Evaluation of Fire-Retardant Treated Structural Glued Laminated Timber

Final Report – Part 2 of 2
USDA Joint Venture Agreement 16-JV-11111135-079

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Executive Summary

This report contains test results for the fire-retardant-treatment (FRT) and hygrothermal effects on structural glued laminated timber (glulam). This is the second part of the collaborative research project between APA – The Engineered Wood Association, Tacoma, WA, and USDA Forest Products Laboratory (FPL), Madison, WI. The first part of this project is related to FRT laminated veneer lumber (LVL) and the results are provided in a separate research report.

Selected mechanical properties, including tension, bending, and shear of the FRT glulam treated with the American Wood Protection Association (AWPA) P49 and P50 fire retardants were evaluated in this study. These results are used to support the development of an ASTM standard for FRT glulam.

This work was a joint research project of APA – The Engineered Wood Association and the USDA FPL. This research was supported in part by funds provided by the USDA FPL, which is acknowledged and greatly appreciated by the project team. The project team also appreciated the contribution of Arch Wood Protection Inc. and Viance, LLC for providing the P49 and P50 fire-retardant treatments, respectively.

Table of Contents

1. Introduction

Interests in using engineered wood products in Type III construction in the U.S. have been rising in recent years. The wood industry has been heavily engaged in the promotion of multi-family and light commercial construction in which wood-frame Type III construction predominates. Type III construction, based on the definition of the International Building Code (IBC) is "that type of construction in which the exterior walls are of noncombustible materials and the interior building elements are of any material permitted by this code," except that fire-retardant-treated (FRT) wood framing complying with the IBC is permitted within exterior wall assemblies of a 2-hour rating or less.

As part of the Type III construction, the exterior bearing walls of wood-frame construction must be FRT wood with a 2-hour fire rating, and the floor framing is required to be 1-hour fire rated. At the intersection of the 2-hour wall and 1-hour floor, where the floor framing is attached to the wall with joist hangers, a popular solution is to use solid structural rimboard or header to provide the needed load transfer mechanism. Due to the requirement for continuity on the 2-hour fire rating, the rimboard or wall header is a good fit for structural glued laminated timber (glulam) and structural composite lumber (SCL) products. Unfortunately, this market demand has faced a strong technical challenge due to the lack of consensus-based evaluation standards or product specifications for FRT glulam and SCL. ASTM and AWPA have published FRT test standards and FRT product specifications for lumber and plywood, but not glulam and SCL. This study focused on glulam.

2. Objective

The objective of this work was to develop ASTM standards for the evaluation of fire-retardant treated (FRT) glulam in support of wood-frame construction, especially in Type III construction. In this study, fire-retardant treatment was performed by treaters using the American Wood Protection Association (AWPA) P49 standard, *Standard for Fire Retardant FR-1*, and P50 standard, *Standard for Fire Retardant FR-2*. Full-scale 302-24 end joint tension tests and 24F-V4 Douglas-fir glulam bending tests were conducted to evaluate both fire-retardant treatment and hygrothermal effects.

3. Materials

3.1 Tension Laminations

302-24 tension laminations in the net dimension of 1-1/2 inches x 5-1/2 inches were graded in accordance with ANSI A190.1, sampled from the same production at a commercial glulam plant, and shipped to the APA Research Center in Tacoma, Washington in April 2016. These materials were randomly divided into 5 groups, as shown in Table 1.

After being prepared, Groups TTA-P49, TTA-P50, TTH-P49, and TTH-P50 were shipped to fire-retardant treatment companies for AWPA P49 and P50 treatments, respectively. After being treated, these materials were shipped back to APA. Then, Groups UTA, TTA-P49, and TTA-P50 were kept in the room conditions for a few weeks before testing. All the other 4 groups, i.e. UTA, UTH, TTH-P49, and TTH-P50 were shipped to the USDA Forest Products Laboratory (FPL). The last 3 groups were subject to hygrothermal conditioning (150 + 4ºF and 50% or higher relative humidity for 108 ± 3 days in accordance with ASTM D5664, *Standard Test Method for Evaluating the Effects of Fire-Retardant Treatments and Elevated Temperatures on Strength Properties of Fire-Retardant Treated Lumber*) and then re-conditioned in the standard moisture conditions (68 ± 11°F and 65 ± 5% RH) before testing.

Table 1. 302-24 tension lamination specimens for long-span E and tension tests

Type[a]	Quantity	Treatment	Conditioning	Dimension	Test Lab
UTA (Untreated Control)	33	NA	As-received	1-1/2 inches x 5-1/2 inches x 13 feet	APA
TTA-P49 (Treated and Matched with UTA)	33	P49			
TTA-P50 (Treated and Matched with UTA)	33	P50			
UTA (Untreated Control)	33	NA			FPL
UTH (Untreated and Matched with UTA)	33	NA	Hygrothermal		
TTH-P49 (Treated and Matched with UTA)	33	P49			
TTH-P50 (Treated and Matched with UTA)	33	P50			

[a] First letter: U (untreated) or T (treated); Second letter: T (tension); Third letter: A (as-received conditions) or H (hygrothermal conditions); P49 and P50 indicate the treatment type

3.2 End Joints

End joints made with 302-24 tension laminations in the net dimension of 1-1/2 inches x 5-1/2 inches were manufactured in accordance with ANSI A190.1, sampled from the same production at the same commercial glulam plant, and shipped to the APA Research Center in Tacoma, Washington in April 2018. These materials were randomly divided into 4 groups, as shown in Table 2.

Table 2. End joint specimens for tension tests

Type[a]	Quantity	Treatment	Conditioning	Dimension	Test Lab
UTA (Untreated Control)	50	NA	Standard	1-1/2 inches x 5-1/2 inches x 7 feet	APA
TTA-P49 (Treated and Matched with UTA)	50	P49			
UTH (Untreated Control)	50	NA	Hygrothermal		FPL
TTH-P49 (Untreated and Matched with UTA)	50	P49			

[a] First letter: U (untreated) or T (treated); Second letter: T (tension); Third letter: A (standard conditions) or H (hygrothermal conditions); P49 indicates the treatment type

After being prepared, Groups TTA-P49 and TTH-P49 were shipped to the same fire-retardant treatment company as that treated the 302-24 tension laminations in accordance with Table 1, for AWPA P49 treatment. After being treated, these materials were shipped back to APA. Then, Groups UTA and TTA-P49 were moisture conditioned at the standard environmental conditions (68 ± 11°F and 65 ± 5% RH) for several weeks. All the other 2 groups, i.e. UTH and TTH-49 were shipped to the USDA FPL for the same hygrothermal conditioning (150 + 4°F and

50% or higher relative humidity for 108 ± 3 days in accordance with ASTM D5664) and then re-conditioned in the standard moisture conditions (68 ± 11°F and 65 ± 5% RH) before testing.

3.3 Glulam Beams

Glulam beams in the net dimension of 5-1/2 inches wide x 6 inches (4 laminations) deep were manufactured in accordance with ANSI A190.1, sampled from the same production at the same commercial glulam plant, and shipped to the APA Research Center in Tacoma, Washington in April 2016 and May 2019. These materials were randomly divided into 4 groups, as shown in Table 3.

Table 3. Glulam specimens for bending tests

Type[(a)]	Quantity	Treatment	Conditioning	Dimension	Test Lab
UBA (Untreated Control)	15	NA	As-received	5-1/2 inches x 6 inches x 9-1/2 feet	APA
TBA-P49 (Treated and Matched with UBA)	15	P49			
UBH (Untreated Control)	15	NA	Hygrothermal		FPL
TBH-P49 (Untreated and Matched with UBA)	15	P49			

[(a)] First letter: U (untreated) or T (treated); Second letter: B (bending); Third letter: A (as-received conditions) or H (hygrothermal conditions); P49 indicates the treatment type

After being prepared, Groups TBA-P49 and TBH-P49 were shipped to the same fire-retardant treatment company as that treated the 302-24 tension laminations in accordance with Table 1, for AWPA P49 treatment. After being treated, these materials were shipped back to APA. Then, Groups UBA and TBA-P49 were kept in the room conditions for a few weeks before testing. All the other 2 groups, i.e. UBH and TBH-49 were shipped to the USDA FPL for the same hygrothermal conditioning (150 + 4ºF and 50% or higher relative humidity for 108 ± 3 days in accordance with ASTM D5664) and then re-conditioned in the standard moisture conditions (68 ± 11°F and 65 ± 5% RH) before testing.

4. Methods

4.1 Tension and Long-Span E Tests

The long-span E tests for 302-24 tension laminations were non-destructively tested in accordance with AITC Test T116. The 302-24 lamination tension and end joint tension tests were conducted in accordance with Section 6.5.2 of ASTM D5456, using an 8-ft and 2-ft gauge length, respectively.

4.2 Glulam Beam Bending Tests

The glulam beam bending tests were conducted in accordance with Section 6.5.1 of ASTM D5456 as shown in Figure 1. Treated (TBA) and untreated (UBA) samples were tested to evaluate the fire-retardant treatment effect on glulam bending properties under as-received conditions. Similarly, treated (TBH) and untreated (UBH) samples were tested to evaluate the fire-retardant treatment effect on glulam bending properties after hygrothermal conditioning.

