.76	11808	0	0	0	0	0	0	0	0	0	0	0	49.8	13.0	32	0.67	22	HRD	Douglas Fir
424	21.25	78.13	1.983	F	102.76	35.93	9.57	1.22	11.79	7836	16	8	0	0	0	0	0	0	0	0	32	40.4	6.0	51	0.50	24	HRD	Douglas Fir
425	21.08	78.13	2.088	L			13.30	3.20		11130													9.3			63	HRD	Douglas Fir
426	22.04	78.13	1.977	L			13.10	5.10		9600													8.3			71	HRD	Douglas Fir
427	21.00	78.13	2.066	F	98	35.09	9.25	1.01	11.81	7850	16	6	0	0	0	0	0	0	0	0	28	43.6	5.0	38	0.46	22	HRD	Douglas Fir
428	20.75	78.13	1.939	F	93.42	34.26	10.59	1.98	14.01	9313	12	3	0	0	0	0	0	0	0	0	18	39.5	6.0	26	0.50	23	HRD	Douglas Fir
429	22.79	78.13	1.743	L			13.20	3.30		8750													5.7			59	HRD	Douglas Fir
430	23.00	78.13	1.874	F	141.02	42.1	13.56	1.57	13.17	8754	15	6	0	0	0	0	0	0	0	0	27	41.8	7.0	41	0.52	25	HRD	Douglas Fir
431	21.50	78.13	1.659	L							13	6	1	0	0	0	0	0	0	0	28	45.7	16.2	36			Population	Douglas Fir
432	21.91	78.13	2.088	L							5	13	0	0	0	0	0	0	0	0	31	39.9	5.4	23			Population	Douglas Fir
433	22.43	78.13	1.829	L							7	11	0	0	0	0	0	0	0	0	29	37.0	5.7	46			Population	Douglas Fir
434	23.33	78.13	2.019	L							8	9	0	0	0	0	0	0	0	0	26	40.9	9.7	32			Population	Douglas Fir
435	21.44	78.13	2.088	L							13	7	0	0	0	0	0	0	0	0	27	44.1	7.0	28			Population	Douglas Fir
436	22.75	78.13	1.458	F	134.99	41.19	10.42	1.56	10.45	6950	3	1	0	0	0	0	0	0	0	0	5	39.3	4.0	28	0.48	26	Population	Douglas Fir
437	21.75	78.13	2.081	F	112.77	37.65	11.04	1.56	12.68	8431	9	6	0	0	0	0	0	0	0	0	21	41.1	5.0	26	0.51	22	Population	Douglas Fir
438	21.50	78.13	2.113	F	107.68	36.78	10.70	1.44	12.72	8455	8	8	0	0	0	0	0	0	0	0	24	42.5	6.0	38	0.53	23	Population	Douglas Fir
439	22.00	78.13	1.607	F	118.05	38.52	9.73	1.89	10.79	7177	6	4	3	0	0	0	0	0	0	0	23	34.6	6.0	45	0.45	24	Population	Douglas Fir
440	21.00	78.13	1.968	F	98	35.09	10.50	2.04	13.40	8911	5	8	0	0	0	0	0	0	0	0	21	45.1	7.0	29	0.58	24	Population	Douglas Fir
441	20.75	78.13	1.717	F	93.42	34.26	10.41	2.04	13.77	9157	11	5	0	0	0	0	0	0	0	0	21	41.3	5.0	28	0.42	22	Population	Douglas Fir
442	20.25	78.13	1.740	F	84.74	32.63	8.31	1.43	11.83	7863	8	12	0	0	0	0	0	0	0	0	32	35.6	5.0	23	0.49	23	Population	Douglas Fir
443	21.00	78.13	1.819	F	98	35.09	9.13	2.22	11.65	7747	9	4	0	0	0	0	0	0	0	0	17	47.1	5.0	22	0.45	27	Population	Douglas Fir
444	20.25	78.13	2.086	F	84.74	32.63	10.04	2.39	14.28	9495	8	4	0	0	0	0	0	0	0	0	16	43.2	6.0	30	0.48	27	Population	Douglas Fir
445	20.75	78.13	2.098	F	93.42	34.26	10.70	3.28	14.15	9408	9	10	0	0	0	0	0	0	0	0	29	43.1	6.0	42	0.50	24	Population	Douglas Fir
446	22.25	78.13	1.649	F	123.51	39.4	8.23	1.11	8.83	5868	5	7	1	0	0	0	0	0	0	0	22	43.7	7.0	32	0.45	26	Population	Douglas Fir
447	22.50	78.13	2.081	F	129.15	40.29	10.68	3.14	11.08	7367	2	10	0	0	0	0	0	0	0	0	22	43.4	6.0	25	0.48	41	Population	Douglas Fir
448	20.25	78.13	2.064	F	84.74	32.63	8.16	1.25	11.61	7721	2	6	3	1	0	0	0	0	0	0	27	47.3	6.0	30	0.52	34	Population	Douglas Fir
449	21.25	78.13	1.747	F	102.76	35.93	10.15	1.96	12.49	8308	13	5	0	0	0	0	0	0	0	0	23	42	6.0	32	0.46	29	Population	Douglas Fir
450	21.00	78.13	2.167	F	98	35.09	11.46	1.39	14.62	9723	15	8	0	0	0	0	0	0	0	0	31	42.4	13.0	26	0.52	24	Population	Douglas Fir
451	20.50	78.13	1.451	F	89	33.44	6.41	2.14	8.79	5847	7	10	5	0	0	0	0	0	0	0	42	42.7	4.0	34	0.41	49	Population	Douglas Fir
452	21.25	78.13	1.800	F	102.76	35.93	10.44	1.70	12.86	8549	9	1	0	0	0	0	0	0	0	0	11	38	8.0	42	0.46	24	Population	Douglas Fir
453	21.25	78.13	2.127	F	102.76	35.93	9.97	1.37	12.28	8164	7	7	1	0	0	0	0	0	0	0	24	40.7	7.0	28	0.54	23	Population	Douglas Fir

