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Advanced General Aviation Transport Experiments

B – Basis Design Allowables for Epoxy – Based Prepreg

Newport E-Glass Fabric 7781 / NB321

AGATE-WP3.3-033051-097

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1.0 INTRODUCTION

1.1 Scope

The Advanced General Aviation Transport Experiments (AGATE) consortium is an industry-university-government partnership initiated by NASA to create the technological basis for revitalization of the United States general aviation industry. It was founded in 1994 to develop affordable new technology as well as the industrial standards and certification methods for composite airframe, cockpit, flight systems and airspace infrastructure for Federal Aviation Regulations (FAR) Part 23 aircraft. The composite material properties contained within the document were generated under Work Package 3 : Integrated Design and Manufacturing Methods.

Although AGATE was focused towards the small general aviation aircraft (Part 23), the test methods and results contained in this document are consistent with MIL-HDBK-17-1E,2D,3E - Military Handbook for Polymer Matrix Composites. All material, specimens, fixtures and test results contained within this document were traceable and conformed by the Federal Aviation Administration (FAA) as part of the AGATE effort. It should be noted that before application of the basis values presented in this document to design, demonstration of the ability to consistently produce equivalent material properties as that evaluated during this program should be substantiated through an acceptable test program.

The test methods and results described in this document are intended to provide basic composite properties essential to most methods of analysis. These properties are considered to provide the initial base of the “building block” approach. Additional coupon level tests and subelement tests may be required to fully substantiate the full-scale design.

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1.2 Symbols Used

ν_{12}^{tu}	major Poisson's ratio, tension
$\mu\varepsilon$	micro-strain
E^{c}	compressive modulus, laminate
E^{t}	tensile modulus, laminate
F_{12}^{su}	in – plane shear strength
F_{13}^{su}	apparent interlaminar shear strength
F^{cu}	compressive strength, laminate
F^{tu}	tensile strength, laminate
G_{12}^{s}	in – plane shear modulus

Superscripts

c	compression
cu	compression ultimate
s	shear
su	shear ultimate
t	tension
tu	tension ultimate

Subscripts

12	in – plane shear
13	interlaminar shear (apparent)

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1.3 Acronyms and Definitions

A – Basis	95% lower confidence limit on the first population percentile
AGATE	Advanced General Aviation Transport Experiments
ASTM	American Society for Testing and Materials
B – Basis	95% lower confidence limit on the tenth population percentile
C. V.	coefficient of variation
CTD	cold temperature dry
CPT	cured ply thickness
DMA	dynamic mechanical analysis
dry	specimen tested with an “as fabricated” moisture content
ETD	elevated temperature dry
ETW	elevated temperature wet
FAR	Federal Aviation Regulations
FAW	fiber areal weight
Gl/Ep	glass/epoxy
NASA	National Aeronautics and Space Administration
RTD	room temperature dry
SACMA	Suppliers of Advanced Composite Materials Association
SRM	SACMA Recommended Method
T_g	glass transition temperature
t_{ply}	cured ply thickness
wet	specimen tested with an equilibrium moisture content per section 1.5.2

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1.4 References

ASTM Standards

D3039-95	Tensile Properties of Polymer Matrix Composite Materials
D5379-93	Shear Properties of Composite Materials by the V-Notched Beam Method
D2344-89	Apparent Interlaminar Shear Strength of Parallel Fiber Composites by Short – Beam Method
D792-91	Density and Specific Gravity (Relative Density) of Plastics by Displacement
D2584-94	Ignition Loss of Cured Reinforced Plastics
D2734-94	Void Content of Reinforced Plastics
D695-91	Compressive Properties of Rigid Plastics

SACMA Standards

SRM 1-94	Compressive Properties of Oriented Fiber-Resin Composites
SRM 8-94	Short Beam Shear Strength of Oriented Fiber-Resin Composites
SRM 18-94	Glass Transition Temperature (T_g) Determination by DMA of Oriented Fiber-Resin Composites

Other Documents

FAA Document DOT/FAA/AR-00/47: Material Qualification and Equivalency for Polymer Matrix Composite Material Systems, J.S. Tomblin, Y.C. Ng and K.S. Raju, 2001.

MIL-HDBK-17 1E, 2D, 3E – Military Handbook for Polymer Matrix Composites

PACUSA Lancair Document No: SX512110 Rev. A, Composite Fabrication of Epoxy Laminates and Assemblies

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1.5 Methodology

1.5.1 Test Matrix

Testing was performed according to the test methods delineated in the test matrix, with modifications as referenced in the AGATE report, *Material Qualification and Equivalency for Polymer Matrix Composite Material Systems*. The test matrix for properties included in this document is listed on the next page, with the following notation cited in each column:

 # x #

where the first # represents the required number of prepreg batches, defined as: Prepreg containing 7781 E-glass fabric from one mill roll, impregnated with one batch of resin in one continuous manufacturing operation with traceability to all components. The second # represents the required number of replicates per prepreg batch. For example, “3 x 6” refers to three prepreg batches of material and six specimens per prepreg batch for a total requirement of 18 test specimens.

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Table 1.5.1: Test Matrix and Standards Used

TEST	METHOD	NO. OF REPLICATES PER TEST CONDITION			
		CTD[1]	RTD[2]	ETW[3]	ETD[4]
Laminate Tension Strength	ASTM D3039-95	1x4	3x4	3x4	
LaminateTension Strength & Modulus,	ASTM D3039-95	1x2	3x2	3x2	
LaminateTension, Poisson's Ratio	ASTM D3039-95		3x1		
Laminate Compression Strength	SACMA SRM 1-94	1x6	3x6	3x6	3x6
Laminate Compression Modulus	SACMA SRM 1-94	1x2	3x2	3x2	
In-Plane Shear Strength	ASTM D5379-93	1x4	3x4	3x4	3x6
In-Plane Shear Modulus and Strength	ASTM D5379-93	1x2	3x2	3x2	
Short Beam Shear	ASTM D2344-89	1x6	3x6	3x6	3x6
Fiber Volume	ASTM D2584-94	One sample per panel			
Resin Volume	ASTM D2584-94	One sample per panel			
Void Content	ASTM D2734-94	One sample per panel			
Cured Neat Resin Density	---	Supplied by manufacturer for material			
Glass Transition Temperature	SACMA RM 18-94	6 dry, 6 wet			

Notes :

1 CTD: One prepreg lot of material tested (test temperature = -65 $\pm$ 5^{o} F, moisture content = as fabricated, soak time at –65 was 10 min.)

2 RTD: Three prepreg lots of material tested (test temperature = 70 $\pm$ 10^{o} F, moisture content = as fabricated)

3 ETW: Three prepreg lots of material tested (test temperature = 175 $\pm$ 5^{o} F, moisture content = equilibrium per section 1.5.2, soak time at 175 was 30-60 sec.)

4 ETD: Three prepreg lots of material tested (test temperature = 175 $\pm$ 5^{o} F, moisture content = as fabricated, soak time at 175 was 10 min.)

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1.5.2 Environmental Conditioning

All 'wet' conditioned samples were exposed to elevated temperature and humidity conditions to establish moisture saturation of the material. Specimens were exposed to 85 ± 5 % relative humidity and 145 ± 5 °F until an equilibrium moisture weight gain of traveler, or witness coupons (1" x 1" x specimen thickness) was achieved. ASTM D5229 and SACMA SRM 11 were used as guidelines for environmental conditioning and moisture absorption.

Effective moisture equilibrium was achieved when the average moisture content of the traveler specimen changed by less than 0.05% for two consecutive readings within a span of 7 ± 0.5 days and was expressed by:

$$\frac{W_i - W_{i-1}}{W_b} < 0.0005$$

where W_i = weight at current time
W_{i-1} = weight at previous time
W_b = baseline weight prior to conditioning

It is common to see small fluctuations in an unfitted plot of the weight gain vs. time curve. There were no fluctuations that made significant errors in results or caused rejection in the moisture equilibrium criteria. Once the traveler coupons passed the criteria for two consecutive readings, the samples were removed from the environmental chamber and placed in a sealed bag with a moist paper or cotton towel for a maximum of 14 days until mechanical testing. Strain gauged specimens were removed from the controlled environment for a maximum of 2 hours for application of gages in ambient laboratory conditions.