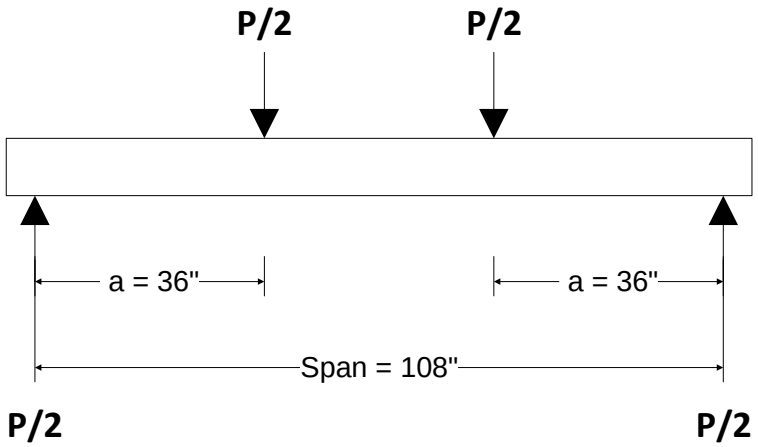

Figure 1. Schematic diagram of glulam beam bending test

The modulus of rupture (MOR) and the modulus of elasticity (MOE) for each specimen were calculated using the actual dimensions recorded at the time of test based on the following equations:

$$MOR = \frac{3\,P_{ult}\,a}{b\,h^2} \quad [1]$$

$$MOE = \frac{\theta\;a\left(3\,L^2 - 4\,a^2\right)}{4\,b\,h^3} \quad [2]$$

Where:

MOR	=	modulus of rupture (psi)
MOE	=	apparent modulus of elasticity (psi)
P_{ult}	=	ultimate total load excluding the dead weight of the specimens (lbf)
a	=	distance between the reaction point to the nearest loading point (in.)
b	=	measured beam width (in.)
h	=	measured beam depth (in.)
L	=	test span (in.), and
θ	=	slope of load vs. deflection plot below the proportional limit (lbf/in.)

As the all glulam beams were tested with the same volume, no volume effect adjustment was applied for the purpose of determining the treatment and combined treatment and hygrothermal effects.

For the glulam beams tested at the as-received conditions at APA, the MOR and MOE were adjusted to the standard 12% moisture content. The adjustment factor for MOR is presented in Equation 3 based on ASTM D1990.

$$MOR_{adj} = \left[MOR + \left(\frac{MOR - \beta_1}{\beta_2 - M_1}\right) \times (M_1 - M_2)\right] \quad [3]$$

where: MOR_{adj} = Adjusted MOR for standard moisture content and beam volume (psi),
MOR = MOR calculated from Equation 1 (psi),
M_1 = actual moisture content of the beam (%),
M_2 = 12 (standard moisture content in %),
β_1 = 2415,

β_2 = 40, and

The moisture content adjustment factor for MOE is shown in Equation 4 based on ASTM D1990.

$$MOE_{adj} = MOE \times \left[\frac{\beta_1 - (\beta_2 \times M_2)}{\beta_1 - (\beta_2 \times M_1)}\right] \quad [4]$$

where: MOE_{adj} = Adjusted MOE for standard moisture content (10^6 psi),
MOE = MOE calculated from Equation 2 (10^6 psi),
M_1 = actual moisture content of the beam (%),
M_2 = 12,
β_1 = 1.857, and
β_2 = 0.0237

5. Results and Discussion

5.1 Tension Laminations

Tension and long-span E test results on 302-24/DF tension laminations are summarized in Table 4. Individual test results are given in Appendix A.

Table 4. Summary of tension and LSE test results for untreated and treated 302-24/DF tension laminations

	UTA[b]		TTA-P49		TTA-P50		UTA[c]	UTH	TTH-P49	TTH-P50
	Tension (psi)	LSE (10^6 psi)	Tension (psi)	LSE (10^6 psi)	Tension (psi)	LSE (10^6 psi)	Tension (psi)	Tension (psi)	Tension (psi)	Tension (psi)
N	33	33	33	33	33	33	33	31	33	33
Mean	7,446	2.52	7,312	2.44	6,693	2.34	7,615	6,650	6,040	6,258
Max	11,409	3.21	10,435	3.02	10,595	2.80	10,532	11,103	10,572	10,595
Min	4,830	1.85	3,919	1.92	3,143	1.90	4,752	4,095	2,937	3,013
COV	0.239	0.119	0.243	0.093	0.267	0.103	0.238	0.258	0.326	0.320
LTL[a]	4,672	—	4,357	—	3,802	—	4,683	4,011	3,068	3,223

[a] Lower tolerance limit, i.e., 5th percentile with 75% confidence ($f_{t,0.05}$), based on an assumed log-normal distribution.
[b] Tested at APA.
[c] Tested at the FPL.

The UTA data between the tests conducted at the FPL and APA are quite similar. This confirmed the comparability of the data obtained from these 2 laboratories. Table 5 shows the treatment effect (TTA/UTA) and combined treatment and hygrothermal effect (TTH/UTA) for both P49 and P50 treatments based on the mean and lower tolerance limit (LTL or 5th percentile with 75% confidence).

Table 5. Treatment and combined treatment and hygrothermal effects on tension and LSE of tension laminations

	Tension				LSE	
	P49		P50		P49	P50
	Mean	LTL	Mean	LTL	Mean	Mean
Treatment effect (TTA/UTA[a])	0.98	0.93	0.90	0.81	0.97	0.93
Combined effect (TTH/UTA[b])	0.79	0.66	0.82	0.69	--	--

[a] Tested at APA.
[b] Tested at the FPL.

5.2 End Joints

Tension test results on 302-24/DF end joints are summarized in Table 6. Individual test results are given in Appendix B.

Table 6. Summary of tension test results for untreated and treated 302-24/DF end joints

	UTA	TTA-P49	UTH	TTH-P49
N	49	50	50	50
Mean (psi)	5,903	5,610	5,307	4,321
Max (psi)	7,198	7,669	7,922	6,014
Min (psi)	3,405	4,531	2,863	2,795
COV	0.146	0.132	0.192	0.150
LTL[(a)] (psi)	4,386	4,420	3,659	3,229

[(d)] Based on an assumed log-normal distribution.

Table 7 shows the treatment effect (TTA/UTA) and combined treatment and hygrothermal effect (TTH/UTA) for the P49 treatment.

Table 7. Treatment and combined treatment and hygrothermal effects on end joint tension

	Mean	LTL
Treatment effect (TTA/UTA)	0.95	1.01
Combined effect (TTH/UTA)	0.73	0.74

5.3 Glulam Beams

Bending test results on 24F-V4/DF glulam beams are summarized in Table 8. Individual test results are given in Appendix C.

Table 8. Summary of bending test results for untreated and treated glulam beams

	UBA		TBA-P49		UBH		TBH-P49	
	MOR_{adj} (psi)	MOE_{adj} (10^6 psi)	MOR_{adj} (psi)	MOE_{adj} (10^6 psi)	MOR_{adj} (psi)	MOE_{adj} (10^6 psi)	MOR_{adj} (psi)	MOE_{adj} (10^6 psi)
N	15	15	15	15	15	15	11	11
Mean	9,698	2.30	11,951	2.21	8,409	2.08	6,625	2.08
Max	11,898	2.59	23,712	2.89	11,652	2.38	8,048	2.36
Min	8,479	2.01	7,067	1.76	4,724	1.82	3,801	1.86
COV	0.097	0.069	0.355	0.132	0.210	0.067	0.218	0.079
LTL[(a)]	7,992	--	6,080	--	5,178	--	3,896	--

[(e)] Based on an assumed log-normal distribution.

Table 9 shows the treatment effect (TBA/UBA) and combined treatment and hygrothermal effect (TBH/UBA) for the P49 treatment.

Table 9. Treatment and combined treatment and hygrothermal effects on glulam beams

	MOR		MOE
	Mean	LTL	Mean
Treatment effect (TBA/UBA)	1.23	0.76	0.96
Combined effect (TBH/UBA)	0.68	0.49	0.90

6. Acknowledgements

This work was a joint research project of APA – The Engineered Wood Association and the USDA Forest Products Laboratory. This research was supported in part by funds provided by the USDA Forest Products Laboratory (16-JV-11111135-079), which is acknowledged and greatly appreciated by the project team. The project team also appreciated the contribution of Arch Wood Protection Inc. and Viance, LLC for providing the fire-retardant treatments.

7. References

1) American Wood Protection Association. 2017. *Standard for Fire Retardant FR-1*, P49-15. Birmingham, AL.

2) American Wood Protection Association. 2017. *Standard for Fire Retardant FR-2*, P50-15. Birmingham, AL.

3) American Wood Protection Association. 2018. Section H Fire Retardant Treated Lumber and Plywood. *Standard for Use Category System: Processing and Treatment Standard*. T1-17. Birmingham, AL.

4) APA. 2017. *American National Standard for Wood Products - Structural Glued Laminated Timber.* ANSI A190.1-2017. Tacoma, WA.

5) ASTM International. 2014. *Standard Specification for Evaluation of Structural Composite Lumber Products. ASTM D5456-14b.* West Conshohocken, PA.

6) ASTM International. 2010. *Standard Test Method for Evaluating the Effects of Fire-Retardant Treatments and Elevated temperatures on Strength Properties of Fire-Retardant Treated Lumber. ASTM D5664-10.* West Conshohocken, PA.

7) International Code Council. 2018. International Building Code. Country Club Hills, IL.