ID	Circum (in)	L (in)	Stresswave E ($x10^6$ lb/in^2)	Test location	I (in^4)	A (in^2)	P Max ($x10^3$ lb)	Tip Deflection at Pmax (in)	Pmax adj 7.25 ($x10^3$ lb)	MOR (lb/in^2)	KN1	KN2	KN3	KN4	KN5	KN6	KN7	KN8	KN9	MD	SUM KN	Density (lb/ft^3)	Ring density (rpi)	Percent late-wood	Sp Gr	MC (%)	Category	Species
454	23.75	78.13	2.306	F	160.33	44.89	14.73	2.13	12.99	8638	7	7	1	0	0	0	0	0	0	0	24	39.5	7.0	42	0.52	24	Population	Douglas Fir
455	22.00	78.13	2.226	F	118.05	38.52	11.24	1.81	12.47	8291	16	0	0	0	0	0	0	0	0	1	16	41.1	9.0	34	0.52	27	Population	Douglas Fir
456	23.75	78.13	2.223	F	160.33	44.89	13.38	2.15	11.80	7847	4	10	0	0	0	0	0	0	0	0	24	48.1	7.0	19	0.51	34	Population	Douglas Fir
457	21.75	78.13	2.044	F	112.77	37.65	12.39	1.41	14.22	9457	15	10	0	0	0	0	0	0	0	0	35	43.5	8.0	17	0.52	21	Population	Douglas Fir
458	21.00	78.13	1.699	F	98	35.09	8.20	1.74	10.47	6959	15	9	0	0	0	0	0	0	0	0	33	38.4	6.0	24	0.44	47	Population	Douglas Fir
459	20.25	78.13	1.693	F	84.74	32.63	9.28	2.11	13.20	8778	8	12	2	0	0	0	0	0	0	0	38	42.9	6.0	29	0.48	24	Population	Douglas Fir
460	21.00	78.13	1.815	F	98	35.09	10.16	1.74	12.96	8617	9	6	0	0	0	0	0	0	0	0	21	39.8	7.0	29	0.53	21	Population	Douglas Fir
461	21.75	78.13	1.904	F	112.77	37.65	8.69	1.96	9.98	6637	9	3	4	0	0	0	0	0	0	0	27	41	5.0	24	0.45	29	Population	Douglas Fir
462	21.00	78.13	1.783	F	129.15	40.29	13.65	1.83	17.41	9411	8	6	4	0	0	0	0	0	0	0	32	41.3	6.0	26	0.49	23	Population	Douglas Fir
463	22.50	78.13	1.620	F	98	35.09	8.57	1.57	8.89	7274	10	6	0	0	0	0	0	0	0	0	22	40.4	5.0	28	0.43	25	Population	Douglas Fir
464	21.25	78.13	1.873	F	102.76	35.93	13.07	1.30	16.09	10698	2	0	0	0	0	0	0	0	0	0	2	42.9	11.0	31	0.62	24	Population	Douglas Fir
465	22.25	78.13	1.675	F	123.51	39.4	10.49	1.50	11.26	7484	4	13	0	0	0	0	0	0	0	0	30	35.1	7.0	28	0.44	25	Population	Douglas Fir
466	19.75	78.13	2.208	F	76.67	31.04	8.71	1.25	13.36	8883	11	6	0	0	0	0	0	0	0	0	23	43	9.0	29	0.50	21	Population	Douglas Fir
467	21.75	78.13	1.672	F	112.77	37.65	8.23	1.72	9.46	6287	2	9	1	1	0	0	0	0	0	0	27	39	7.0	25	0.46	33	Population	Douglas Fir
468	20.25	78.13	0.986	F	84.74	32.63	8.64	1.35	12.29	8174	11	4	0	0	0	0	0	0	0	0	19	35.7	8.0	27	0.48	20	Population	Douglas Fir
469	21.25	78.13	1.916	F	102.76	35.93	9.73	1.39	11.98	7963	3	7	2	0	0	0	0	0	0	0	23	39.5	6.0	35	0.48	26	Population	Douglas Fir
470	21.00	78.13	1.947	F	98	35.09	10.04	2.16	12.80	8514	4	7	1	0	0	0	0	0	0	1	21	42.7	7.0	26	0.50	25	Population	Douglas Fir
471	22.00	78.13	1.831	F	118.05	38.52	12.98	2.12	14.40	9578	3	4	2	0	0	0	0	0	0	0	17	40.9	8.0	31	0.52	28	Population	Douglas Fir
472	21.50	78.13	1.845	F	107.68	36.78	9.11	1.25	10.83	7201	15	7	1	0	0	0	0	0	0	0	32	40	11.0	40	0.48	25	Population	Douglas Fir
473	21.00	78.13	1.946	F	98	35.09	9.73	1.71	12.42	8256	9	4	0	0	0	0	0	0	0	0	17	41.9	9.0	33	0.49	23	Population	Douglas Fir
474	21.25	78.13	1.749	F	102.76	35.93	10.51	2.36	12.95	8609	11	9	1	0	0	0	0	0	0	0	32	42	11.0	43	0.46	23	Population	Douglas Fir
475	21.25	78.13	1.756	F	102.76	35.93	9.52	2.04	11.72	7792	2	9	3	0	0	0	0	0	0	0	29	37.7	7.0	26	0.45	26	Population	Douglas Fir
501	22.00	78.13	0.682	F	118.05	38.52	6.51	1.16	7.23	4803	3	5	5	4	1	0	0	0	0	0	49	29.6	3.0	37	0.43	21	Knot	Ponderosa Pine
502	22.21	78.13	0.629	L			9.30	3.20		6700													5.7			42	Knot	Ponderosa Pine
503	25.25	78.13	0.645	F	204.84	50.74	9.93	1.07	7.29	4846		3	2	4	2	0	1	0	0	1	45	32.5	6.0	24	0.49	21	Knot	Ponderosa Pine
504	20.75	78.13	0.866	F	93.42	34.26	6.21	1.42	8.22	5465	5	5	7	3	3	0	0	0	0	0	63	33.7	8.0	29	0.46	17	Knot	Ponderosa Pine
505	22.46	78.13	0.738	L			10.10	3.20		7000													6.3			48	Knot	Ponderosa Pine
506	22.21	78.13	0.483	L			9.40	3.60		6730													4.7			46	Knot	Ponderosa Pine
507	21.25	78.13	0.473	F	102.76	35.93	6.65	1.69	8.19	5449	1	1	4	5	4	4	0	0	0	0	79	35.4	6.0	38	0.47	17	Knot	Ponderosa Pine
508	22.67	78.13	0.645	L			6.90	3.20		4620													4.3			48	Knot	Ponderosa Pine
509	22.50	78.13	0.590	F	129.15	40.29	6.93	1.96	7.19	4779	1	2	4	2	1	0	0	0	0	0	30	34.1	7.0	38	0.48	19	Knot	Ponderosa Pine
510	20.08	78.13	0.661	L			8.50	6.00		8200													3.3			48	Knot	Ponderosa Pine
511	20.50	78.13	0.436	F	89	33.44	5.67	1.89	7.77	5171	2	3	5	6	1	0	0	0	0	0	52	34.1	7.0	36	0.43	19	Baseline	Ponderosa Pine
512	21.50	78.13	0.548	F	107.68	36.78	7.78	2.07	9.23	6135	1		1	3	0	0	0	0	0	1	16	28.7	6.0	34	0.45	17	Baseline	Ponderosa Pine
513	21.25	78.13	0.792	F	102.76	35.93	5.58	1.77	6.87	4569	2	4	4	3	0	0	0	0	0	0	34	32.9	6.0	39	0.43	18	Baseline	Ponderosa Pine
514	20.50	78.13	0.630	F	89	33.44	4.82	1.47	6.61	4395	0	5	7	6	0	1	0	0	0	0	61	32.2	5.0	33	0.48	16	Baseline	Ponderosa Pine
515	19.92	78.13	0.533	L			7.10	3.80		7050													5.3			46	Baseline	Ponderosa Pine
516	20.83	78.13	0.664	L			9.60	3.40		8310													7.0			49	Baseline	Ponderosa Pine
517	21.58	78.13	0.749	L			7.30	3.70		5710													5.3			46	Baseline	Ponderosa Pine
518	21.21	78.13	0.803	L			10.40	3.90		8530													6.7			34	Baseline	Ponderosa Pine
519	20.25	78.13	0.619	L			7.40	3.40		6980													7.7			38	Baseline	Ponderosa Pine
520	19.25	78.13	0.693	F	69.2	29.49	4.61	0.97	7.63	5075	4	5	4	3	0	0	0	0	0	0	38	27.8	7.0	27	0.44	18	Baseline	Ponderosa Pine
521	28.83	78.13	1.527	L			17.80	4.80		10300													15.0			40	HRD	Ponderosa Pine
522	23.00	78.13	1.166	F	141.02	42.1	10.23	1.19	9.93	6605	9	2	1	0	0	0	0	0	0	1	16	34.6	12.0	24	0.45	27	HRD	Ponderosa Pine
523	24.75	78.13	1.536	F	189.09	48.75	11.35	0.94	8.85	5881	13	0	0	0	0	0	0	0	0	0	13	35.8	11.0	44	0.44	59	HRD	Ponderosa Pine
524	23.25	78.13	0.862	F	147.25	43.02	8.25	1.00	7.76	5161	6	6	5	0	1	0	0	0	0	0	38	32	20.0	30	0.44	25	HRD	Ponderosa Pine
525	23.25	78.13	1.089	F	147.25	43.02	14.59	1.99	13.72	9123	3	3	0	0	0	0	0	0	0	1	9	29.4	14.0	41	0.49	15	HRD	Ponderosa Pine
526	23.71	78.13	1.120	L			14.60	4.60		8630													19.3			46	HRD	Ponderosa Pine
527	22.38	78.13	0.986	L			9.10	3.70		6360													13.3			58	HRD	Ponderosa Pine
528	23.29	78.13	1.387	L			11.30	4.50		7030													26.3			39	HRD	Ponderosa Pine
529	21.50	78.13	0.978	F	107.68	36.78	7.93	1.64	9.42	6265	3	2	1	0	0	0	0	0	0	0	10	34.4	9.0	38	0.44	36	HRD	Ponderosa Pine
530	23.08	78.13	0.888	L			8.50	3.60		5450													15.0			43	HRD	Ponderosa Pine
531	24.75	78.13	1.09	F	189.09	48.75	11.62	1.01	9.06	6022	4	4	3	2	4	2	0	0	0	0	61	31.7	8.0	27	0.50	15	Population	Ponderosa Pine