1.5.3 Normalization Procedures

The normalization procedure attempts to reduce variability in fiber-dominated material properties by adjusting raw test values to a specified fiber volume content. Only the following properties were normalized:

- Laminate Tensile Strength and Modulus
- Laminate Compression Strength and Modulus

The normalization procedure was adopted from MIL-HDBK-17-1E, section 2.4.3.3. The procedure which was used to normalize the data is based on two primary assumptions:

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- The relationship between fiber volume fraction and ultimate laminate strength is linear over the entire range of fiber/resin ratios. (It neglects the effects of resin starvation at high fiber contents.)

- Fiber volume is not commonly measured for each test sample, so this method accounts for the fiber volume variation between individual test specimens by utilizing a relationship between fiber volume fraction and laminate cured ply thickness. This relationship is virtually linear in the 0.45 to 0.65 fiber volume fraction range.

Additional information is detailed in FAA Document DOT/FAA/AR-00/47: Material Qualification and Equivalency for Polymer Matrix Composite Material Systems. For all normalized data contained in this document, the test values are normalized by cured ply thickness according to:

$$Normalized\ \ Value = Test\ Value \times \frac{CPT_{specimen}}{CPT_{normalizing}}$$

where:

$$CPT_{specimen} = \frac{Average\ \ Sample\ Thickness}{\#\ of\ \ plies}$$

1.5.4 Statistical Analysis

When compared to metallic materials, fiber reinforced composite materials exhibit a high degree of material property variability. This variability is due to many factors, including but not limited to: raw material and prepreg manufacture, material handling, part fabrication techniques, ply stacking sequence, environmental conditions, and testing techniques. This inherent variability drives up the cost of composite testing and tends to render smaller data sets than those produced for metallic materials. This necessitates the usage of statistical techniques for determining reasonable design allowables for composites.

The analyses and design allowable generation for both A and B basis values were performed using the procedure detailed in section 5.3 of FAA Document DOT/FAA/AR-00/47: Material Qualification and Equivalency for Polymer Matrix Composite Material Systems.

1.5.5 Material Performance Envelope and Interpolation

Using the B-basis numbers, a material performance envelope may be generated for the material system by plotting these values as a function of temperature. Figure 1.5.1 shows an example material performance envelope using B-basis values.

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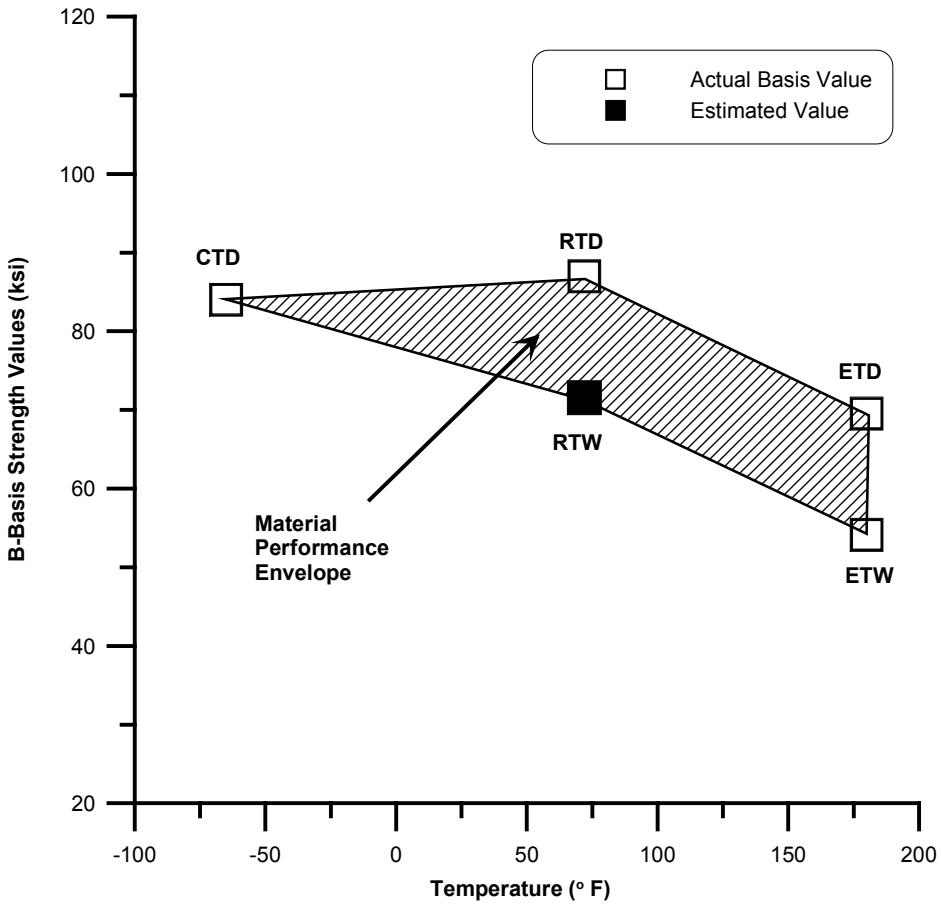

Figure 1.5.1 Material performance envelope.

Since each specific aircraft application of the qualified material may have different Material Operational Limits (MOL) than those tested in the material qualification (which is usually the upper limit), some applications may require a reduced MOL. In this case, simple linear interpolation may be used to obtain the corresponding basis values at the new application MOL.

This interpolation may be accomplished using the following simple relationships assuming $T_{RTD} < T_{MOL} < T_{ETD}$:

For the corresponding MOL "dry" basis value, the "interpolated" basis value using the qualification data is

$$B_{MOL} = B_{RTD} - \frac{(B_{RTD} - B_{ETD})(T_{RTD} - T_{MOL})}{(T_{RTD} - T_{ETD})}$$

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where B_{MOL} = new application basis value interpolated to T_{MOL}
B_{RTD} = basis RTD strength value
B_{ETD} = basis ETD strength value
T_{RTD} = RTD test temperature
T_{ETD} = ETD test temperature
T_{MOL} = new application MOL temperature

For the corresponding MOL "wet" basis value, an estimated Room Temperature Wet (RTW) value must be calculated. This may be accomplished by the simple relation

$$B_{RTW} = B_{RTD} - (B_{ETD} - B_{ETW})$$

The "interpolated" wet basis value using the qualification data may then be obtained by

$$B_{MOL} = B_{RTW} - \frac{(B_{RTW} - B_{ETW})(T_{RTW} - T_{MOL})}{(T_{RTW} - T_{ETW})}$$

where: B_{MOL} = new application basis value interpolated to T_{MOL}
B_{RTW} = estimated basis RTW strength value
B_{ETW} = basis ETW strength value
T_{RTW} = RTW (i.e., RTD) test temperature
T_{ETW} = ETW test temperature
T_{MOL} = new application MOL temperature

These equations may also be used for interpolated mean strengths as well as A-basis values with the appropriate substitutions. It should be noted that because unforeseen material property drop-offs with respect to temperature and environment can occur, *extrapolation* to a higher MOL should not be attempted without additional testing and verification. In addition, the interpolation equations shown above are practical for materials obeying *typical* mechanical behavior. In most cases, some minimal amount of testing may also be required to verify the interpolated values.

1.5.5.1 Interpolation Example

This section provides an example of linear interpolations to a specific application environment less than the tested upper material limit used in qualification. Assuming a specific application environment of 150° F, Figure 1.5.2 depicts the linear interpolation of the B-basis design allowable to this environment. Using the above equations along with

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the nominal testing temperatures (see Table 1.5.1), the interpolated basis values at 150° F become