Appendix A. Tension Lamination Test Results

Objective: Tension lamination long-span E and tension tests
Material: 302-24/DF
Test lab: APA Research Center, Tacoma, WA
Referenced test methods: Long-span E in accordance with AITC T116; tension per AITC T123
Test conditions: As-received

Specimen Number	Width (in.)	Thickness (in.)	D [a] (pcf)	MC (%)	LSE (10^6 psi) [b]			Max Load (lbf)	Tension [c] (psi)	Lognormal Tension	Failure Mode
					Side A	Side B	Average				
UTA-1	5.503	1.507	39.6	12.3	2.70	2.69	2.70	50,977	6,150	8.72	Slope of Grain
UTA-2	5.478	1.506	37.9	11.6	2.57	2.58	2.58	68,000	8,243	9.02	Slope of Grain
UTA-3	5.506	1.506	33.1	12.3	2.21	2.19	2.20	54,843	6,615	8.80	Knot
UTA-4	5.498	1.503	34.4	11.5	2.25	2.20	2.23	53,922	6,526	8.78	Slope of Grain
UTA-5	5.484	1.505	34.5	11.4	2.35	2.35	2.35	54,058	6,550	8.79	Slope of Grain
UTA-6	5.464	1.497	39.2	12.1	2.86	2.82	2.84	93,323	11,409	9.34	Pure tension
UTA-7	5.461	1.498	39.1	12.8	2.66	2.47	2.57	57,284	7,002	8.85	Knot
UTA-8	5.505	1.503	42.8	12.2	2.55	2.54	2.54	78,584	9,498	9.16	Brashy
UTA-9	5.475	1.505	42.5	11.7	3.18	3.24	3.21	70,579	8,566	9.06	Shelling
UTA-10	5.503	1.507	33.1	10.9	2.68	2.66	2.67	40,869	4,930	8.50	Slope of Grain
UTA-11	5.475	1.502	39.2	11.3	2.41	2.45	2.43	59,174	7,196	8.88	Knot
UTA-12	5.481	1.497	39.9	11.4	2.55	2.54	2.55	65,195	7,946	8.98	Knot
UTA-13	5.494	1.502	37.0	11.7	1.86	1.83	1.85	56,417	6,840	8.83	Brashy
UTA-14	5.492	1.506	37.8	12.0	2.35	2.26	2.31	79,590	9,627	9.17	Pure tension
UTA-15	5.503	1.509	38.0	11.7	2.64	2.67	2.66	58,759	7,079	8.86	Pure tension
UTA-16	5.509	1.508	34.5	11.0	2.27	2.19	2.23	40,109	4,830	8.48	Knot
UTA-17	5.493	1.511	43.0	11.4	3.15	3.19	3.17	88,443	10,657	9.27	Pure tension
UTA-18	5.515	1.511	39.1	10.8	2.18	2.17	2.17	40,296	4,837	8.48	Knot
UTA-19	5.506	1.512	34.3	11.0	2.64	2.63	2.64	66,952	8,045	8.99	Pure tension
UTA-20	5.511	1.511	36.6	11.1	2.46	2.49	2.48	86,509	10,392	9.25	Knot
UTA-21	5.501	1.505	34.3	11.0	2.45	2.43	2.44	62,881	7,596	8.94	Knot
UTA-22	5.475	1.503	37.9	11.9	2.49	2.38	2.43	41,888	5,090	8.54	Knot
UTA-23	5.506	1.503	34.5	11.1	2.83	2.86	2.84	80,755	9,762	9.19	Pure tension
UTA-24	5.476	1.503	38.8	12.6	2.21	2.21	2.21	46,067	5,599	8.63	Brashy
UTA-25	5.503	1.507	39.6	12.9	2.46	2.46	2.46	84,467	10,185	9.23	Brashy
UTA-26	5.479	1.500	39.7	12.0	2.97	2.96	2.97	54,872	6,677	8.81	Slope of Grain
UTA-27	5.507	1.505	37.9	12.2	2.39	2.37	2.38	70,494	8,506	9.05	Pure tension
UTA-28	5.496	1.510	37.4	11.9	2.26	2.24	2.25	61,567	7,422	8.91	Knot
UTA-29	5.485	1.501	34.6	11.0	2.43	2.43	2.43	55,756	6,775	8.82	Knot
UTA-30	5.520	1.508	37.2	11.5	2.43	2.30	2.37	45,108	5,419	8.60	Knot
UTA-31	5.474	1.505	42.3	12.0	3.13	2.87	3.00	54,110	6,571	8.79	Knot
UTA-32	5.523	1.506	31.6	11.2	2.29	2.32	2.31	53,111	6,385	8.76	Knot
UTA-33	5.520	1.513	40.0	11.7	2.82	2.69	2.76	56,818	6,803	8.83	Shelling
Total no. of observations			33	33			33	33	33	33	
Mean			37.6	11.7			2.52	61,569	7,446	8.89	
Maximum			43.0	12.9			3.21	93,323	11,409	9.34	
Minimum			31.6	10.8			1.85	40,109	4,830	8.48	
COV			0.079	0.048			0.119	0.239	0.239	0.027	
K									1.856	1.856	
Lower tolerance limit (LTL)									4,143	4,672	
LTL/2.1									1,973	2,225	

[a] Density based on weight and volume at test.
[b] Span 150 inches; span to depth ratio 100:1.
[c] Tension tested at an 8-ft gauge length.

Objective: Tension lamination long-span E and tension tests
Material: 302-24/DF (P49 treated)
Test lab: APA Research Center, Tacoma, WA
Referenced test methods: Long-span E in accordance with AITC T116; tension per AITC T123
Test conditions: Standard condition

Specimen Number	Width (in.)	Thickness (in.)	D [a] (pcf)	MC (%)	LSE (10^6 psi) [b]			Max Load (lbf)	Tension [c] (psi)	Lognormal Tension	Failure Mode
					Side A	Side B	Average				
TTA-49-1	5.548	1.524	40.2	12.6	2.49	2.46	2.48	66,483	7,866	8.97	Tension
TTA-49-2	5.615	1.540	35.8	13.4	2.33	2.32	2.33	62,195	7,196	8.88	Tension
TTA-49-3	5.564	1.531	46.7	12.6	3.05	2.99	3.02	83,776	9,836	9.19	Tension
TTA-49-4	5.565	1.530	39.7	12.2	2.51	2.53	2.52	79,830	9,380	9.15	Tension
TTA-49-5	5.562	1.526	35.3	13.2	2.08	2.10	2.09	63,778	7,515	8.92	Tension
TTA-49-6	5.557	1.525	35.6	13.2	2.21	2.22	2.21	53,631	6,331	8.75	Tension
TTA-49-7	5.519	1.519	39.8	13.0	2.61	2.69	2.65	35,831	4,276	8.36	Tension
TTA-49-8	5.554	1.521	38.1	12.9	2.14	2.15	2.15	35,788	4,238	8.35	Tension
TTA-49-9	5.555	1.526	36.8	13.1	2.29	2.31	2.30	82,068	9,681	9.18	Tension
TTA-49-10	5.547	1.535	39.4	13.5	2.57	2.57	2.57	51,783	6,082	8.71	Tension
TTA-49-11	5.585	1.531	40.3	13.9	2.55	2.57	2.56	60,821	7,115	8.87	Tension
TTA-49-12	5.560	1.541	40.3	13.6	2.48	2.50	2.49	62,912	7,346	8.90	Tension
TTA-49-13	5.560	1.541	40.2	12.7	2.56	2.51	2.54	48,167	5,624	8.63	Tension
TTA-49-14	5.540	1.523	44.6	13.6	2.45	2.47	2.46	81,830	9,698	9.18	Tension
TTA-49-15	5.538	1.526	41.1	13.0	2.73	2.74	2.74	81,287	9,619	9.17	Tension
TTA-49-16	5.607	1.526	38.8	12.7	2.55	2.57	2.56	60,376	7,056	8.86	Tension
TTA-49-17	5.607	1.526	42.2	12.1	2.45	2.44	2.44	68,830	8,044	8.99	Tension
TTA-49-18	5.535	1.535	40.5	13.4	2.27	2.37	2.32	79,671	9,378	9.15	Tension
TTA-49-19	5.570	1.533	38.0	13.1	2.29	2.29	2.29	41,228	4,830	8.48	Tension
TTA-49-20	5.537	1.532	38.5	13.0	2.55	2.62	2.58	88,485	10,435	9.25	Tension
TTA-49-21	5.536	1.522	40.7	13.1	2.59	2.58	2.58	78,761	9,348	9.14	Tension
TTA-49-22	5.538	1.525	34.9	13.6	2.07	2.07	2.07	62,134	7,358	8.90	Tension
TTA-49-23	5.498	1.524	41.6	12.7	2.56	2.63	2.59	63,328	7,561	8.93	Tension
TTA-49-24	5.536	1.523	41.7	12.8	2.60	2.52	2.56	66,107	7,843	8.97	Tension
TTA-49-25	5.529	1.524	37.7	13.0	2.17	2.16	2.17	65,897	7,824	8.96	Tension
TTA-49-26	5.560	1.528	39.2	13.0	2.34	2.35	2.35	42,358	4,986	8.51	Tension
TTA-49-27	5.560	1.528	36.1	13.3	1.87	1.96	1.92	54,567	6,423	8.77	Tension
TTA-49-28	5.547	1.527	36.6	13.1	2.45	2.43	2.44	60,098	7,096	8.87	Tension
TTA-49-29	5.519	1.533	40.9	12.6	2.54	2.52	2.53	33,154	3,919	8.27	Tension
TTA-49-30	5.519	1.533	37.3	13.1	2.59	2.63	2.61	45,227	5,346	8.58	Tension
TTA-49-31	5.502	1.539	38.2	13.0	2.52	2.55	2.53	52,967	6,258	8.74	Tension
TTA-49-32	5.567	1.519	38.0	13.4	2.07	2.11	2.09	68,019	8,044	8.99	Tension
TTA-49-33	5.567	1.519	41.7	11.6	2.64	2.65	2.65	65,614	7,760	8.96	Tension
Total no. of observations			33	33			33	33	33	33	
Mean			39.3	13.0			2.44	62,030	7,312	8.87	
Maximum			46.7	13.9			3.02	88,485	10,435	9.25	
Minimum			34.9	11.6			1.92	33,154	3,919	8.27	
COV			0.067	0.035			0.093	0.242	0.243	0.030	
K									1.856	1.856	
Lower tolerance limit (LTL)									4,020	4,357	
LTL/2.1									1,914	2,075	

[a] Density based on weight and volume at test.
[b] Span 150 inches; span to depth ratio 100:1.
[c] Tension tested at an 8-ft gauge length.