ID	Circum (in)	L (in)	Stresswave E ($\times10^6$ lb/in^2)	Test location	I (in^4)	A (in^2)	P Max ($\times10^3$ lb)	Tip Deflection at Pmax (in)	Pmax adj 7.25 ($\times10^3$ lb)	MOR (lb/in^2)	KN1	KN2	KN3	KN4	KN5	KN6	KN7	KN8	KN9	MD	SUMKN	Density (lb/ft^3)	Ring density (rpi)	Percent late-wood	Sp Gr	MC (%)	Category	Species
532	23.00	78.13	0.91	F	141.02	42.1	9.60	1.34	9.32	6198	9	5	3	2	0	1	0	0	0	0	42	32.9	12.0	34	0.45	16	Population	Ponderosa Pine
533	24.00	78.13	1.021	F	167.19	45.84	10.37	1.61	8.87	5894	0	1	0	0	0	0	0	0	0	1	2	35.6	12.0	32	0.42	42	Population	Ponderosa Pine
534	25.00	78.13	1.203	F	196.85	49.74	7.63	0.71	5.77	3835	6	7	1	0	1	0	0	0	0	0	28	33.5	12.0	30	0.42	48	Population	Ponderosa Pine
535	24.50	78.13	0.862	F	181.57	47.77	10.61	1.23	8.52	5665	4	4	7	4	4	1	0	0	0	0	75	37.3	5.0	18	0.56	16	Population	Ponderosa Pine
536	24.75	78.13	0.905	F	189.09	48.75	10.95	1.27	8.53	5676	10	3	4	1	2	0	0	0	0	0	42	38.2	13.0	35	0.54	18	Population	Ponderosa Pine
537	24.25	78.13	1.135	F	174.27	46.8	6.96	1.02	5.77	3833	3	4	2	1	0	2	1	0	0	0	40	38.9	8.0	37	0.43	88	Population	Ponderosa Pine
538	25.25	78.13	1.218	F	204.84	50.74	13.79	1.97	10.12	6728	5	1	1	6	0	2	0	1	0	0	54	45.8	10.0	25	0.49	20	Population	Ponderosa Pine
539	24.50	78.13	0.846	F	181.57	47.77	8.67	1.13	6.97	4630	3	5	1	0	2	0	1	0	0	0	33	34.5	11.0	28	0.45	29	Population	Ponderosa Pine
540	23.25	78.13	0.788	F	147.25	43.02	9.67	1.89	9.09	6045	11	7	3	1	0	0	0	0	0	0	38	31.5	13.0	25	0.45	24	Population	Ponderosa Pine
541	22.25	78.13	0.867	F	123.51	39.4	6.63	0.89	7.11	4727	4	3	3	7	4	0	0	0	0	0	67	26.6	5.0	22	0.46	14	Population	Ponderosa Pine
542	23.50	78.13	1.259	F	153.69	43.95	10.31	0.94	9.39	6245	4	2	4	2	0	0	0	0	0	0	28	31.4	7.0	30	0.50	13	Population	Ponderosa Pine
543	24.25	78.13	1.065	F	174.27	46.8	11.65	1.12	9.66	6422	1	3	9	5	4	0	1	0	0	0	81	31.6	7.0	27	0.47	15	Population	Ponderosa Pine
544	23.25	78.13	1.07	F	147.25	43.02	10.38	1.07	9.75	6487	2	3	5	1	3	0	0	0	0	0	42	31.4	8.0	21	0.57	15	Population	Ponderosa Pine
545	23.00	78.13	1.415	F	141.02	42.1	14.49	1.58	14.07	9352	3	2	3	0	0	0	0	0	0	0	16	31	8.0	31	0.46	17	Population	Ponderosa Pine
546	23.00	78.13	1.114	F	141.02	42.1	12.30	1.46	11.95	7942	2	6	2	1	0	1	0	0	0	1	30	29.6	7.0	20	0.46	15	Population	Ponderosa Pine
547	23.25	78.13	1.44	F	147.25	43.02	13.55	1.82	12.73	8466	2	6	3	0	0	0	0	0	0	1	23	34.1	11.0	31	0.48	16	Population	Ponderosa Pine
548	22.75	78.13	1.276	F	134.99	41.19	11.67	1.14	11.71	7787	8	3		0	0	0	0	0	0	0	14	33.6	8.0	19	0.44	16	Population	Ponderosa Pine
549	22.00	78.13	1.259	F	118.05	38.52	7.48	1.02	8.30	5517	1	3	3	5	2	0	0	1	0	0	54	31.6	7.0	25	0.43	14	Population	Ponderosa Pine
550	22.00	78.13	1.35	F	118.05	38.52	13.44	1.80	14.91	9917	3	3	0	1	0	0	0	0	0	0	13	30.8	7.0	28	0.45	15	Population	Ponderosa Pine
551	23.00	78.13	1.04	F	141.02	42.1	7.53	0.96	7.31	4863	1	6	1	0	0	1	0	0	1	0	31	32.2	8.0	27	0.47	15	Population	Ponderosa Pine
552	24.75	78.13	0.933	F	189.09	48.75	11.22	1.16	8.75	5815	2	3	10	2	1	0	0	0	0	2	51	31.3	8.0	29	0.49	15	Population	Ponderosa Pine
553	24.25	78.13	0.818	F	174.27	46.8	9.49	1.14	7.86	5226	2	2	6	3	1	1	0	0	0	0	47	27.7	10.0	24	0.44	16	Population	Ponderosa Pine
554	21.50	78.13	1.185	F	107.68	36.78	8.62	1.56	10.25	6811	5	7	1	0	1	0	0	0	0	0	27	28.6	15.0	26	0.46	12	Population	Ponderosa Pine
555	21.75	78.13	1.03	F	112.77	37.65	8.11	1.01	9.32	6197	5	5	2	0	1	0	0	0	0	0	26	29.7	13.0	33	0.46	13	Population	Ponderosa Pine
556	23.00	78.13	0.932	F	141.02	42.1	10.17	1.60	9.88	6568	11	3	1	1	0	0	0	0	0	0	24	29.3	11.0	29	0.49	13	Population	Ponderosa Pine