ETD : B_{MOL} = 75.106 ksi

ETW : B_{MOL} = 59.746 ksi

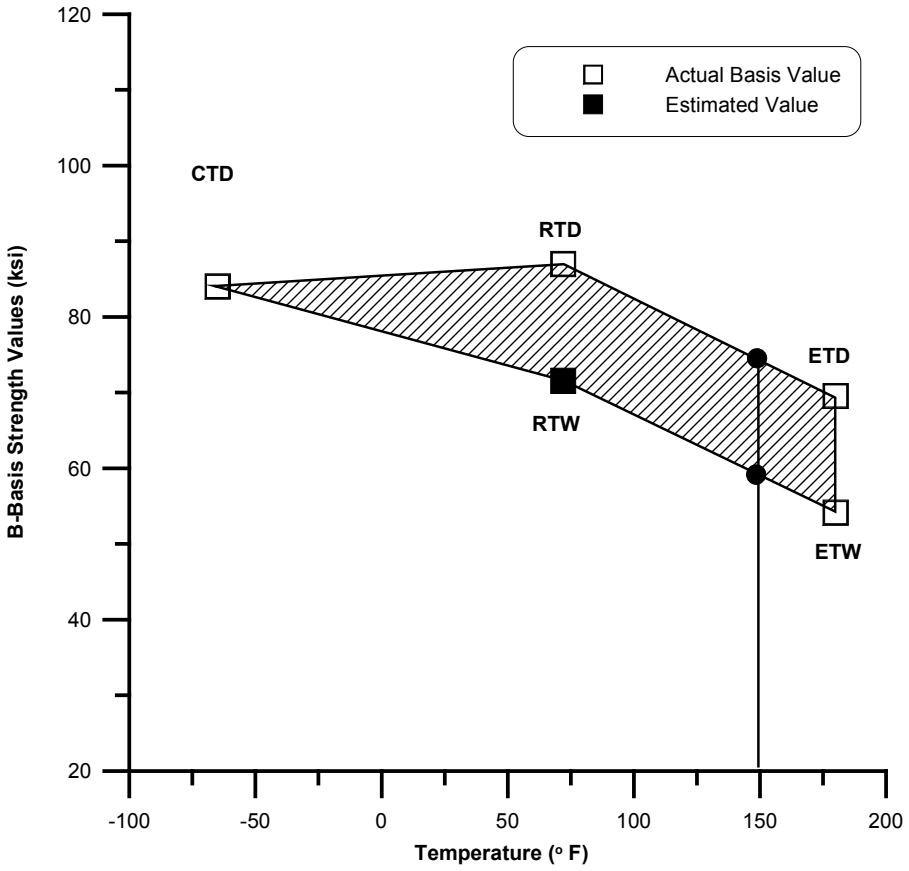

Figure 1.5.2 Example of 150° F interpolation for B-basis values.

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2.0 NEWPORT 7781 E-GLASS / NB321 PREPREG PROPERTIES

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2.1 Prepreg Documentation by Prepreg Lot

Prepreg Documentation	**Prepreg Manufacturer & Product ID: Newport NB321-7781** **Impregnation Method: Hot Melt - Direct Coating**		
Prepreg Batch or Lot #	4612A	4632A	5318B
Batch # as labeled on specimens[1]	2	3	4
Date of Manufacture	7/25/96	8/2/96	6/12/97
Expiration Date	1/29/97	2/5/97	12/17/97
Resin Content [%]	38±3%		
Reinforcement Areal Weight & Test Method	0.062 PSF NACTM 013		
Resin Flow & Test Conditions	23.1% 275°F/25 PSI	21.40% 275°F/25 PSI	21.7% 275°F/25 PSI
Gel Time & Test Conditions	7'10" @ 275°F	7'16" @ 275°F	8'22" @ 275°F
Volatile Content	Not Tested (less than 0.5% typical)		
Reinforcement Documentation	**Fiber/Fabric Manufacturer & Product ID: BFG IND. 7781** **Precursor Type: silica sand, limestone, clay (molten glass)** **Finish/Sizing Type and %: 0.10% 497A sizing** **Nominal tow or yarn count/inch: 59.0 X 54.0** **Twist:2 twist yarn**		
Fabric Batch or Lot #	835216-40-4	836118-50-01	838780-30-5
Date of Manufacture	2/5/96	2/21/96	5/14/97
Average Fiber Density per Lot & Test Method	2.54 g/cc ASTM D792		
Matrix Documentation	**Resin Manufacturer & Product ID: Newport NB321**		
Matrix Batch or Lot #	4612A	4632A	5318B
Date of Manufacture	7/25/96	8/2/96	6/12/97
Average Neat Resin Density by Lot & Test Method	1.20 g/cc ASTM D792		

[1] NOTE: No specimens were labeled as Batch #1 since this was an experimental lot of prepreg and thus not included in the data set.

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2.2 Process Specification

This specification does not address issues relating to safety, quality control, bagging material selection, bagging procedure, tool preparation, or equipment selection. Although these may affect overall part quality, it is the responsibility of the end user to develop procedures related to these issues in a manner that produces parts with high quality and consistency.

The following oven cure procedures are excerpts from PAC USA Lancair SX512110 Rev. A, *Composite Fabrication of Epoxy Laminates and Assemblies*. All test specimens were cured per this specification by Pacific Aviation Composites. However, the effects of the upper and lower limits of vacuum, temperature, cure time, heat-up rate and hold temperature on the mechanical and thermal properties have not been investigated.

Prior to Cure

- Woven fabric orientation angle shall be within ±10° of the specified orientation.
- At least two vacuum connections shall be used for any part larger than 4 square feet. For larger parts, at least one vacuum connection shall be provided for every 18 square feet of laminate surface.
- Allow the bagged assembly to stand for at least 15 minutes with an applied vacuum of at least 22” Hg. Before placing a bagged assembly in the oven, apply at least 22” Hg vacuum and check for bag leaks. Bag leaks greater than 3.0” Hg during 5 minutes shall be corrected. If correction procedures are unsuccessful in eliminating the leak, the entire bag shall be re-bagged and the new bag shall be checked for leaks.

Oven Cure Procedure

- Install the bagged assembly in a cool oven (temperatures less than 100° F). Connect the calibrated thermocouples to the parts, allowing at least one thermocouple per part.
- Cure all prepreg parts as follows:

    1. Heat the part to 270±10° F at a rate of 1 to 6° F per minute based upon the part thermocouple reading. The part must reach 270±10° F in 60 to 180 minutes. At least 22” Hg vacuum shall be maintained throughout the heat up, hold, and cool down to 170° F.
    2. Hold at 270±10° F for 100±10 minutes. The hold period begins when the lowest part thermocouple reaches 260° F.
    3. When multiple parts are cured in the same oven load, the part thermocouple showing the slowest temperature heat-up rate in the load shall be used to determine the start of the 270° F hold period.
    4. Cool the part to below 170°F at a rate not to exceed 10° F per minute as measured on the part thermocouple while maintaining full vacuum.

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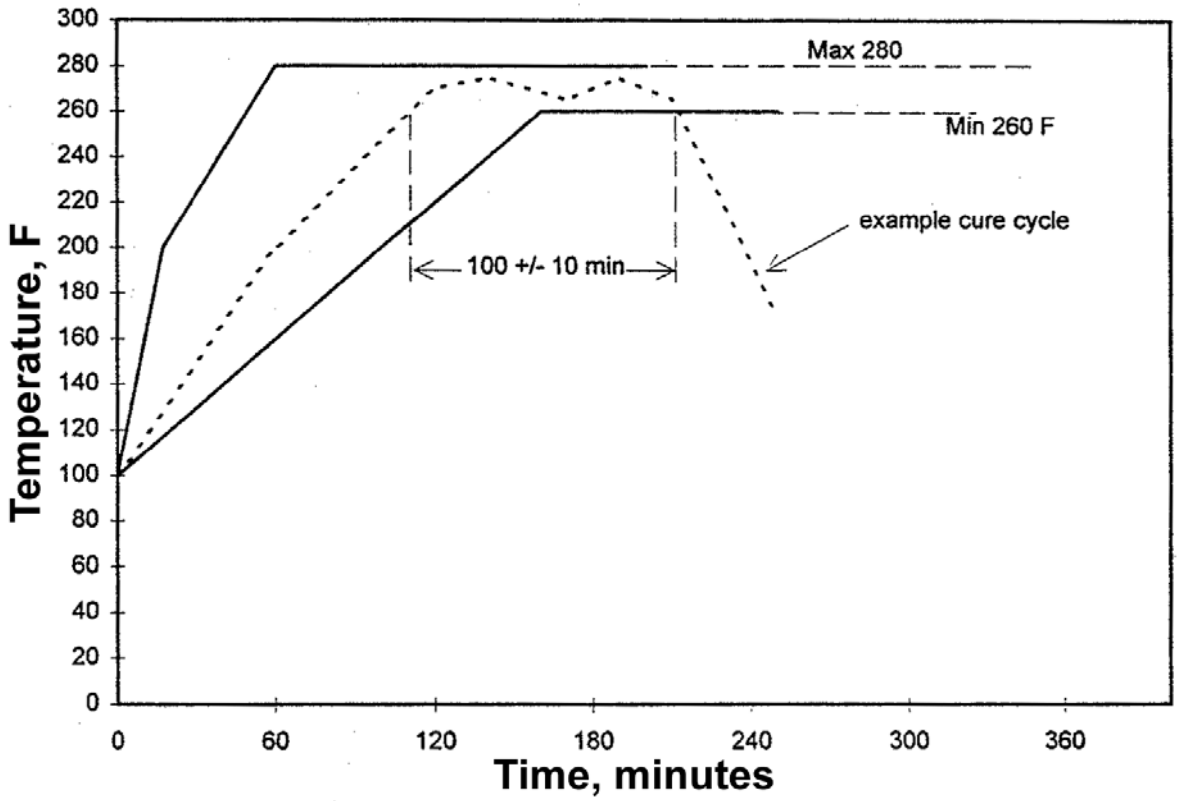

Figure 2.2: Sample prepreg cure cycle for NB 321/7781 E-glass.
Figure courtesy of Pacific Aviation Composites, USA LLC.