Objective: Tension lamination long-span E and tension tests
Material: 302-24/DF (P50 treated)
Test lab: APA Research Center, Tacoma, WA
Referenced test methods: Long-span E in accordance with AITC T116; tension per AITC T123
Test conditions: Standard condition

Specimen Number	Width (in.)	Thickness (in.)	D [a] (pcf)	MC (%)	LSE (10^6 psi) [b]			Max Load (lbf)	Tension [c] (psi)	Lognormal Tension	Failure Mode
					Side A	Side B	Average				
TTA-50-1	5.494	1.518	42.6	10.8	2.33	2.38	2.35	62,365	7,478	8.92	Slope of Grain
TTA-50-2	5.456	1.521	41.2	11.3	2.67	2.71	2.69	56,921	6,862	8.83	Knot
TTA-50-3	5.478	1.504	38.3	12.5	2.38	2.39	2.38	56,763	6,891	8.84	Knot
TTA-50-4	5.468	1.514	36.1	11.3	2.22	2.21	2.22	70,091	8,468	9.04	Tension
TTA-50-5	5.481	1.500	33.8	11.0	2.04	1.99	2.02	41,934	5,100	8.54	Knot
TTA-50-6	5.535	1.513	37.3	11.3	1.96	1.98	1.97	54,762	6,539	8.79	Knot
TTA-50-7	5.374	1.496	34.5	11.1	2.21	2.23	2.22	46,613	5,798	8.67	Tension
TTA-50-8	5.434	1.507	37.9	10.8	2.36	2.45	2.40	53,600	6,545	8.79	Knot
TTA-50-9	5.448	1.505	38.4	11.1	2.79	2.80	2.80	68,733	8,381	9.03	Knot
TTA-50-10	5.441	1.506	39.9	11.0	2.56	2.60	2.58	34,802	4,248	8.35	Knot
TTA-50-11	5.447	1.509	38.8	11.0	2.63	2.58	2.60	56,031	6,816	8.83	SLG
TTA-50-12	5.458	1.501	39.4	12.1	2.63	2.64	2.64	66,260	8,088	9.00	Knot
TTA-50-13	5.465	1.508	37.7	11.0	2.55	2.54	2.54	67,733	8,220	9.01	Tension
TTA-50-14	5.374	1.504	36.6	10.8	2.39	2.41	2.40	62,130	7,685	8.95	Knot
TTA-50-15	5.458	1.506	38.3	11.0	2.17	2.18	2.18	25,828	3,143	8.05	Knot
TTA-50-16	5.443	1.507	30.9	10.9	2.10	2.10	2.10	51,292	6,256	8.74	Knot
TTA-50-17	5.441	1.505	39.8	11.4	2.39	2.48	2.44	83,011	10,142	9.22	SLG
TTA-50-18	5.419	1.499	36.6	11.0	2.44	2.43	2.43	74,914	9,221	9.13	Knot
TTA-50-19	5.487	1.492	37.7	12.2	2.33	2.37	2.35	50,950	6,225	8.74	Knot
TTA-50-20	5.462	1.504	34.8	10.9	2.34	2.35	2.34	36,344	4,424	8.39	Tension
TTA-50-21	5.449	1.499	36.9	11.1	2.13	2.10	2.12	60,302	7,382	8.91	Knot
TTA-50-22	5.422	1.509	36.5	10.4	1.89	1.90	1.90	36,122	4,417	8.39	Knot
TTA-50-23	5.443	1.504	38.7	11.4	2.53	2.51	2.52	73,054	8,923	9.10	Knot
TTA-50-24	5.432	1.511	35.2	11.5	1.99	2.09	2.04	64,154	7,815	8.96	Knot
TTA-50-25	5.434	1.511	34.9	10.8	2.18	2.20	2.19	55,620	6,775	8.82	Shelling
TTA-50-26	5.482	1.509	35.9	11.1	1.94	1.91	1.93	44,197	5,343	8.58	Knot
TTA-50-27	5.424	1.499	41.5	10.9	2.61	2.64	2.62	50,236	6,177	8.73	Knot
TTA-50-28	5.454	1.505	35.2	12.9	2.15	2.14	2.15	59,261	7,222	8.88	SLG
TTA-50-29	5.520	1.501	32.3	10.7	2.22	2.21	2.21	44,687	5,393	8.59	Knot
TTA-50-30	5.472	1.498	37.6	11.6	2.48	2.48	2.48	31,066	3,790	8.24	SLG
TTA-50-31	5.466	1.515	38.9	11.1	2.35	2.33	2.34	37,954	4,584	8.43	SLG
TTA-50-32	5.455	1.503	40.9	10.9	2.38	2.48	2.43	48,673	5,938	8.69	Knot
TTA-50-33	5.476	1.502	43.9	10.8	2.70	2.78	2.74	87,155	10,595	9.27	Tension
Total no. of observations			33	33			33	33	33	33	
Mean			37.6	11.2			2.34	54,956	6,693	8.77	
Maximum			43.9	12.9			2.80	87,155	10,595	9.27	
Minimum			30.9	10.4			1.90	25,828	3,143	8.05	
COV			0.075	0.048			0.103	0.267	0.267	0.032	
K									1.856	1.856	
Lower tolerance limit (LTL)									3,374	3,802	
LTL/2.1									1,606	1,811	

[a] Density based on weight and volume at test.
[b] Span 150 inches; span to depth ratio 100:1.
[c] Tension tested at an 8-ft gauge length.

Objective: Tension lamination tension tests
Material: 302-24/DF
Test lab: FPL, Madison, WI
Referenced test methods: Long-span E in accordance with AITC T116; tension per AITC T123
Test conditions: Standard condition

Specimen Number	Width (in.)	Thickness (in.)	Max Load (lbf)	Tension [a] (psi)	Lognormal Tension
9876-UTA-34	5.464	1.499	44,783	5,468	8.61
9876-UTA-35	5.497	1.503	56,915	6,889	8.84
9876-UTA-36A	5.427	1.490	85,163	10,532	9.26
9876-UTA-37	5.451	1.495	72,263	8,867	9.09
9876-UTA-38	5.508	1.510	43,841	5,271	8.57
9876-UTA-39	5.474	1.501	40,966	4,986	8.51
9876-UTA-40	5.474	1.498	45,586	5,559	8.62
9876-UTA-41	5.440	1.498	85,301	10,468	9.26
9876-UTA-42	5.498	1.533	87,744	10,410	9.25
9876-UTA-43B	5.481	1.499	83,430	10,155	9.23
9876-UTA-44	5.481	1.499	55,836	6,796	8.82
9876-UTA-45	5.503	1.508	61,952	7,465	8.92
9876-UTA-46	5.463	1.506	71,996	8,751	9.08
9876-UTA-47	5.497	1.507	78,316	9,454	9.15
9876-UTA-48	5.474	1.504	70,576	8,572	9.06
9876-UTA-49	5.434	1.482	62,162	7,719	8.95
9876-UTA-50	5.455	1.488	56,050	6,905	8.84
9876-UTA-51	5.513	1.509	79,466	9,552	9.16
9876-UTA-52	5.450	1.494	42,066	5,166	8.55
9876-UTA-53	5.451	1.491	56,864	6,997	8.85
9876-UTA-54	5.510	1.507	51,734	6,230	8.74
9876-UTA-55	5.469	1.504	77,430	9,414	9.15
9876-UTA-56	5.486	1.501	54,538	6,623	8.80
9876-UTA-57	5.453	1.504	80,023	9,757	9.19
9876-UTA-58	5.458	1.494	50,284	6,167	8.73
9876-UTA-59	5.499	1.502	39,252	4,752	8.47
9876-UTA-60	5.444	1.496	63,920	7,848	8.97
9876-UTA-61	5.497	1.495	39,918	4,857	8.49
9876-UTA-62	5.475	1.495	55,762	6,813	8.83
9876-UTA-63	5.469	1.507	73,464	8,914	9.10
9876-UTA-64	5.483	1.503	56,392	6,843	8.83
9876-UTA-65	5.469	1.492	73,378	8,993	9.10
9876-UTA-66	5.486	1.496	66,433	8,095	9.00
Total no. of observations			33	33	33
Mean			62,540	7,615	8.91
Maximum			87,744	10,532	9.26
Minimum			39,252	4,752	8.47
COV			0.239	0.238	0.028
K				1.856	1.856
Lower tolerance limit (LTL)				4,254	4,683
LTL/2.1				2,026	2,230

[a] Tension tested at an 8-ft gauge length.