557	22.00	78.13	0.818	F	118.05	38.52	5.97	0.74	6.62	4400	8	9	1	0	0	0	0	0	0	1	29	25.9	15.0	28	0.42	13	Population	Ponderosa Pine
558	23.50	78.13	1.089	F	153.69	43.95	10.65	1.32	9.70	6449	3	3	2	3	1	1	0	0	0	0	38	32.9	13.0	36	0.48	15	Population	Ponderosa Pine
559	22.25	78.13	1.088	F	123.51	39.4	9.13	1.06	9.79	6511	1	2	1	3	2	2	0	0	0	0	42	31.2	10.0	20	0.51	14	Population	Ponderosa Pine
560	23.00	78.13	1.26	F	141.02	42.1	9.85	1.33	9.57	6359	6	4	2	2	0	0	0	0	0	0	28	36.9	10.0	37	0.50	15	Population	Ponderosa Pine
561	24.00	78.13	0.705	F	167.19	45.84	8.89	0.96	7.60	5051	10	3	2	1	0	1	2	0	1	0	55	31	9.0	24	0.41	16	Population	Ponderosa Pine
562	24.25	78.13	1.072	F	174.27	46.8	11.65	1.25	9.65	6420	3	5	5	0	0	0	0	0	0	0	28	27.6	11.0	25	0.39	18	Population	Ponderosa Pine
563	25.25	78.13	0.781	F	204.84	50.74	11.52	1.19	8.45	5621	7	7	3	1	0	0	0	0	0	0	34	33.2	17.0	26	0.46	103	Population	Ponderosa Pine
564	23.75	78.13	1.025	F	160.33	44.89	10.33	1.00	9.11	6059	4	7	4	5	1	1	0	0	0	0	61	32.7	15.0	23	0.48	17	Population	Ponderosa Pine
565	22.75	78.13	1.061	F	134.99	41.19	7.38	0.72	7.41	4925	8	7	2	1	1	0	0	0	0	0	37	34.1	9.0	32	0.52	22	Population	Ponderosa Pine
566	23.75	78.13	0.863	F	160.33	44.89	8.75	1.21	7.72	5135	1	3	6	3	2	1	0	0	0	0	53	29.2	10.0	27	0.42	15	Population	Ponderosa Pine
567	24.50	78.13	0.838	F	181.57	47.77	8.28	1.33	6.65	4423	7	5	3	0	0	0	0	0	0	0	26	28.1	10.0	25	0.39	95	Population	Ponderosa Pine
568	25.00	78.13	1.035	F	196.85	49.74	10.36	1.34	7.83	5208	4	4	2	1	1	0	0	0	0	2	27	34.6	5.0	29	0.43	49	Population	Ponderosa Pine
569	23.00	78.13	0.896	F	141.02	42.1	9.73	1.33	9.45	6285	3	6	2	2	1	1	0	0	0	0	40	31.5	11.0	32	0.51	17	Population	Ponderosa Pine
570	24.75	78.13	0.915	F	189.09	48.75	7.46	0.94	5.81	3864	2	3	1	4	3	0	0	0	0	6	42	32.4	9.0	30	0.37	47	Population	Ponderosa Pine
571	23.25	78.13	0.872	F	147.25	43.02	9.37	1.09	8.81	5858	4	2	1	4	3	1	1	0	0	1	55	33.1	8.0	18	0.52	18	Population	Ponderosa Pine
572	22.25	78.13	0.493	F	123.51	39.4	6.25	1.04	6.70	4457	6	9	4	0	1	2	0	0	0	0	53	32	10.0	23	0.43	17	Population	Ponderosa Pine
573	24.25	78.13	0.842	F	174.27	46.8	7.74	1.02	6.41	4264	2	7	5	5	1	0	0	0	0	1	56	29.5	12.0	27	0.49	16	Population	Ponderosa Pine
574	24.00	78.13	0.906	F	167.19	45.84	12.79	1.92	10.93	7269	3	6	4	5	2	0	0	0	0	0	57	32.1	8.0	18	0.44	15	Population	Ponderosa Pine
575	22.75	78.13	1.236	F	134.99	41.19	9.53	1.14	9.57	6359	2	4	1	1	1	1	0	1	0	0	36	31.1	10.0	24	0.48	20	Population	Ponderosa Pine
601	22.75	78.00	1.218	F	134.99	41.19	7.92	1.08	7.95	5284	2	2	1	4	0	0	0	0	0	0	25	29.511	3.4	21.4	0.41	13	Knot	Southern Pine
602	22.60	74.00	1.033	L			9.00	14.40		6200	0	0	0	0	0	0	0	0	0	0	0	31.525	2.7			45	Knot	Southern Pine
603	22.25	78.50	1.626	F	123.51	39.4	10.55	1.06	11.32	7527	1	3	1	0	1	1	0	0	0	0	21	34.862	3.8	21.7	0.52	15	Knot	Southern Pine
604	22.60	73.88	0.568	L			7.50	3.30		5170	0	0	0	0	0	0	0	0	0	0	0	31.159	2.7			57	Knot	Southern Pine
605	22.30	74.00	0.786	L			5.70	2.70		3930	0	0	0	0	0	0	0	0	0	0	0	30.422	2.7			53	Knot	Southern Pine
606	22.50	74.25	0.959	L			6.10	2.90		4120	0	0	0	0	0	0	0	0	0	0	0	35.414	2.7			40	Knot	Southern Pine
607	22.25	73.50	0.972	F	123.51	39.4	4.81	0.67	5.16	3428	0	1	0	4	0	0	0	1	0	0	26	34.574	2.9	26.5	0.48	25	Knot	Southern Pine
608	22.25	74.88	0.773	F	123.51	39.4	7.36	1.80	7.89	5249	0	2	3	3	0	0	0	0	0	0	25	37.872	1.9	28.4	0.46	21	Knot	Southern Pine
609	22.25	74.63	0.789	F	123.51	39.4	5.53	0.80	5.93	3942	0	2	4	3	0	1	0	0	0	0	34	37.75	2.3	31.1	0.41	21	Knot	Southern Pine