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3.0 NEWPORT 7781 E-GLASS / NB321 LAMINATE PROPERTIES

NOTE: The mechanical properties included in this document are representative only of the lay-up schedule used for the test laminates (which include combinations of both 0° and 90° plies), and thus do not represent the true lamina properties of the prepreg. Therefore, the term laminate is used throughout the document for clarity.

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3.1 Test Results

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3.1.1 Summary

MATERIAL:	NB321/7781 E-Glass Cloth	**NB321/7781 Summary**
PREPREG:	Newport NB321/7781 E-Glass Cloth, 497A Finish	
FIBER:	BGF 7781	**RESIN:** Newport NB321
T_g (dry): 250.5 °F	**T_g (wet):** 223.2 °F	**T_g METHOD:** DMA (SRM 18-94)
PROCESSING:	Vacuum bag cure (22+ in. Hg.): 270 ± 10°F for 100 ± 10 min.	

Date of fiber manufacture	2/96 -- 5/97	**Date of testing**	10/97 -- 4/98
Date of resin manufacture	7/96 – 6/97	**Date of data submittal**	5/98
Date of prepreg manufacture	7/96 -- 6/97	**Date of analysis**	10/97 – 4/98
Date of composite manufacture	7/97 – 10/97		

LAMINATE MECHANICAL PROPERTY SUMMARY
Data Reported as: Measured
(Normalized by CPT=0.0098 in)

	CTD		RTD		ETD		ETW	
	B-Basis	**Mean**	**B-Basis**	**Mean**	**B-Basis**	**Mean**	**B-Basis**	**Mean**
F^{tu} (ksi)	51.90 (54.63)	65.40 (64.57)	52.25 (53.86)	63.57 (62.10)	---	---	34.98 (36.76)	42.56 (42.39)
E^{t} (Msi)	---	4.06 (4.01)	---	4.19 (4.08)	---	---	---	3.40 (3.39)
ν_{12}^{t}	---	0.155	---	0.138	---	---	---	---
F^{cu} (ksi)	84.38 (85.14)	96.79 (97.31)	69.66 (69.79)	78.26 (78.17)	59.38 (59.58)	66.75 (66.77)	49.93 (49.84)	56.09 (55.82)
E^{c} (Msi)	---	3.99 (3.94)	---	3.90 (3.88)	---	---	---	3.84 (3.81)
F_{12}^{su} (ksi)	20.52	23.35	17.09	19.10	14.46	16.15	11.51	12.86
G_{12}^{s} (Msi)	---	0.72	---	0.61	---	---	---	0.40
F_{13}^{su**} (ksi)	---	---	8.65	9.37	---	---	---	---

** *Apparent* interlaminar shear strength

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3.1.2 Individual Test Summaries

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3.1.2.1 Tension, Laminate

Tension, Laminate
GI/Ep
Newport NB321/7781
[0_f/90_f/0_f/90_f/0_f/90_f/0_f/90_f/0_f]

Material: Newport NB321/7781 E-glass cloth

Resin content: 32 - 36 wt. %
Fiber volume: 44 - 49 %
Ply thickness: 0.0091 - 0.0103 in.
Ply range: 9 ply

Comp. density: 1.74 - 1.86 g/cc
Void content: 0.4 - 4.8 %

Test method: D3039-95

Modulus calculation: linear fit from 1000 - 3000 με

Normalized by: 0.0098 in. ply thickness

		CTD		RTD		ETD		ETW					
Test Temperature [°F]		-65		70				175					
Moisture Conditioning		dry		dry				equilibrium					
Equilibrium at T, RH		as fabricated		as fabricated				145 F, 85 %					
Source code		MBJXXXXB		MBJXXXXA				MBJXXXXC					
		Normalized	**Measured**	**Normalized**	**Measured**	**Normalized**	**Measured**	**Normalized**	**Measured**	**Normalized**	**Measured**	**Normalized**	**Measured**
	Mean	64.57	65.40	62.10	63.57			42.39	42.56				
	Minimum	59.94	60.26	56.40	55.96			37.56	36.60				
	Maximum	69.69	70.35	69.54	73.30			48.50	51.16				
	C.V.(%)	5.75	5.75	7.06	9.28			8.64	12.04				
F^{tu} (ksi)	**B-value**	54.63	51.90	53.86	52.25			36.76	34.98				
	A-value	49.00	44.25	48.26	44.56			32.94	29.83				
	No. Specimens	6		20				20					
	No. Prepreg Lots	1		3				3					
E^t (Msi)	**Mean**	4.01	4.06	4.08	4.19			3.39	3.40				
	Minimum	3.99	4.05	3.42	3.43			3.18	3.02				
	Maximum	4.03	4.07	4.37	4.69			3.66	3.74				
	C.V.(%)	0.76	0.20	8.73	9.83			4.00	7.33				
	No. Specimens	2		12				12					
	No. Prepreg Lots	1		3				3					
ν_{12}^t	**Mean**		0.155		0.138								
	No. Specimens	2		4									
	No. Prepreg Lots	1		3									

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3.1.2.2 Compression, Laminate

Compression,Laminate
Gl/Ep
Newport NB321/7781
$[0_f/90_f]_{3S}$

Material: Newport NB321/7781 E-glass cloth

Resin content: 34 - 36 wt. %
Fiber volume: 47 - 48 %
Ply thickness: 0.0095 - 0.0104 in.
Ply range: 12 ply

Comp. density: 1.83 - 1.86 g/cc
Void content: 0.0 - 0.3 %

Test method: SRM 1-94, D695-91 (mod)

Modulus calculation: linear fit from 1000 - 3000 με

Normalized by: 0.0098 in. ply thickness

		CTD		RTD		ETD		ETW					
Test Temperature [°F]		-65		70		175		175					
Moisture Conditioning		dry		dry		dry		equilibrium					
Equilibrium at T, RH		as fabricated		as fabricated		as fabricated		145 F, 85 %					
Source code		MBKXXXXB		MBKXXXXA		MBKXXXXE		MBKXXXXC					
		Normalized	**Measured**	**Normalized**	**Measured**	**Normalized**	**Measured**	**Normalized**	**Measured**	**Normalized**	**Measured**	**Normalized**	**Measured**
F^{cu} (ksi)	**Mean**	97.31	96.79	78.17	78.26	66.77	66.75	55.82	56.09				
	Minimum	94.63	93.40	68.42	69.45	58.72	59.92	48.72	48.03				
	Maximum	101.13	99.34	86.80	86.69	72.96	72.86	63.24	64.11				
	C.V.(%)	2.67	2.23	5.26	4.74	6.45	5.94	7.73	8.84				
	B-value	85.14	84.38	69.79	69.66	59.58	59.38	49.84	49.93				
	A-value	78.36	77.46	64.18	63.90	54.79	54.47	45.83	45.80				
	No. Specimens	6		20		19		20					
	No. Prepreg Lots	1		3		3		3					
E^c (Msi)	**Mean**	3.94	3.99	3.88	3.90			3.81	3.84				
	Minimum	3.88	3.93	3.48	3.53			3.39	3.44				
	Maximum	4.01	4.04	4.09	4.24			3.98	4.06				
	C.V.(%)	2.34	1.93	5.64	6.19			5.71	5.86				
	No. Specimens	2		6				6					
	No. Prepreg Lots	1		3				3					

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3.1.2.3 Shear, 12 axis

Shear, 12-axis
GI/Ep
Newport NB321/7781
$[(0_f/90_f)_2/0_f]_S$

Material: Newport NB321/7781 E-glass cloth

Resin content: 33 - 36 wt. %
Fiber volume: 45 - 50 %
Ply thickness: 0.0091 - 0.0105 in.
Ply range: 10 ply