Objective: Tension lamination long-span E and tension tests
Material: 302-24/DF
Test lab: FPL, Madison, WI
Referenced test methods: Long-span E in accordance with AITC T116; tension per AITC T123
Test conditions: Standard condition after hygrothermal conditioning

Specimen Number	Width (in.)	Thickness (in.)	Max Load (lbf)	Tension [a] (psi)	Lognormal Tension
UTH-01	5.465	1.502	33,616	4,095	8.32
UTH-02	5.450	1.493	46,401	5,703	8.65
UTH-03	5.411	1.495	62,569	7,735	8.95
UTH-04	5.318	1.489	48,074	6,071	8.71
UTH-05	5.392	1.496	51,766	6,417	8.77
UTH-06	5.364	1.485	88,438	11,103	9.31
UTH-07	5.425	1.595	55,956	6,467	8.77
UTH-08	5.414	1.492	47,315	5,858	8.68
UTH-09	5.476	1.509	34,533	4,179	8.34
UTH-10	5.476	1.502	50,870	6,185	8.73
UTH-11	5.446	1.499	45,988	5,633	8.64
UTH-12	5.390	1.497	33,170	4,111	8.32
UTH-13	5.445	1.493	46,738	5,749	8.66
UTH-14	5.425	1.494	40,160	4,955	8.51
UTH-15	5.399	1.484	39,110	4,881	8.49
UTH-16	5.419	1.480	57,485	7,168	8.88
UTH-17	5.436	1.490	66,942	8,265	9.02
UTH-18	5.411	1.493	46,623	5,771	8.66
UTH-19	5.444	1.499	45,185	5,537	8.62
UTH-20	5.413	1.508	44,500	5,452	8.60
UTH-21	5.418	1.497	43,218	5,329	8.58
UTH-22	5.416	1.488	66,859	8,296	9.02
UTH-23	5.419	1.495	50,399	6,221	8.74
UTH-24	5.408	1.493	68,819	8,523	9.05
UTH-25	5.427	1.494	43,971	5,423	8.60
UTH-26	5.432	1.503	72,213	8,845	9.09
UTH-28	5.450	1.496	74,253	9,107	9.12
UTH-29	5.452	1.492	74,193	9,121	9.12
UTH-30	5.388	1.502	62,652	7,742	8.95
UTH-31	5.464	1.499	67,856	8,285	9.02
UTH-32	5.423	1.495	64,255	7,925	8.98
Total no. of observations			31	31	31
Mean			54,004	6,650	8.77
Maximum			88,438	11,103	9.31
Minimum			33,170	4,095	8.32
COV			0.256	0.258	0.029
K				1.856	1.856
Lower tolerance limit (LTL)				3,462	4,011
LTL/2.1				1,649	1,910

[a] Tension tested at an 8-ft gauge length.

Objective: Tension lamination long-span E and tension tests
Material: 302-24/DF (P49 treated)
Test lab: FPL, Madison, WI
Referenced test methods: Long-span E in accordance with AITC T116; tension per AITC T123
Test conditions: Standard condition after hygrothermal conditioning

Specimen Number	Width (in.)	Thickness (in.)	Max Load (lbf)	Tension [a] (psi)	Lognormal Tension
TTH-P49-01	5.475	1.509	79,264	9,594	9.17
TTH-P49-02	5.515	1.520	47,373	5,651	8.64
TTH-P49-03	5.527	1.540	25,001	2,937	7.99
TTH-P49-04	5.453	1.502	56,492	6,897	8.84
TTH-P49-05	5.545	1.510	25,017	2,988	8.00
TTH-P49-06	5.481	1.510	49,005	5,921	8.69
TTH-P49-07	5.494	1.500	65,298	7,924	8.98
TTH-P49-07X	5.470	1.512	45,055	5,448	8.60
TTH-P49-08	5.500	1.516	41,578	4,987	8.51
TTH-P49-09	5.590	1.524	46,340	5,440	8.60
TTH-P49-10	5.540	1.536	42,796	5,029	8.52
TTH-P49-11A	5.449	1.493	86,006	10,572	9.27
TTH-P49-12	5.499	1.512	62,080	7,466	8.92
TTH-P49-13	5.462	1.503	30,209	3,680	8.21
TTH-P49-14	5.462	1.508	51,819	6,291	8.75
TTH-P49-15	5.447	1.492	51,738	6,366	8.76
TTH-P49-16	5.433	1.508	79,093	9,654	9.18
TTH-P49-17	5.534	1.512	30,763	3,676	8.21
TTH-P49-18	5.563	1.513	26,412	3,138	8.05
TTH-P49-19	5.499	1.516	62,157	7,456	8.92
TTH-P49-20	5.487	1.515	74,915	9,012	9.11
TTH-P49-21	5.490	1.506	37,192	4,498	8.41
TTH-P49-22	5.449	1.534	48,908	5,851	8.67
TTH-P49-23	5.490	1.511	39,654	4,780	8.47
TTH-P49-24	5.523	1.510	61,361	7,358	8.90
TTH-P49-25	5.530	1.519	59,580	7,093	8.87
TTH-P49-26	5.535	1.535	39,707	4,673	8.45
TTH-P49-28	5.510	1.512	40,340	4,842	8.49
TTH-P49-29	5.439	1.505	49,869	6,092	8.71
TTH-P49-30	5.475	1.514	47,936	5,783	8.66
TTH-P49-31	5.507	1.511	33,019	3,968	8.29
TTH-P49-32	5.452	1.505	66,485	8,103	9.00
TTH-P49-33	5.485	1.516	51,048	6,139	8.72
Total no. of observations			33	33	33
Mean			50,106	6,040	8.65
Maximum			86,006	10,572	9.27
Minimum			25,001	2,937	7.99
COV			0.319	0.326	0.039
K				1.856	1.856
Lower tolerance limit (LTL)				2,388	3,068
LTL/2.1				1,137	1,461

[a] Tension tested at an 8-ft gauge length.

Objective: Tension lamination long-span E and tension tests
Material: 302-24/DF (P50 treated)
Test lab: FPL, Madison, WI
Referenced test methods: Long-span E in accordance with AITC T116; tension per AITC T123
Test conditions: Standard condition after hygrothermal conditioning

Specimen Number	Width (in.)	Thickness (in.)	Max Load (lbf)	Tension [a] (psi)	Lognormal Tension
TTH-P50-01	5.435	1.522	40,243	4,865	8.49
TTH-P50-02	5.442	1.496	35,743	4,390	8.39
TTH-P50-03	5.438	1.508	24,705	3,013	8.01
TTH-P50-04	5.343	1.499	57,214	7,144	8.87
TTH-P50-05	5.415	1.508	28,589	3,501	8.16
TTH-P50-06	5.369	1.488	37,315	4,671	8.45
TTH-P50-07	5.391	1.502	78,526	9,698	9.18
TTH-P50-08	5.402	1.493	32,345	4,010	8.30
TTH-P50-09	5.415	1.500	56,686	6,979	8.85
TTH-P50-10	5.447	1.506	34,777	4,239	8.35
TTH-P50-11	5.392	1.503	46,280	5,711	8.65
TTH-P50-12	5.397	1.504	49,489	6,097	8.72
TTH-P50-13	5.396	1.490	60,426	7,516	8.92
TTH-P50-14	5.447	1.484	42,901	5,307	8.58
TTH-P50-15	5.461	1.517	46,352	5,595	8.63
TTH-P50-16	5.467	1.514	46,114	5,571	8.63
TTH-P50-17	5.440	1.495	51,587	6,343	8.76
TTH-P50-18	5.396	1.499	67,496	8,345	9.03
TTH-P50-19	5.370	1.492	65,425	8,166	9.01
TTH-P50-20	5.440	1.515	74,990	9,099	9.12
TTH-P50-21	5.460	1.511	25,834	3,131	8.05
TTH-P50-22	5.417	1.504	76,139	9,345	9.14
TTH-P50-23	5.389	1.496	42,253	5,241	8.56
TTH-P50-24	5.412	1.490	67,238	8,338	9.03
TTH-P50-25	5.402	1.500	43,361	5,351	8.59
TTH-P50-26	5.456	1.500	43,661	5,335	8.58
TTH-P50-28	5.403	1.501	71,163	8,775	9.08
TTH-P50-29	5.428	1.503	61,980	7,597	8.94
TTH-P50-30	5.416	1.503	58,709	7,212	8.88
TTH-P50-31	5.381	1.494	41,538	5,167	8.55
TTH-P50-32	5.405	1.501	48,827	6,018	8.70
TTH-P50-33	5.443	1.501	33,773	4,134	8.33
33	5.476	1.502	87,155	10,595	9.27
Total no. of observations			33	33	33
Mean			50,874	6,258	8.69
Maximum			87,155	10,595	9.27
Minimum			24,705	3,013	8.01
COV			0.319	0.320	0.038
K				1.856	1.856
Lower tolerance limit (LTL)				2,544	3,223
LTL/2.1				1,212	1,535

[a] Tension tested at an 8-ft gauge length.

Appendix B. End Joint Test Results

Objective: Full-scale finger joint tension tests
Material: Finger jointed 302-24/DF (untreated)
Test lab: APA Research Center, Tacoma, WA
Referenced test methods: Full-scale end joint tension in accordance with AITC T119
Test conditions: Standard condition