ID	Circum (in)	L (in)	Stresswave E ($x10^6$ lb/in^2)	Test location	I (in^4)	A (in^2)	P Max ($x10^3$ lb)	Tip Deflection at Pmax (in)	Fmax adj 7.25 ($x10^3$ lb)	MOR (lb/in^2)	KN1	KN2	KN3	KN4	KN5	KN6	KN7	KN8	KN9	MD	SUM KN	Density (lb/ft^3)	Ring density (rpi)	Percent late-wood	Sp Gr	MC (%)	Category	Species
610	20.70	77.69	1.228	L			9.60	3.00		8490	0	0	0	0	0	0	0	0	0	0	0	29.91	2.7			60	Knot	Southern Pine
611	22.25	73.88	0.915	F	123.51	39.4	8.58	1.42	9.20	6119	0	1	1	0	0	0	0	0	0	0	5	38.774	2.6	24.1	0.40	23	Baseline	Southern Pine
612	22.60	73.63	0.34	L			4.90	1.20		3350	0	0	0	0	0	0	0	0	0	0	0	35.369	2.7			56	Baseline	Southern Pine
613	22.60	74.00	0.939	L			10.90	3.00		7460	0	0	0	0	0	0	0	0	0	0	0	34.257	2.7			48	Baseline	Southern Pine
614	22.50	73.50	0.313	F	129.15	40.29	5.84	3.06	6.06	4028	2	1	3	0	0	0	0	0	0	0	13	36.788	2.5	29.9	0.45	23	Baseline	Southern Pine
615	22.60	74.63	0.549	L			9.90	4.50		6710	0	0	0	0	0	0	0	0	0	0	0	31.405	2.0			44	Baseline	Southern Pine
616	22.00	73.50	0.945	F	118.05	38.52	9.50	1.95	10.54	7009	0	0	0	0	0	0	0	0	0	0	0	34.378	3.3	17.2	0.50	21	Baseline	Southern Pine
617	22.25	73.63	0.411	F	123.51	39.4	10.12	2.82	10.86	7218	0	0	2	0	0	0	0	0	0	0	6	39.125	1.6	37.7	0.52	26	Baseline	Southern Pine
618	22.60	74.50	0.951	L			11.70	4.20		8080	0	0	0	0	0	0	0	0	0	0	0	41.593	4.3			51	Baseline	Southern Pine
619	22.90	73.38	0.427	L			9.80	4.60		6450	0	0	0	0	0	0	0	0	0	0	0	40.698	1.7			48	Baseline	Southern Pine
620	22.25	73.25	0.46	F	123.51	39.4	5.28	1.35	5.66	3766	0	4	2	1	0	0	0	0	0	0	18	37.304	2.5	42.2	0.50	21	Baseline	Southern Pine
621	22.30	78.38	2.015	L			15.10	4.50		10570	0	0	0	0	0	0	0	0	0	0	0	39.48	4.0			50	HRD	Southern Pine
622	22.90	78.38	1.621	L			9.30	1.40		6140	0	0	0	0	0	0	0	0	0	0	0	39.74	12.7			50	HRD	Southern Pine
623	23.00	78.38	2.120	F	141.02	42.1	18.41	1.64	17.88	11885	0	0	0	0	0	0	0	0	0	0	0	39.536	7.9	32.5	0.59	15	HRD	Southern Pine
624	22.00	76.63	1.943	F	118.05	38.52	15.22	2.05	16.89	11229	4	2	1	0	0	0	0	0	0	0	11	34.404	7.1	14.3	0.49	14	HRD	Southern Pine
625	22.30	75.00	2.159	L			12.20	3.60		8710	0	0	0	0	0	0	0	0	0	0	0	34.822	8.0			59	HRD	Southern Pine
626	22.30	73.75	1.068	L			13.80	4.20		9620	0	0	0	0	0	0	0	0	0	0	0	38.633	5.0			38	HRD	Southern Pine
627	22.60	73.88	1.822	L			14.10	4.50		9670	0	0	0	0	0	0	0	0	0	0	0	42.239	9.0			37	HRD	Southern Pine
628	22.25	74.38	1.809	F	123.51	39.4	14.75	2.21	15.82	10518	1	0	0	0	0	0	0	0	0	0	1	38.144	6.2	35.3	0.48	22	HRD	Southern Pine
629	22.25	74.38	1.224	F	123.51	39.4	11.99	3.02	12.87	8554	0	0	0	0	0	0	0	0	0	0	0	45.186	3.9	29.1	0.58	51	HRD	Southern Pine
630	22.25	73.50	0.862	F	123.51	39.4	12.88	2.51	13.82	9186	0	0	0	0	0	0	0	0	0	0	0	38.554	4.0	39.1	0.54	22	HRD	Southern Pine
631	22.00	72.00	1.681	F	118.05	38.52	12.59	1.54	13.97	9292	0	0	2	0	1	0	0	0	0	0	11	34.923	4.3	20.9	0.46	26	Population	Southern Pine
632	22.00	72.50	1.532	F	118.05	38.52	11.06	2.45	12.27	8160	1	1	1	0	0	0	0	0	0	0	6	36.634	4.1	32.2	0.49	31	Population	Southern Pine
633	22.25	72.25	1.419	F	123.51	39.4	10.07	2.19	10.80	7178	0	0	0	1	2	1	0	0	0	0	20	32.472	4.3	20.9	0.44	24	Population	Southern Pine
634	22.25	72.25	1.773	F	123.51	39.4	14.04	2.24	15.06	10014	0	0	1	0	0	0	0	0	0	0	3	38.165	4.1	38.3	0.53	39	Population	Southern Pine
635	22.25	72.50	1.723	F	123.51	39.4	11.69	1.26	12.54	8336	0	1	0	0	0	0	0	0	0	0	2	40.448	3.0	35.2	0.58	21	Population	Southern Pine
636	22.25	72.75	1.201	F	123.51	39.4	8.57	0.95	9.20	6116	0	0	1	1	0	0	0	0	0	0	7	32.295	4.2	20.6	0.44	19	Population	Southern Pine