Comp. density: 1.81 - 1.89 g/cc
Void content: 0.0 - 0.8 %

Test method: D5379-93

Modulus calculation: linear fit from 1000 - 6000 με

Normalized by: N/A

		CTD		RTD		ETD		ETW					
Test Temperature [°F]		-65		70		175		175					
Moisture Conditioning		dry		dry		dry		equilibrium					
Equilibrium at T, RH		as fabricated		as fabricated		as fabricated		145 F ,85 %					
Source code		MBNXXXXB		MBNXXXXA		MBNXXXXE		MBNXXXXC					
		Normalized	**Measured**	**Normalized**	**Measured**	**Normalized**	**Measured**	**Normalized**	**Measured**			**Normalized**	**Measured**
F_{12}^{su} (ksi)	**Mean**		23.35		19.10		16.15		12.86				
	Minimum		21.44		17.42		14.07		11.40				
	Maximum		26.55		20.28		17.39		14.74				
	C.V.(%)		7.81		3.80		5.44		7.94				
	B-value		20.52		17.09		14.46		11.51				
	A-value		18.93		15.76		13.33		10.61				
	No. Specimens	6		18		19		18					
	No. Prepreg Lots	1		3		3		3					
G_{12}^{s} (Msi)	**Mean**		0.72		0.61				0.40				
	Minimum		0.67		0.53				0.31				
	Maximum		0.76		0.73				0.50				
	C.V.(%)		8.61		13.09				16.24				
	No. Specimens	2		6				6					
	No. Prepreg Lots	1		3				3					

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3.1.2.4 Shear, 13 axis

Shear, 13-axis
GI/Ep
Newport NB321/7781
[$0_f/90_f/0_f/90_f/0_f/90_f/0_f/90_f/0_f$]

Material:	Newport NB321/7781 E-glass cloth			
Resin content:	33 - 36 wt. %	**Comp. density:**	1.79 - 1.88 g/cc	
Fiber volume:	47 - 50 %	**Void content:**	0.0 - 4.0 %	
Ply thickness:	0.0091 - 0.0095 in.			
Ply range:	9 ply			
Test method:	D2344-89	**Modulus calculation:**	N/A	
Normalized by:	N/A			

		RTD									
Test Temperature [°F]		70									
Moisture Conditioning		dry									
Equilibrium at T, RH		as fabricated									
Source code		MBQXXXXA									
		Normalized	**Measured**					**Normalized**	**Measured**	**Normalized**	**Measured**
	Mean		9.37								
	Minimum		8.68								
	Maximum		9.94								
	C.V.(%)		3.96								
F_{13}^{su} (ksi)	**B-value**		8.65								
	A-value		8.14								
	No. Specimens		20								
	No. Pregpreg Lots		3								

NOTES: These values represent the apparent interlaminar shear properties and are to be used for quality control purposes only. Do not use these values for interlaminar shear strength design values.

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3.1.3 Individual Test Charts

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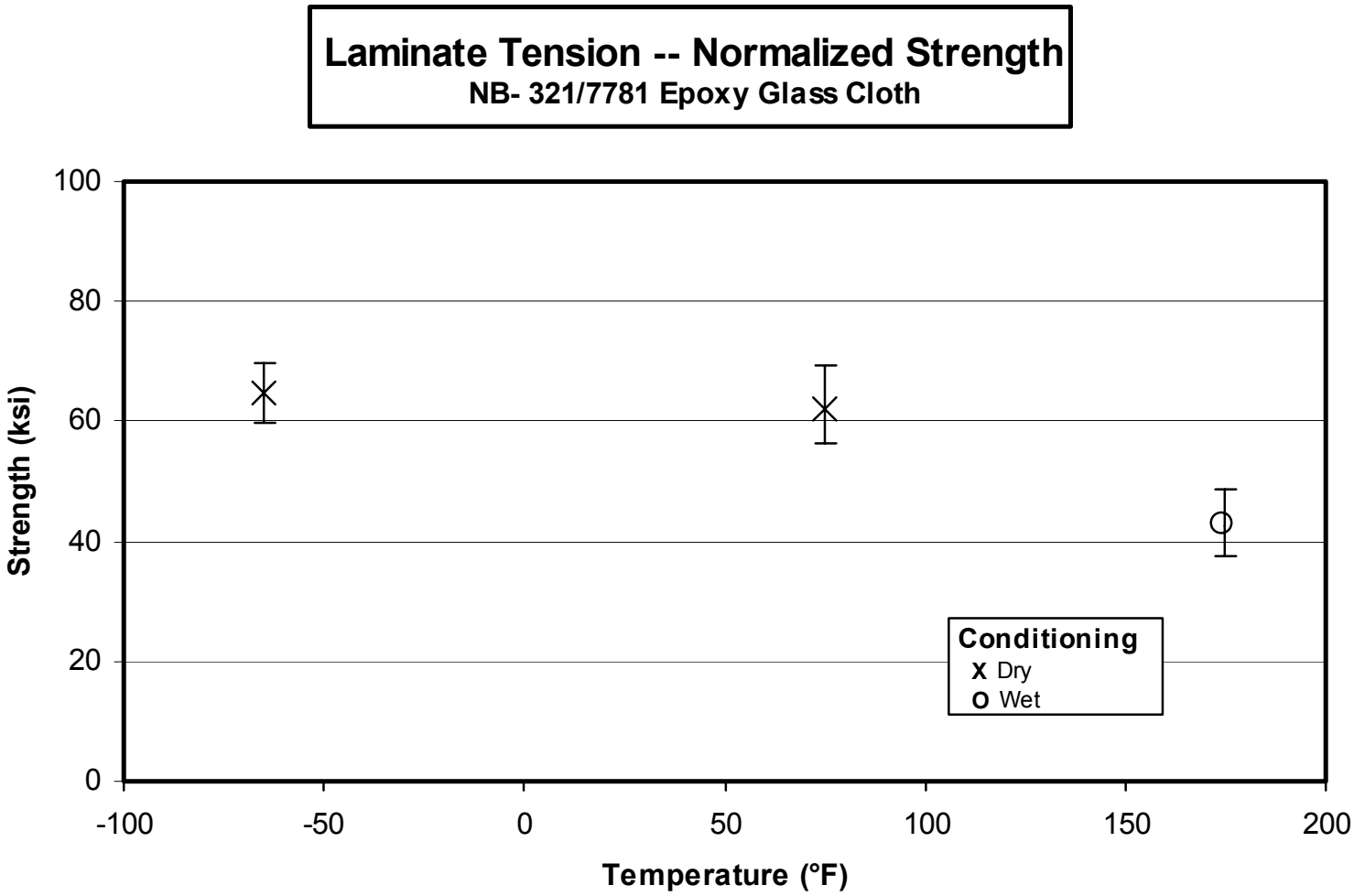
3.1.3.1 Tension, Laminate



NOTE: The symbols represent the 'pooled' average of all tests, and the bars represent the upper and lower limit of the data.