Specimen Number	Width (in.)	Thickness (in.)	D [a] (pcf)	MC (%)	Max Load (lbf)	Tension [b] (psi)	Lognormal Tension	Failure Mode [c]	Wood Failure (%)
UTA1	5.483	1.493	34.4	12.3	--	--	--	2	95
UTA2	5.492	1.513	34.1	12.8	54,577	6,570	8.79	2	95
UTA3	5.514	1.485	32.1	12.3	27,875	3,405	8.13	3	95
UTA4	5.506	1.500	30.2	12.5	42,737	5,176	8.55	3	95
UTA5	5.497	1.493	33.4	13.4	45,035	5,489	8.61	2	95
UTA6	5.500	1.494	35.1	13.1	47,467	5,777	8.66	3	95
UTA7	5.497	1.488	31.8	13.0	43,319	5,298	8.58	3	93
UTA8	5.483	1.493	38.7	12.2	35,329	4,318	8.37	3	96
UTA9	5.506	1.508	33.0	13.0	44,265	5,333	8.58	3	98
UTA10	5.502	1.499	31.7	13.4	54,784	6,642	8.80	3	94
UTA11	5.487	1.488	34.3	13.2	51,408	6,296	8.75	3	95
UTA12	5.511	1.490	36.0	12.2	47,649	5,803	8.67	3	98
UTA13	5.502	1.507	31.9	13.2	50,695	6,115	8.72	3	93
UTA14	5.518	1.496	34.0	12.4	53,896	6,530	8.78	2	99
UTA15	5.512	1.505	31.9	12.7	58,416	7,043	8.86	2	94
UTA16	5.514	1.499	30.8	11.9	39,909	4,830	8.48	4	94
UTA17	5.502	1.508	37.6	12.6	53,131	6,404	8.76	3	97
UTA18	5.511	1.502	31.4	12.5	47,108	5,693	8.65	4	95
UTA19	5.494	1.489	36.8	13.4	55,610	6,798	8.82	2	93
UTA20	5.509	1.496	33.6	13.2	53,779	6,525	8.78	4	98
UTA21	5.516	1.497	33.8	12.2	47,407	5,741	8.66	3	96
UTA22	5.494	1.497	36.4	13.3	58,269	7,085	8.87	2	97
UTA23	5.520	1.492	31.6	12.9	39,122	4,751	8.47	3	95
UTA24	5.512	1.513	33.1	12.8	45,055	5,403	8.59	3	94
UTA25	5.501	1.496	33.4	13.0	59,207	7,198	8.88	2	96
UTA26	5.496	1.509	32.2	13.4	41,290	4,980	8.51	4	95
UTA27	5.481	1.490	36.5	14.9	56,763	6,954	8.85	2	97
UTA28	5.500	1.494	38.1	12.5	44,265	5,389	8.59	2	97
UTA29	5.492	1.506	33.9	13.4	57,975	7,010	8.86	3	94
UTA30	5.492	1.497	33.8	13.6	48,758	5,932	8.69	3	95
UTA31	5.505	1.500	32.9	13.5	53,804	6,519	8.78	3	98
UTA32	5.499	1.496	36.5	12.6	48,771	5,929	8.69	3	93
UTA33	5.500	1.494	37.2	12.4	53,052	6,458	8.77	2	96
UTA34	5.511	1.526	32.7	12.4	36,329	4,320	8.37	3	99
UTA35	5.510	1.502	36.9	13.1	49,579	5,993	8.70	3	94
UTA36	5.508	1.501	32.5	13.6	55,178	6,676	8.81	4	95
UTA37	5.506	1.530	31.7	12.4	39,124	4,645	8.44	4	95
UTA38	5.501	1.517	37.1	12.7	49,170	5,894	8.68	3	80
UTA39	5.490	1.518	33.8	13.3	50,230	6,028	8.70	3	85
UTA40	5.509	1.513	31.9	12.7	58,278	6,994	8.85	3	80
UTA41	5.520	1.510	37.6	13.3	59,109	7,092	8.87	2	70
UTA42	5.511	1.510	37.9	12.2	45,754	5,499	8.61	6	100
UTA43	5.566	1.531	32.8	11.9	58,267	6,840	8.83	4	85
UTA44	5.504	1.519	31.2	12.8	47,230	5,652	8.64	3	85
UTA45	5.509	1.527	32.4	12.9	42,636	5,068	8.53	4	90
UTA46	5.513	1.528	37.8	12.7	53,926	6,404	8.76	3	80
UTA47	5.499	1.501	25.8	12.8	38,068	4,612	8.44	4	95
UTA48	5.497	1.491	34.7	13.9	51,215	6,249	8.74	3	85
UTA49	5.530	1.517	34.7	13.1	52,720	6,287	8.75	2	70
UTA50	5.508	1.514	39.1	13.4	46,875	5,622	8.63	5	100
Total no. of observations			50	50	49	49	49		50
Mean			34.1	12.9	48,866	5,903	8.67		93
Maximum			39.1	14.9	59,207	7,198	8.88		100
Minimum			25.8	11.9	27,875	3,405	8.13		70
COV			0.077	0.043	0.147	0.146	0.018		0.019
K						1.813	1.813		
Lower tolerance limit (LTL)						4,336	4,386		
LTL/1.67 (QSL)						2,596	2,626		

[a] Density based on weight and volume at test.
[b] Tension tested at a 2-ft gauge length.
[c] Failure Mode based on Section A1 of ASTM D7469.

Objective: Full-scale finger joint tension tests
Material: Finger jointed 302-24/DF (P-49 treated)
Test lab: APA Research Center, Tacoma, WA
Referenced test methods: Full-scale end joint tension in accordance with AITC T119
Test conditions: Standard condition

Specimen Number	Width (in.)	Thickness (in.)	D [a] (pcf)	MC (%)	Max Load (lbf)	Tension [b] (psi)	Lognormal Tension	Failure Mode [c]	Wood Failure (%)
TTA-1	5.488	1.527	31.7	14.4	42,172	5,032	8.52	3	90
TTA-2	5.595	1.534	36.2	15.3	55,188	6,430	8.77	5	95
TTA-3	5.506	1.511	37.5	13.7	42,023	5,052	8.53	5	100
TTA-4	5.524	1.522	36.1	14.6	50,974	6,063	8.71	5	100
TTA-5	5.542	1.518	37.6	14.4	55,368	6,581	8.79	3	90
TTA-6	5.559	1.534	34.0	14.6	40,877	4,794	8.48	3	95
TTA-7	5.579	1.541	36.1	13.8	45,940	5,344	8.58	4	95
TTA-8	5.532	1.523	32.9	15.1	53,044	6,299	8.75	4	95
TTA-9	5.556	1.517	34.1	15.3	51,437	6,103	8.72	4	95
TTA-10	5.521	1.525	32.4	14.6	53,380	6,342	8.75	3	80
TTA-11	5.533	1.506	35.6	14.0	40,464	4,858	8.49	3	70
TTA-12	5.524	1.527	34.4	15.9	41,701	4,944	8.51	4	90
TTA-13	5.530	1.528	38.4	14.8	56,505	6,688	8.81	4	90
TTA-14	5.521	1.535	33.6	15.3	45,929	5,420	8.60	3	90
TTA-15	5.591	1.522	33.5	16.3	38,541	4,531	8.42	3	90
TTA-16	5.531	1.536	37.1	25.4	46,792	5,510	8.61	4	95
TTA-17	5.543	1.516	34.7	11.9	64,210	7,644	8.94	2	70
TTA-18	5.554	1.525	34.3	15.7	50,425	5,956	8.69	3	85
TTA-19	5.582	1.517	35.5	16.0	52,399	6,190	8.73	5	90
TTA-20	5.548	1.520	33.5	15.1	50,458	5,985	8.70	3	85
TTA-21	5.560	1.514	33.0	14.4	51,477	6,117	8.72	3	90
TTA-22	5.559	1.520	35.3	15.7	64,775	7,669	8.94	2	75
TTA-23	5.504	1.503	33.8	14.3	43,429	5,250	8.57	4	95
TTA-24	5.587	1.535	34.5	14.6	62,228	7,258	8.89	3	80
TTA-25	5.521	1.539	33.4	14.6	46,922	5,523	8.62	4	100
TTA-26	5.511	1.526	32.8	14.1	41,388	4,922	8.50	3	80
TTA-27	5.532	1.524	33.3	14.8	39,367	4,670	8.45	3	90
TTA-28	5.539	1.524	36.2	13.5	41,922	4,966	8.51	4	80
TTA-29	5.511	1.528	37.0	14.0	38,247	4,542	8.42	3	70
TTA-30	5.588	1.530	35.8	12.5	41,752	4,885	8.49	3	85
TTA-31	5.526	1.524	35.7	14.5	42,252	5,018	8.52	3	90
TTA-32	5.557	1.522	32.6	13.1	47,293	5,594	8.63	3	80
TTA-33	5.553	1.524	39.2	13.0	47,309	5,590	8.63	5	90
TTA-34	5.523	1.514	32.4	13.6	48,634	5,818	8.67	3	90
TTA-35	5.550	1.527	34.7	13.0	51,038	6,024	8.70	5	100
TTA-36	5.567	1.527	35.1	13.6	44,724	5,263	8.57	3	85
TTA-37	5.518	1.532	36.5	13.9	47,294	5,595	8.63	4	90
TTA-38	5.553	1.523	35.7	15.8	44,696	5,287	8.57	4	95
TTA-39	5.515	1.522	34.1	14.9	52,773	6,290	8.75	4	95
TTA-40	5.545	1.541	35.4	15.3	48,949	5,729	8.65	3	85
TTA-41	5.533	1.535	32.9	14.3	49,827	5,867	8.68	4	95
TTA-42	5.527	1.504	37.1	14.7	48,135	5,793	8.66	3	85
TTA-43	5.560	1.522	36.4	14.6	44,468	5,255	8.57	3	85
TTA-44	5.540	1.548	33.2	13.7	46,557	5,431	8.60	3	90
TTA-45	5.555	1.522	37.8	14.5	40,643	4,807	8.48	4	95
TTA-46	5.518	1.531	34.1	14.6	41,614	4,926	8.50	3	85
TTA-47	5.533	1.538	33.8	13.3	43,781	5,147	8.55	5	100
TTA-48	5.520	1.522	32.2	13.6	46,588	5,546	8.62	3	90
TTA-49	5.556	1.539	35.5	14.3	42,151	4,932	8.50	3	85
TTA-50	5.559	1.541	33.8	13.4	42,887	5,009	8.52	3	90
Total no. of observations			50	50	50	50	50		50
Mean			34.8	14.6	47,419	5,610	8.62		89
Maximum			39.2	25.4	64,775	7,669	8.94		100
Minimum			31.7	11.9	38,247	4,531	8.42		70
COV			0.051	0.123	0.133	0.132	0.015		0.086
K						1.811	1.811		
Lower tolerance limit (LTL)						4,264	4,420		
LTL/1.67 (QSL)						2,554	2,647		

[a] Density based on weight and volume at test.
[b] Tension tested at a 2-ft gauge length.
[c] Failure Mode based on Section A1 of ASTM D7469.