637	22.00	72.75	1.622	F	118.05	38.52	11.00	1.82	12.21	8118	0	0	1	0	0	0	0	0	0	0	3	35.292	4.2	26.8	0.55	25	Population	Southern Pine
638	22.25	73.00	1.659	F	123.51	39.4	9.57	1.18	10.26	6822	1	0	0	0	0	0	0	0	0	0	1	35.821	5.0	30.6	0.47	22	Population	Southern Pine
639	22.00	72.25	1.642	F	118.05	38.52	12.93	1.50	14.35	9541	1	0	3	0	0	0	0	0	0	0	10	34.506	4.4	24.7	0.50	20	Population	Southern Pine
640	22.25	72.75	1.604	F	123.51	39.4	10.03	1.37	10.76	7150	0	0	1	1	0	0	0	0	0	0	7	35.794	3.9	32.1	0.46	32	Population	Southern Pine
641	22.25	72.00	0.485	F	123.51	39.4	10.60	2.85	11.37	7561	1	1	1	0	0	0	0	0	0	0	6	32.277	3.5	30.9	0.48	27	Population	Southern Pine
642	22.50	72.50	1.111	F	129.15	40.29	8.20	1.11	8.51	5654	0	0	2	0	1	0	0	0	0	0	11	34.026	3.8	24.8	0.43	52	Population	Southern Pine
643	22.25	73.00	1.13	F	123.51	39.4	11.09	2.27	11.89	7907	0	0	0	1	0	0	0	0	0	0	4	36.28	3.0	29.1	0.46	24	Population	Southern Pine
644	22.25	72.75	1.737	F	123.51	39.4	13.73	2.76	14.72	9792	0	0	0	0	0	0	0	0	0	0	0	36.884	3.2	30.1	0.47	26	Population	Southern Pine
645	22.00	73.00	1.232	F	118.05	38.52	10.41	1.45	11.56	7682	0	1	2	0	1	0	0	0	0	0	13	32.56	3.9	14	0.45	27	Population	Southern Pine
646	22.25	72.50	1.522	F	123.51	39.4	10.93	1.16	11.73	7798	1	0	2	1	1	0	0	0	0	0	16	37.43	4.4	27.5	0.52	24	Population	Southern Pine
647	22.00	73.00	1.579	F	118.05	38.52	10.70	1.13	11.87	7894	0	2	1	0	0	0	0	0	0	0	7	35.875	5.1	34.3	0.49	18	Population	Southern Pine
648	22.25	72.75	1.599	F	123.51	39.4	10.65	1.45	11.43	7596	0	0	0	1	0	0	0	0	1	0	13	37.512	4.5	34	0.55	23	Population	Southern Pine
649	22.00	73.00	1.519	F	118.05	38.52	12.57	1.97	13.94	9270	1	0	0	0	0	0	0	0	0	0	1	36.383	4.7	28.2	0.48	30	Population	Southern Pine
650	22.00	72.50	1.209	F	118.05	38.52	13.34	1.64	14.80	9841	0	0	0	0	0	0	0	0	0	0	0	33.684	3.6	23.7	0.50	21	Population	Southern Pine
651	22.25	72.75	1.944	F	123.51	39.4	15.07	1.84	16.17	10750	1	0	0	0	0	0	0	0	0	0	1	41.747	5.0	32.3	0.59	21	Population	Southern Pine
652	22.25	72.50	1.599	F	123.51	39.4	13.27	1.77	14.24	9468	1	0	0	0	0	0	0	0	0	0	1	36.229	4.7	25.2	0.51	16	Population	Southern Pine
653	22.25	72.50	1.853	F	123.51	39.4	14.23	2.32	15.27	10149	1	0	0	0	0	0	0	0	0	0	1	35.302	4.2	23.4	0.49	24	Population	Southern Pine
654	22.25	72.50	1.078	F	123.51	39.4	12.43	2.81	13.33	8861	0	0	0	0	0	0	0	0	0	0	0	36.722	4.3	34.4	0.52	25	Population	Southern Pine
655	22.25	72.25	1.683	F	123.51	39.4	12.17	1.89	13.05	8679	0	0	2	0	1	0	0	0	0	0	11	38.257	4.3	33.9	0.50	20	Population	Southern Pine
656	22.00	72.75	0.539	F	118.05	38.52	12.95	2.83	14.37	9551	0	0	0	0	0	0	0	0	0	0	0	40.48	3.7	44.6	0.57	20	Population	Southern Pine
657	22.50	73.00	1.051	F	129.15	40.29	11.77	1.73	12.21	8114	0	0	0	0	0	0	0	0	0	0	0	37.868	4.0	31.9	0.49	28	Population	Southern Pine
658	22.25	72.75	1.941	F	123.51	39.4	15.55	1.72	16.68	11090	0	0	0	0	0	0	0	0	0	0	0	44.709	6.7	26	0.63	28	Population	Southern Pine
659	22.25	72.00	0.553	F	123.51	39.4	11.01	2.94	11.81	7854	0	0	0	0	0	0	0	0	0	0	0	38.46	4.9	32.8	0.55	25	Population	Southern Pine
660	22.25	72.25	1.384	F	123.51	39.4	13.38	2.11	14.35	9544	0	0	0	0	0	0	0	0	0	0	0	43.494	4.2	33.6	0.60	22	Population	Southern Pine
661	22.00	73.00	2.212	F	118.05	38.52	13.03	2.92	14.46	9609	0	0	0	0	0	0	0	0	0	0	0	41.001	4.4	34.5	0.56	39	Population	Southern Pine
662	22.25	72.25	0.588	F	123.51	39.4	10.87	2.97	11.66	7754	2	1	0	0	0	0	0	0	0	0	4	39.268	1.9	38.5	0.51	20	Population	Southern Pine