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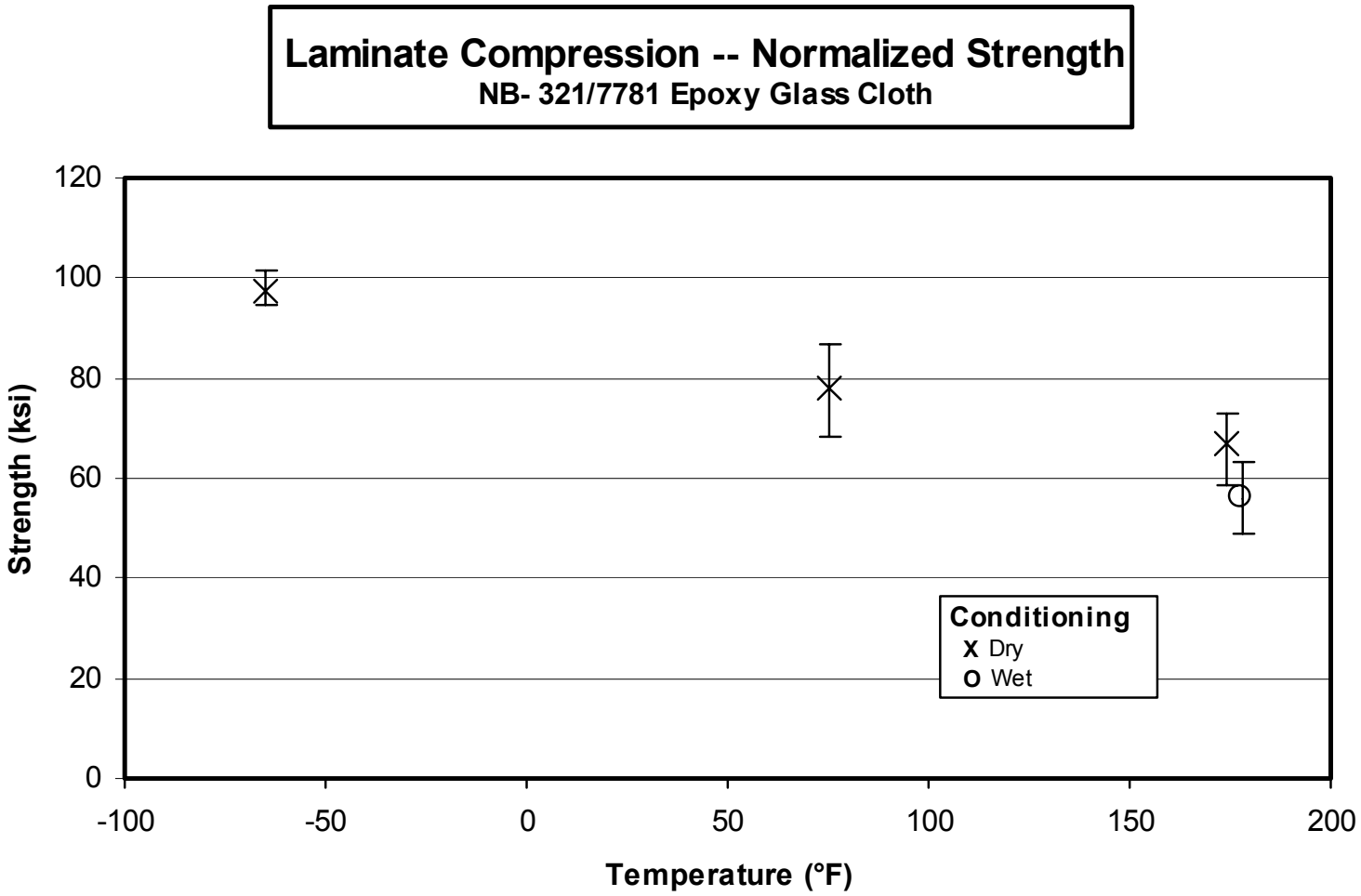
3.1.3.2 Compression, Laminate



NOTE: The symbols represent the 'pooled' average of all tests, and the bars represent the upper and lower limit of the data. The 175° dry and wet data has been staggered for clarity.

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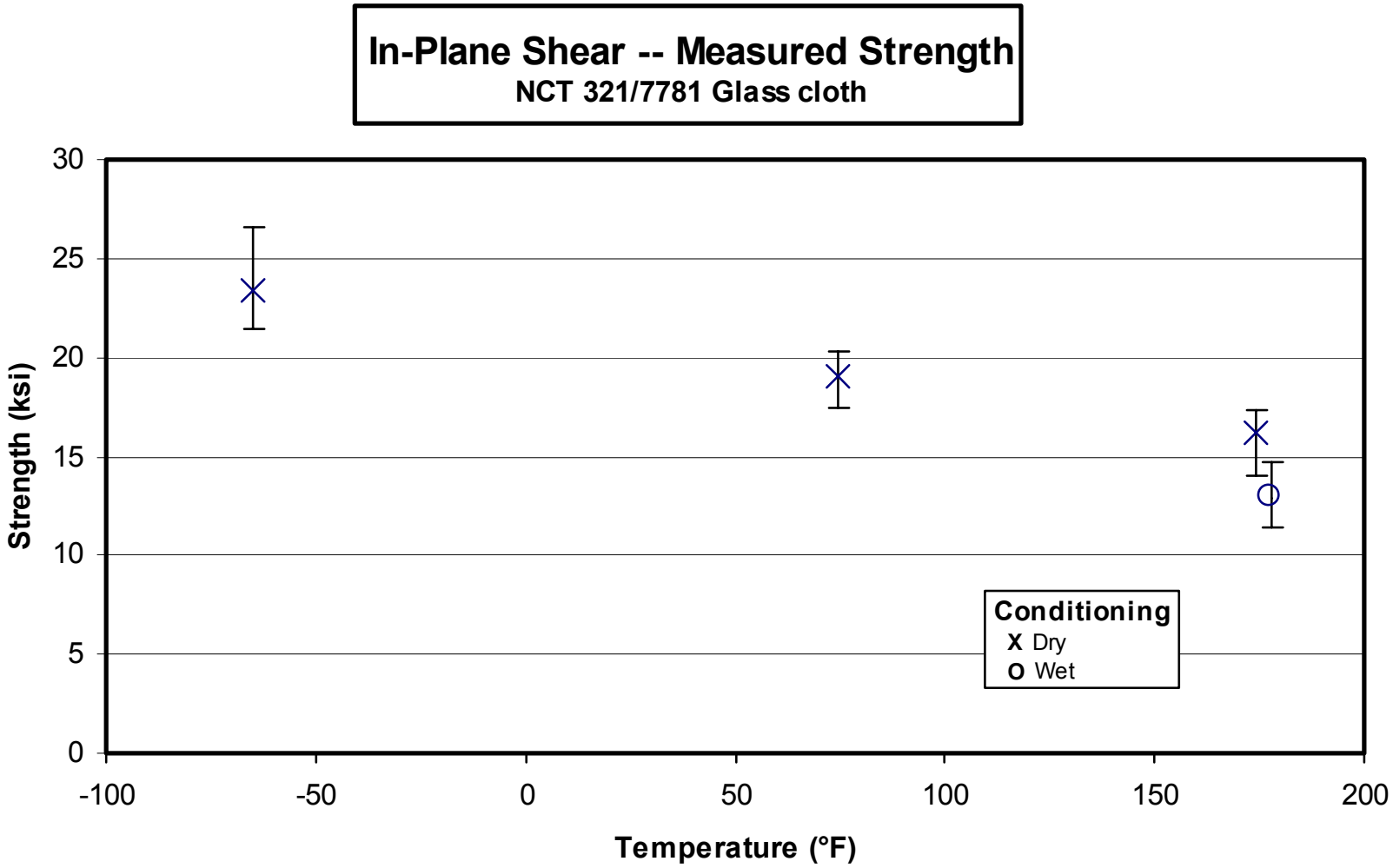
3.1.3.3 Shear, 12 axis



NOTE: The symbols represent the 'pooled' average of all tests, and the bars represent the upper and lower limit of the data. The 175° dry and wet data has been staggered for clarity.

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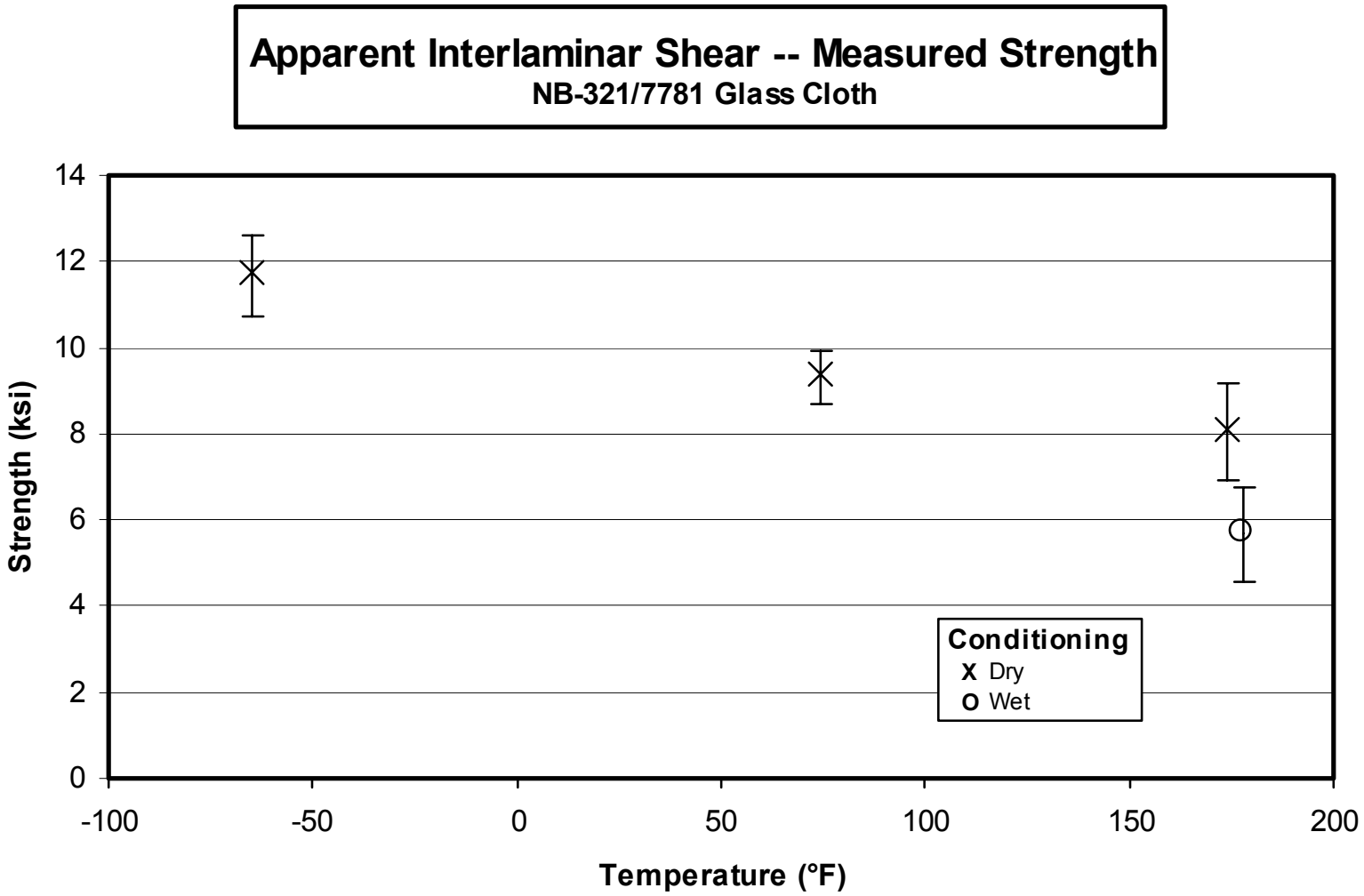
3.1.3.4 Shear, 13 axis