Objective: Full-scale finger joint tension tests
Material: Finger jointed 302-24/DF (untreated)
Test lab: FPL, Madison, WI
Referenced test methods: Full-scale end joint tension in accordance with AITC T119
Test conditions: Standard condition after hygrothermal conditioning

Specimen Number	Width (in.)	Thickness (in.)	Max Load (lbf)	Tension [a] (psi)	Lognormal Tension	Failure Mode [b]
UTH-01D	5.467	1.490	44,014	5,403	8.59	2
UTH-02	5.411	1.469	41,990	5,283	8.57	2
UTH-03	5.426	1.487	39,041	4,839	8.48	2
UTH-04	5.412	1.484	49,348	6,144	8.72	1
UTH-05	5.431	1.481	46,009	5,720	8.65	5
UTH-06	5.375	1.486	46,277	5,794	8.66	1
UTH-07	5.437	1.476	48,571	6,052	8.71	1
UTH-08	5.433	1.495	45,890	5,650	8.64	2
UTH-09	5.392	1.478	40,440	5,074	8.53	1
UTH-10	5.424	1.482	43,199	5,374	8.59	5
UTH-11	5.402	1.472	42,850	5,389	8.59	5
UTH-12	5.433	1.497	60,867	7,484	8.92	2
UTH-13B	5.434	1.493	43,683	5,384	8.59	2
UTH-14	5.418	1.490	63,953	7,922	8.98	1
UTH-15C	5.433	1.486	46,890	5,808	8.67	1
UTH-16C	5.444	1.499	43,282	5,304	8.58	1
UTH-17	5.442	1.480	45,478	5,647	8.64	2
UTH-18	5.444	1.501	32,705	4,002	8.29	5
UTH-19	5.411	1.486	59,516	7,402	8.91	2
UTH-20	5.407	1.474	35,262	4,424	8.39	1
UTH-21	5.376	1.482	37,459	4,702	8.46	2
UTH-22	5.412	1.499	43,643	5,380	8.59	3
UTH-23	5.478	1.490	54,878	6,723	8.81	2
UTH-24	5.410	1.467	42,582	5,365	8.59	5
UTH-25	5.413	1.491	36,157	4,480	8.41	5
UTH-26	5.459	1.482	39,693	4,906	8.50	2
UTH-27	5.427	1.495	42,939	5,292	8.57	5
UTH-28	5.442	1.481	36,648	4,547	8.42	2
UTH-29	5.443	1.496	29,447	3,616	8.19	5
UTH-30	5.496	1.503	42,758	5,176	8.55	5
UTH-31	5.447	1.490	28,069	3,458	8.15	5
UTH-32	5.389	1.484	59,173	7,399	8.91	5
UTH-33	5.423	1.475	44,076	5,510	8.61	5
UTH-34A	5.451	1.516	34,735	4,203	8.34	5
UTH-35	5.470	1.472	35,706	4,435	8.40	2
UTH-36	5.455	1.488	40,458	4,984	8.51	6
UTH-37B	5.430	1.493	43,088	5,315	8.58	3
UTH-38	5.409	1.468	22,731	2,863	7.96	5
UTH-39	5.433	1.507	41,889	5,116	8.54	5
UTH-40B	5.428	1.472	34,780	4,353	8.38	6
UTH-41A	5.452	1.496	35,425	4,343	8.38	6
UTH-42	5.440	1.485	55,597	6,882	8.84	2
UTH-43	5.423	1.461	45,183	5,703	8.65	2
UTH-44	5.450	1.504	38,595	4,709	8.46	5
UTH-45	5.418	1.487	39,494	4,902	8.50	1
UTH-46	5.428	1.474	45,580	5,697	8.65	2
UTH-47	5.486	1.482	36,384	4,475	8.41	6
UTH-48	5.446	1.477	52,125	6,480	8.78	1
UTH-49	5.467	1.484	44,021	5,426	8.60	6
UTH-50	5.427	1.477	38,529	4,807	8.48	5
Total no. of observations			50	50	50	
Mean			42,822	5,307	8.56	
Maximum			63,953	7,922	8.98	
Minimum			22,731	2,863	7.96	
COV			0.192	0.192	0.023	
K				1.811	1.811	
Lower tolerance limit (LTL)				3,460	3,659	
LTL/1.67 (QSL)				2,072	2,191	

[a] Tension tested at a 2-ft gauge length.
[b] Failure Mode based on Section A1 of ASTM D7469.

Objective: Full-scale finger joint tension tests
Material: Finger jointed 302-24/DF (P-49 treated)
Test lab: FPL, Madison, WI
Referenced test methods: Full-scale end joint tension in accordance with AITC T119
Test conditions: Standard condition after hygrothermal conditioning

Specimen Number	Width (in.)	Thickness (in.)	Max Load (lbf)	Tension [a] (psi)	Lognormal Tension	Failure Mode [b]
TTH-01	5.420	1.485	37,410	4,648	8.44	3
TTH-02	5.459	1.480	35,063	4,340	8.38	5
TTH-03	5.505	1.505	33,833	4,084	8.31	5
TTH-04	5.506	1.502	41,141	4,975	8.51	5
TTH-05	5.470	1.500	29,678	3,617	8.19	3
TTH-06	5.474	1.498	30,760	3,751	8.23	3
TTH-07	5.446	1.497	27,605	3,386	8.13	4
TTH-08	5.453	1.501	26,123	3,192	8.07	4
TTH-09	5.490	1.518	39,424	4,731	8.46	4
TTH-10	5.496	1.512	38,426	4,624	8.44	3
TTH-11	5.411	1.491	22,552	2,795	7.94	3
TTH-12	5.454	1.488	36,005	4,437	8.40	4
TTH-13	5.475	1.495	43,077	5,263	8.57	4
TTH-14	5.552	1.503	31,971	3,831	8.25	3
TTH-15	5.462	1.510	33,583	4,072	8.31	3
TTH-16	5.475	1.491	38,825	4,756	8.47	4
TTH-17	5.430	1.489	26,281	3,250	8.09	2
TTH-18	5.436	1.492	36,445	4,494	8.41	3
TTH-19	5.444	1.499	38,772	4,751	8.47	5
TTH-20	5.408	1.491	37,410	4,640	8.44	3
TTH-21	5.455	1.505	38,222	4,656	8.45	3
TTH-22	5.462	1.503	35,767	4,357	8.38	2
TTH-23	5.441	1.494	37,971	4,671	8.45	4
TTH-24	5.440	1.497	45,088	5,537	8.62	3
TTH-25	5.449	1.525	33,950	4,086	8.32	4
TTH-26	5.477	1.500	29,687	3,614	8.19	3
TTH-27	5.451	1.496	35,312	4,330	8.37	3
TTH-28	5.463	1.520	35,763	4,307	8.37	4
TTH-29	5.439	1.486	33,952	4,201	8.34	3
TTH-30	5.380	1.480	40,288	5,060	8.53	3
TTH-31	5.421	1.497	48,803	6,014	8.70	3
TTH-32	5.440	1.486	40,489	5,009	8.52	3
TTH-33	5.451	1.493	38,759	4,763	8.47	5
TTH-34	5.479	1.496	30,713	3,747	8.23	3
TTH-35	5.417	1.494	33,809	4,178	8.34	5
TTH-36	5.426	1.499	41,550	5,108	8.54	3
TTH-37	5.438	1.494	30,679	3,776	8.24	4
TTH-38	5.467	1.491	34,521	4,235	8.35	4
TTH-39	5.427	1.493	26,938	3,325	8.11	4
TTH-40	5.465	1.506	35,039	4,257	8.36	3
TTH-41	5.478	1.509	38,771	4,690	8.45	4
TTH-42	5.426	1.503	35,530	4,357	8.38	3
TTH-43	5.490	1.511	32,193	3,881	8.26	3
TTH-44	5.409	1.483	38,896	4,849	8.49	3
TTH-45	5.477	1.473	28,303	3,508	8.16	4
TTH-46	5.436	1.526	38,924	4,692	8.45	3
TTH-47	5.404	1.487	34,654	4,313	8.37	5
TTH-48	5.402	1.475	40,995	5,145	8.55	3
TTH-49	5.461	1.498	35,320	4,318	8.37	3
TTH-50	5.399	1.474	27,146	3,411	8.13	3
Total no. of observations			50	50	50	
Mean			35,248	4,321	8.36	
Maximum			48,803	6,014	8.70	
Minimum			22,552	2,795	7.94	
COV			0.149	0.150	0.018	
K				1.811	1.811	
Lower tolerance limit (LTL)				3,148	3,229	
LTL/1.67 (QSL)				1,885	1,933	

[a] Tension tested at a 2-ft gauge length.
[b] Failure Mode based on Section A1 of ASTM D7469.