ID	Circum (in)	L (in)	Stresswave E ($\times 10^6$ lb/in^2)	Test location	I (in^4)	A (in^2)	P Max ($\times 10^3$ lb)	Tip Deflection at Pmax (in)	Pmax adj 7.25 ($\times 10^3$ lb)	MOR (lb/in^2)	KN1	KN2	KN3	KN4	KN5	KN6	KN7	KN8	KN9	MD	SUMKN	Density (lb/ft^3)	Ring density (rpi)	Percent late-wood	Sp Gr	MC (%)	Category	Species
663	22.25	72.75	1.024	F	123.51	39.4	10.85	1.88	11.64	7735	0	0	0	0	0	0	0	0	0	0	0	38.396	5.2	32.5	0.52	26	Population	Southern Pine
664	22.00	72.50	1.362	F	118.05	38.52	12.61	2.30	13.99	9301	0	0	1	1	0	0	0	0	0	0	7	37.51	4.7	31.3	0.49	32	Population	Southern Pine
665	22.00	72.25	1.318	F	118.05	38.52	12.34	2.14	13.69	9103	0	3	0	0	0	0	0	0	0	0	6	32.087	4.3	19.3	0.45	27	Population	Southern Pine
666	22.25	72.50	1.471	F	123.51	39.4	12.18	1.70	13.07	8687	0	1	0	0	0	0	0	0	0	0	2	35.518	4.5	25.6	0.52	24	Population	Southern Pine
667	22.25	72.25	1.384	F	123.51	39.4	9.18	0.89	9.85	6548	1	0	1	2	0	0	0	0	0	0	12	30.634	4.4	22.1	0.45	18	Population	Southern Pine
668	22.75	76.50	1.862	F	134.99	41.19	15.58	1.58	15.63	10397	0	1	4	0	0	0	0	0	0	0	14	37.692	8.1	17.6	0.55	16	Population	Southern Pine
669	22.25	77.25	2.077	F	123.51	39.4	14.37	1.11	15.42	10249	0	0	0	0	0	0	0	0	0	0	0	38.794	9.5	31.9	0.58	15	Population	Southern Pine
670	22.25	76.00	1.203	F	123.51	39.4	9.50	1.14	10.19	6775	3	0	1	1	0	1	0	0	0	0	16	31.934	5.7	51.5	0.52	16	Population	Southern Pine
671	22.00	75.75	0.813	F	118.05	38.52	9.86	1.85	10.94	7277	2	0	1	0	0	0	0	0	0	0	5	33.786	4.2	28.8	0.49	14	Population	Southern Pine
672	22.50	76.00	1.581	F	129.15	40.29	13.57	1.51	14.07	9356	0	1	2	0	0	1	0	0	0	0	14	35.989	10.5	48	0.50	16	Population	Southern Pine
673	21.50	75.75	1.676	F	107.68	36.78	12.70	1.59	15.10	10041	0	4	1	1	0	0	0	1	0	0	23	33.308	6.3	19.8	0.52	13	Population	Southern Pine
674	22.75	76.50	2.281	F	134.99	41.19	16.91	1.43	16.97	11282	1	0	0	0	0	0	0	0	0	0	1	40.45	9.4	24.6	0.60	18	Population	Southern Pine
675	22.75	77.75	1.264	F	134.99	41.19	8.90	1.30	8.93	5930	0	1	2	3	0	0	0	0	0	0	20	32.45	6.6	47.5	0.41	14	Population	Southern Pine