NOTE: The symbols represent the 'pooled' average of all tests, and the bars represent the upper and lower limit of the data. The 175° dry and wet data has been staggered for clarity.

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3.2 Raw Data

Specimen Naming Convention

Test coupons were identified using an eight-digit specimen code, with the significance of each digit delineated below. A representative sample ID is shown for reference purposes.

M B J 2 1 2 5 C

1st Character: Fabricator
'M' designates Lancair

2nd Character: Material System
'B' designates 7781 E-glass / NB 321

3rd Character: Test Type
'J' designates Laminate Tension Strength and Modulus, other test types will be clearly labeled at the top of each sheet

4th Character: Prepreg Batch ID
See Table 2.1 for Newport Batch ID / Sample Batch ID correlation.

5th Character: Panel Number
The panel(s) fabricated for a specific test method.

6th Character: Subpanel Number
The sub-panel(s) cut from each panel, with subpanel numbers labeled increasing from reference edge.

7th Character: Sample Number
The sample(s) cut from each subpanel, with sample numbers labeled increasing from reference edge.

8th Character: Test Condition
'A' --- RTD
'B' --- CTD
'C' --- ETW
'E' --- ETD
See Table 1.5.1 for condition parameters.

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3.2.1 Raw Data Spreadsheets and Scatter Charts

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Laminate Tension -- (RTD)
Strength & Modulus
NB-321/7781 Epoxy Glass Cloth

normalizing t_{ply} [in]: 0.0098

Specimen Number	Strength [ksi]	Modulus [Msi]	Poisson's Ratio	Batch Number	Avg. Specimen Thickn. [in]	# Plies in Laminate	Avg. t_{ply} [in]	$Strength_{norm}$ [ksi]	$Modulus_{norm}$ [Msi]
MBJ23A1A	70.391	4.689		2	0.082	9	0.0091	65.376	4.355
MBJ23A2A	69.714	4.585		2	0.083	9	0.0092	65.710	4.322
MBJ23A3A	67.467	4.515		2	0.084	9	0.0093	64.051	4.286
MBJ23A4A	66.059	4.295		2	0.084	9	0.0094	63.126	4.104
MBJ21A5A	73.300			2	0.083	9	0.0092	69.020	
MBJ21A6A	73.143			2	0.084	9	0.0093	69.536	
MBJ21A7A	71.047	3.929	0.138	2	0.084	9	0.0093	67.301	3.722
MBJ32A5A	64.386	4.377		3	0.088	9	0.0098	64.130	4.360
MBJ32A6A	57.971	4.365		3	0.087	9	0.0097	57.369	4.319
MBJ32A7A	58.451	4.464		3	0.086	9	0.0096	57.203	4.369
MBJ33A3A	58.147	4.300		3	0.089	9	0.0099	58.762	4.345
MBJ33A4A	66.205			3	0.087	9	0.0097	65.304	
MBJ33A5A	66.047			3	0.088	9	0.0098	65.972	
MBJ33A1A	61.222	3.708	0.147	3	0.088	9	0.0098	61.153	3.704
MBJ4121A	58.878	3.431	0.128	4	0.088	9	0.0098	58.678	3.419
MBJ4122A	56.677	3.628	0.138	4	0.088	9	0.0098	56.399	3.610
MBJ4132A	57.380			4	0.088	9	0.0098	57.260	
MBJ4134A	61.195			4	0.089	9	0.0098	61.449	
MBJ4135A	57.661			4	0.088	9	0.0098	57.584	
MBJ4136A	55.955			4	0.089	9	0.0099	56.653	

Average	**63.565**	**4.191**	**0.138**	**$Average_{norm}$**	**0.0096**	**62.102**	**4.076**
Standard Dev.	**5.896**	**0.412**	**0.008**	**$Standard\ Dev._{norm}$**		**4.382**	**0.356**
Coeff. of Var. [%]	**9.276**	**9.830**	**5.600**	**$Coeff.\ of\ Var.\ [\%]_{norm}$**		**7.055**	**8.729**
Min. Value	**55.955**	**3.431**	**0.128**	**$Min.\ Value_{norm}$**	**0.0091**	**56.399**	**3.419**
Max. Value	**73.300**	**4.689**	**0.147**	**$Max.\ Value_{norm}$**	**0.0099**	**69.536**	**4.369**
Number	**20**	**12**	**4**	**$Number_{norm}$**		**20**	**12**

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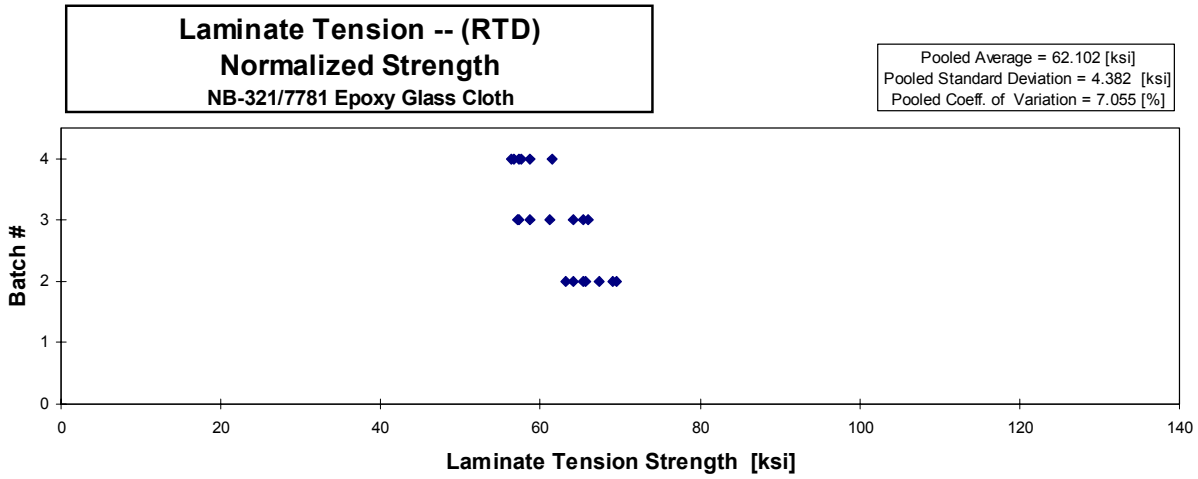