Appendix C. Glulam Beam Test Results

Objective: Full-scale glulam beam tests
Material: 24F-V4 DF (Untreated)
Test lab: APA Research Center, Tacoma, WA
Referenced test methods: Four-point bending in accordance with ASTM D198
Test conditions: As-received

#	h (in.)	b (in.)	L (in.)	a (in.)	D (pcf)	P_{ult} (lbf)	θ (lbf/in.)	MC (%)	MOR[(a)] (psi)	MOR_{adj}[(b)] (psi)	Lognormal MOR_{adj}[(b)]	MOE (10^6 psi)	MOE_{adj}[(c)] (10^6 psi)	Failure Mode
UBA1-1	5.995	5.514	108	36	35.4	18,082	10,337	11.9	9,885	9,863	9.20	2.33	2.33	Knot and compression
UBA1-2	5.982	5.440	108	36	34.7	17,093	10,036	12.3	9,513	9,579	9.17	2.31	2.32	Knot in tension zone, shear
UBA1-3	5.983	5.439	108	36	37.6	17,899	9,521	13.5	9,962	10,383	9.25	2.19	2.24	Shear within lamination
UBA1-4	6.015	5.461	108	36	35.4	18,933	10,022	12.0	10,381	10,367	9.25	2.26	2.26	Knot in tension zone
UBA1-5	5.965	5.465	108	36	35.6	17,322	9,880	12.5	9,651	9,790	9.19	2.29	2.30	Knot, compression, tension
UBA1-6	5.986	5.451	108	36	35.3	18,778	10,402	12.0	10,413	10,408	9.25	2.39	2.39	Shear within lamination
UBA1-7	6.005	5.441	108	36	34.0	16,525	8,931	11.4	9,126	8,975	9.10	2.03	2.01	Knot in tension zone
UBA1-8	5.962	5.413	108	36	38.7	16,753	10,287	13.7	9,436	9,895	9.20	2.41	2.47	SOG and tension
UBA1-9	5.981	5.365	108	36	37.8	20,353	10,896	13.2	11,488	11,898	9.38	2.55	2.59	Compression and tension
UBA1-10	5.998	5.420	108	36	38.8	15,814	11,093	12.4	8,792	8,885	9.09	2.54	2.56	FJ in tension lam and knot
UBA1-11	5.974	5.403	108	36	34.3	15,053	9,354	12.2	8,462	8,500	9.05	2.18	2.18	Knot in tension zone
UBA1-12	5.976	5.456	108	36	33.5	15,981	8,965	11.6	8,887	8,793	9.08	2.07	2.05	Knot in tension zone
UBA1-13	5.978	5.414	108	36	35.0	16,246	9,701	12.0	9,098	9,104	9.12	2.25	2.25	Compression and tension, knot
UBA1-14	5.955	5.454	108	36	34.8	19,147	10,027	11.4	10,724	10,553	9.26	2.34	2.32	Shear within lamination
UBA1-15	5.971	5.462	108	36	35.5	14,987	9,667	12.6	8,342	8,479	9.05	2.23	2.25	Knot in tension zone
Total no. of observations					15			15	15	15	15	15	15	
Mean					35.8			12.3	9,611	9,698	9.18	2.29	2.30	
Maximum					38.8			13.7	11,488	11,898	9.38	2.55	2.59	
Minimum					33.5			11.4	8,342	8,479	9.05	2.03	2.01	
COV					0.047			0.058	0.092	0.097	0.01	0.064	0.069	
K										1.991	1.991			
Lower tolerance limit (LTL)										7,827	7,992			
LTL/2.1										3,727	3,806			

[(a)] MOR includes beam weight.
[(b)] Adjusted MOR to 12% MC.
[(c)] Adjusted MOE to 12% MC.

Objective: Full-scale glulam beam tests
Material: 24F-V4 DF (P49 treated)
Test lab: APA Research Center, Tacoma, WA
Referenced test methods: Four-point bending in accordance with ASTM D198
Test conditions: As-received

#	h (in.)	b (in.)	L (in.)	a (in.)	D (pcf)	P_{ult} (lbf)	θ (lbf/in.)	MC (%)	MOR[a] (psi)	MOR_{adj}[b] (psi)	Lognormal MOR_{adj}[b]	MOE (10^6 psi)	MOE_{adj}[c] (10^6 psi)	Failure Mode
TBA1-1	6.027	5.485	108	36	42.4	17,749	10,853	23.5	9,658	12,471	9.43	2.43	2.93	Shear
TBA1-2	6.109	5.479	108	36	36.8	12,158	8,754	21.0	6,452	7,067	8.86	1.88	2.17	Shear
TBA1-3	6.069	5.499	108	36	37.2	9,115	8,077	32.6	4,892	9,234	9.13	1.76	2.55	Tension
TBA1-4	6.032	5.440	108	36	37.1	16,292	10,889	21.4	8,921	10,364	9.25	2.45	2.85	Tension
TBA1-5	6.077	5.537	108	36	34.7	18,965	10,153	23.6	10,046	13,133	9.48	2.19	2.66	Shear
TBA1-6	6.071	5.472	108	36	40.4	17,671	10,776	29.2	9,497	17,489	9.77	2.36	3.19	Tension
TBA1-7	6.032	5.517	108	36	37.5	18,262	11,041	21.3	9,858	11,549	9.35	2.45	2.85	Shear
TBA1-8	6.026	5.473	108	36	41.2	17,164	9,663	25.1	9,363	13,091	9.48	2.16	2.70	Tension
TBA1-9	6.023	5.400	108	36	40.7	14,045	12,694	22.4	7,779	9,222	9.13	2.89	3.42	Tension
TBA1-10	6.016	5.486	108	36	42.4	16,841	10,482	27.0	9,198	14,277	9.57	2.35	3.04	Shear
TBA1-11	6.021	5.427	108	36	34.0	14,596	8,858	16.9	8,042	7,886	8.97	2.01	2.17	Tension
TBA1-12	6.019	5.571	108	36	40.7	13,181	9,274	22.5	7,089	8,345	9.03	2.05	2.43	Shear
TBA1-13	6.021	5.487	108	36	36.3	13,380	8,371	26.9	7,296	10,713	9.28	1.88	2.42	Shear
TBA1-14	6.072	5.439	108	36	43.1	16,805	10,403	32.9	9,086	23,712	10.07	2.29	3.34	Tension
TBA1-15	6.025	5.488	108	36	36.8	12,475	8,981	28.3	6,796	10,708	9.28	2.01	2.66	Tension
Total no. of observations					15			15	15	15	15	15	15	
Mean					38.7			25.0	8,265	11,951	9.34	2.21	2.76	
Maximum					43.1			32.9	10,046	23,712	10.07	2.89	3.42	
Minimum					34.0			16.9	4,892	7,067	8.86	1.76	2.17	
COV					0.076			0.180	0.182	0.355	0.03	0.132	0.139	
K										1.991	1.991			
Lower tolerance limit (LTL)										3,515	6,080			
LTL/2.1										1,674	2,895			

[a] MOR includes beam weight.
[b] Adjusted MOR to 12% MC.
[c] Adjusted MOE to 12% MC.

Objective: Full-scale glulam beam tests
Material: 24F-V4 DF (Untreated)
Test lab: FPL, Madison, WI
Referenced test methods: Four-point bending in accordance with ASTM D198
Test conditions: Standard condition after hygrothermal conditioning

#	h (in.)	b (in.)	L (in.)	a (in.)	P_{ult} (lbf)	MOR[(a)] (psi)	Lognormal MOR[(a)]	MOE (10^6 psi)
UBH-1	5.955	5.412	108	36	17,057	9,628	9.17	2.04
UBH-2	5.948	5.418	108	36	15,018	8,491	9.05	2.12
UBH-3	5.954	5.422	108	36	10,178	5,749	8.66	2.12
UBH-4	5.919	5.448	108	36	8,297	4,724	8.46	2.02
UBH-5	5.959	5.414	108	36	16,162	9,109	9.12	1.86
UBH-6	5.938	5.383	108	36	13,310	7,603	8.94	2.17
UBH-7	5.972	5.429	108	36	13,590	7,610	8.94	1.82
UBH-8	5.954	5.410	108	36	11,526	6,521	8.78	2.08
UBH-9	5.958	5.380	108	36	15,130	8,586	9.06	2.00
UBH-10	5.961	5.396	108	36	20,633	11,652	9.36	2.19
UBH-11	5.963	5.366	108	36	17,071	9,693	9.18	2.03
UBH-12	5.932	5.339	108	36	17,678	10,192	9.23	2.38
UBH-13	5.910	5.369	108	36	15,247	8,811	9.08	2.13
UBH-14	5.965	5.370	108	36	16,090	9,124	9.12	2.21
UBH-15	5.962	5.423	108	36	15,361	8,636	9.06	1.97
Total no. of observations						15	15	15
Mean						8,409	9.01	2.08
Maximum						11,652	9.36	2.38
Minimum						4,724	8.46	1.82
COV						0.210	0.026	0.067
K						1.991	1.991	
Lower tolerance limit (LTL)						4,896	5,178	
LTL/2.1						2,331	2,466	

[(a)] MOR includes beam weight.

Objective: Full-scale glulam beam tests
Material: 24F-V4 DF (P49 treated)
Test lab: FPL, Madison, WI
Referenced test methods: Four-point bending in accordance with ASTM D198
Test conditions: Standard condition after hygrothermal conditioning

#	h (in.)	b (in.)	L (in.)	a (in.)	P_{ult} (lbf)	MOR[(a)] (psi)	Lognormal MOR[(a)]	MOE (10^6 psi)
TBH-2	5.962	5.383	108	36	6,681	3,801	8.24	2.18
TBH-3	5.987	5.397	108	36	9,191	5,161	8.55	2.10
TBH-4	6.045	5.414	108	36	13,480	7,388	8.91	1.96
TBH-5	5.984	5.421	108	36	14,328	8,001	8.99	2.36
TBH-6	5.990	5.380	108	36	14,010	7,868	8.97	1.93
TBH-7	6.000	5.421	108	36	12,860	7,146	8.87	2.06
TBH-8	6.015	5.427	108	36	9,260	5,123	8.54	1.86
TBH-9	5.972	5.426	108	36	14,368	8,048	8.99	2.17
TBH-10	5.981	5.399	108	36	11,183	6,283	8.75	1.87
TBH-13	5.961	5.364	108	36	14,021	7,974	8.98	2.14
TBH-14	5.975	5.278	108	36	10,563	6,084	8.71	2.29
Total no. of observations						11	11	11
Mean						6,625	8.77	2.08
Maximum						8,048	8.99	2.36
Minimum						3,801	8.24	1.86
COV						0.218	0.028	0.079
K						2.073	2.073	
Lower tolerance limit (LTL)						3,626	3,896	
LTL/2.1						1,727	1,855	

[(a)] MOR includes beam weight.