Appendix D—Percentiles of Phase II Data

		MOR (lb/in^2) at various percentile values								
Obs.	Species	20	25	30	35	40	45	50	55	60
Phase IIa partial percentile test data										
With population only, *n* = 45										
1	Douglas-fir	6,342	6,506	6,686	6,965	7,243	7,281	7,419	7,572	7,722
2	Ponderosa pine	4,110	4,422	4,550	4,685	5,025	5,208	5,360	5,509	5,831
3	Southern yellow pine	5,122	5,297	6,127	6,544	6,979	7,469	7,621	8,168	8,774
With population plus SKN LRD, *n* = 50										
1	Douglas-fir	6,420	6,705	6,965	7,241	7,268	7,372	7,480	7,627	7,801
2	Ponderosa pine	4,169	4,425	4,669	4,728	5,078	5,289	5,360	5,489	5,677
3	Southern yellow pine	5,244	5,586	6,480	6,561	7,113	7,475	7,621	8,106	8,510
Phase IIb partial percentile test data										
With population only, *n* = 45 (note *n* for DF is 40)										
1	Douglas-fir	7,237	7,426	7,734	7,819	7,913	8,169	8,273	8,369	8,484
2	Ponderosa pine	4,795	5,051	5,208	5,517	5,671	5,858	6,022	6,059	6,221
3	Southern yellow pine	7,419	7,682	7,754	7,854	8,010	8,160	8,679	8,861	9,281
With population plus SKN LRD, *n* = 50 (note *n* for DF is 45)										
1	Douglas-fir	7,320	7,721	7,792	7,847	7,913	8,174	8,291	8,430	8,531
2	Ponderosa pine	4,894	5,135	5,217	5,621	5,746	5,881	6,033	6,197	6,255
3	Southern yellow pine	7,578	7,735	7,826	7,907	8,139	8,554	8,774	9,186	9,296

Appendix E—Guardrail Post Grading Criteria

General Criteria

All posts shall meet the current quality requirements of the American National Standards Institute (ANSI) 05.1, "Wood Poles" except as supplemented herein.

Manufacture

All posts shall be smooth shaved by machine. No "ringing" of the posts, as caused by improperly adjusted peeling machine, is permitted. All outer and inner bark shall be removed during the shaving process. All knots and knobs shall be trimmed smooth and flush with the surface of the posts. The guardrail posts will be a minimum of 1.75 m (69 in.) long. The use of peeler cores is prohibited.

Groundline

The groundline, for the purpose of applying these restrictions of ANSI 05.1 that reference the groundline, shall be defined as being located 914 mm (36 in.) from the butt end of each post.

Size

The size of the posts shall be classified based on their diameter at the groundline and their length and will be species specific. The groundline diameter shall be specified by diameter in 6-mm (1/4-in.) breaks. The length shall be specified in 300-mm (1-ft) breaks. Dimensions shall apply to fully seasoned posts. When measured between their extreme ends, the post shall be no shorter than the specified lengths but may be up to 75 mm (3 in.) longer.

Scars

Scars are permitted in the middle third as defined in ANSI 05.1 provided that the depth of the trimmed scar is not more than 1 in.

Shape and Straightness

All timber posts shall be nominally round in cross section. A straight line drawn from the centerline of the top to the center of the butt of any post shall not deviate from the centerline of the post more than 32 mm (1-1/4 in.) at any point. Posts shall be free from reverse bends.

Splits and Shakes

Splits or ring shakes are not permitted in the top two-thirds of the post. Splits not to exceed the diameter in length are permitted in the bottom third of the post. A single shake is permitted in the bottom third, provided it is not wider than one-half the butt diameter.

Decay

Allowed in knots only.

Holes

Pin holes 1 mm (1/16 in.) or less are not restricted.

Slope of Grain

1:10.

Compression Wood

Not allowed in the outer 25 mm (1 in.) or if exceeding 1/4 of the radius.

Timber Spacers

When timber spacers are required, the timber species shall be the same as those furnished for the timber posts. The size and hole location shall be as shown on the plans, with a tolerance of 6 mm (1/4 in.). Spacers shall be of medium grain, at least 4 rings per inch on one end, and free from splits, shakes, compression wood, or decay in any form. Individual knots, knot clusters, or knots in the same cross section of a face are permitted, provided they are sound or firm, and are limited in cumulative width (when measured between lines parallel to the edges) to no more than one-half the width of the face. Wane or the absence of wood is limited to one-third of the face on no more than 10% of the lot. Slope of grain deviation is limited to 1 in 6. The material may be rough sawn or surfaced, full size, hit or miss, with a tolerance of 6 mm (1/4 in.) for all dimensions.

Treatment

Each post treated shall have a minimum sapwood depth of 19 mm (3/4 in.) as determined by examination of the tops and butts of each post. Material that has been air-dried or kiln-dried shall be inspected for MC in accordance with AWPA standard M2 prior to treatment. Tests of representative pieces shall be conducted. The lot shall be considered acceptable when the average MC does not exceed 25%. Pieces exceeding 29% MC shall be rejected and removed from the lot, but the moisture reading for those pieces included in the average for the lot.

Treatment shall be in accordance with the following: American Wood-Preservers' Association (AWPA) Standards, Use Category System (UCS) U1-05: User specification for treated wood commodity, specification B for Posts; 4.1 Wood for Highway Construction; guardrail and spacerblocks must meet Classification UC4B retention levels using the processing and treatment standards outlined in T1-05 Section 8.2 for Posts. This includes the pressure treatment process requirements listed in Table 8.2.2 and penetration specifications given in Table 8.2.6 for UC4B exposure.

Species-Specific Criteria

Douglas-fir

Knot diameter for posts of Douglas-fir shall not exceed 51 mm (2 in.). Ring density for the species shall be at least 6 rpi as measured over a 76-mm (3-in.) distance. The diameter of the Douglas-fir posts shall be 184 mm (7.25 in.) at the groundline with an upper limit of 203 mm (8.0 in.).

Ponderosa Pine

Knot diameter for posts of ponderosa pine posts shall not exceed 100 mm (4 in.). Ring density for the species shall be at least 6 rings per inch as measured over a 76-mm (3-in.) distance. The diameter of the ponderosa pine posts shall be 203 mm (8.0 in.) at the groundline with an upper limit of 222 mm (8.75 in.).

Southern Yellow Pine

Knot diameter for posts of southern yellow pine shall not exceed 76 mm (3 in). Ring density for the species shall be at least 6 rings per inch as measured over a 76- mm (3-in.) distance. The diameter of the southern yellow pine posts shall be 197 mm (7-3/4 in.) at the groundline with an upper limit of 216 mm (8-1/2 in.).