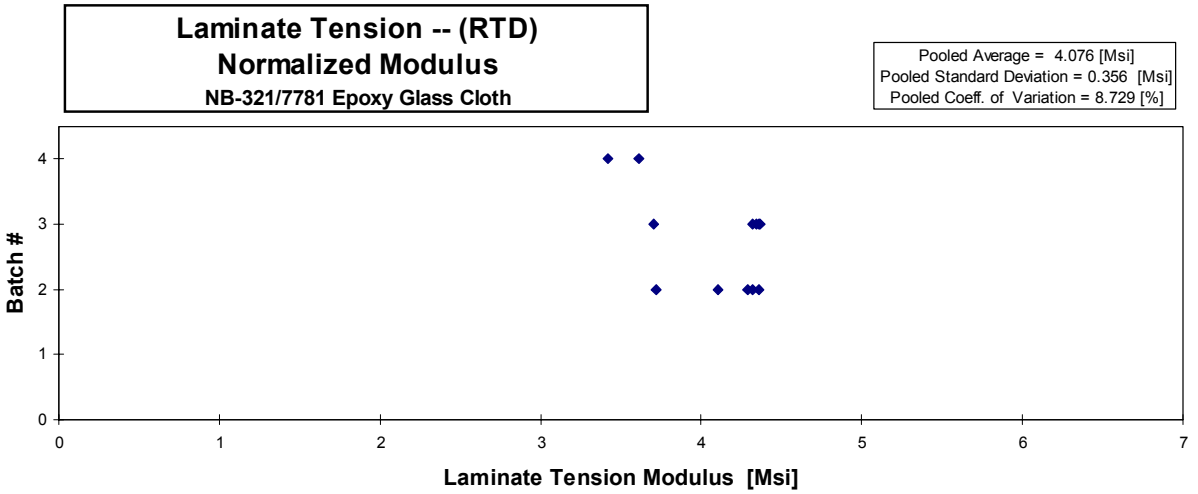

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Laminate Tension -- (CTD)
Strength & Modulus
NB-321/7781 Epoxy Glass Cloth

normalizing t_{ply} [in]: 0.0098

Specimen Number	Strength [ksi]	Modulus [Msi]	Poisson's Ratio	Batch Number	Avg. Specimen Thickn. [in]	# Plies in Laminate	Avg. t_{ply} [in]	$Strength_{norm}$ [ksi]	$Modulus_{norm}$ [Msi]
MBJ3211B	65.366	4.066	0.161	3	0.087	9	0.0096	64.143	3.990
MBJ3212B	60.259	4.054	0.149	3	0.088	9	0.0097	59.941	4.033
MBJ3213B	64.698			3	0.087	9	0.0096	63.500	
MBJ3214B	62.792			3	0.087	9	0.0097	61.938	
MBJ3215B	70.345			3	0.087	9	0.0097	69.694	
MBJ3216B	68.931			3	0.087	9	0.0097	68.176	

Average	**65.399**	**4.060**	**0.155**	**$Average_{norm}$**	**0.00968**	**64.565**	**4.011**
Standard Dev.	**3.759**	**0.008**	**0.009**	**Standard $Dev._{norm}$**		**3.713**	**0.030**
Coeff. of Var. [%]	**5.747**	**0.203**	**5.668**	**Coeff. of Var. $[\%]_{norm}$**		**5.751**	**0.757**
Min. Value	**60.259**	**4.054**	**0.149**	**Min. $Value_{norm}$**	**0.0096**	**59.941**	**3.990**
Max. Value	**70.345**	**4.066**	**0.161**	**Max. $Value_{norm}$**	**0.0097**	**69.694**	**4.033**
Number	**6**	**2**	**2**	**$Number_{norm}$**		**6**	**2**

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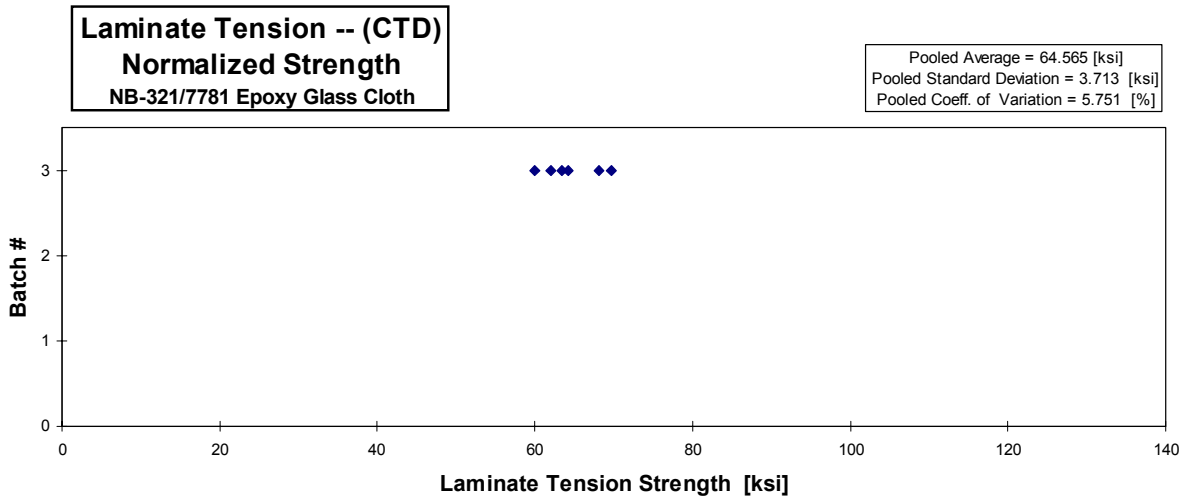

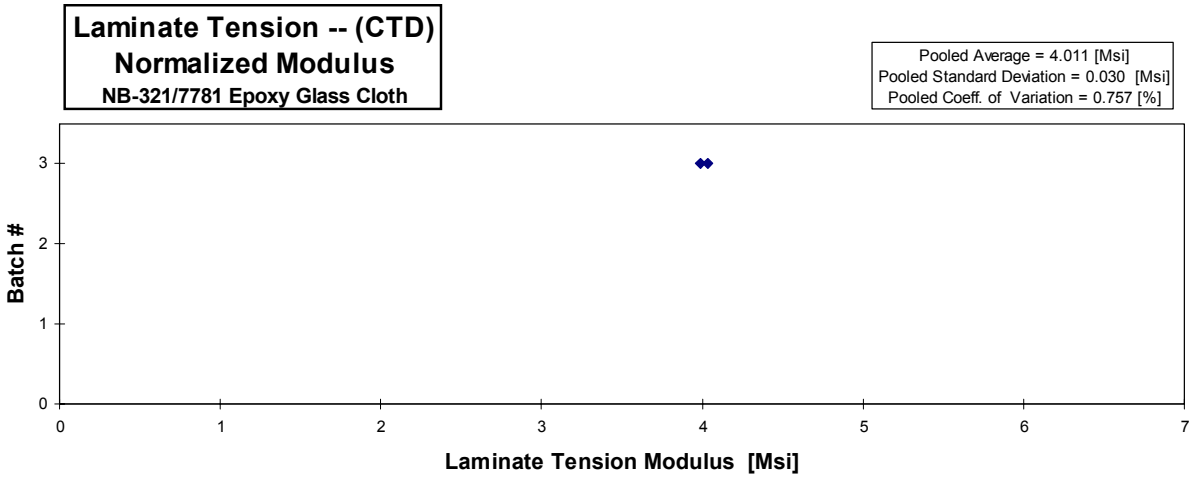

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Laminate Tension -- (ETW)
Strength & Modulus
NB-321/7781 Epoxy Glass Cloth

normalizing t_{ply} [in]: 0.0098

Specimen Number	Strength [ksi]	Modulus [Msi]	Batch Number	Avg. Specimen Thickn. [in]	# Plies in Laminate	Avg. t_{ply} [in]	$Strength_{norm}$ [ksi]	$Modulus_{norm}$ [Msi]
MBJ2211C	50.666	3.590	2	0.084	9	0.00936	48.369	3.427
MBJ2212C	48.872	3.677	2	0.084	9	0.00932	46.489	3.498
MBJ2213C	48.457	3.575	2	0.084	9	0.00937	46.351	3.419
MBJ2214C	49.790	3.739	2	0.084	9	0.00929	47.194	3.544
MBJ2215C	46.453	3.583	2	0.084	9	0.00934	44.294	3.416
MBJ2216C	51.164		2	0.084	9	0.00929	48.496	
MBJ2217C	47.918		2	0.084	9	0.00931	45.500	
MBJ3111C	38.344		3	0.092	9	0.01019	39.859	
MBJ3112C	41.151	3.278	3	0.090	9	0.01005	42.193	3.361
MBJ3113C	37.900		3	0.090	9	0.01003	38.795	
MBJ3114C	37.401	3.071	3	0.092	9	0.01024	39.076	3.209
MBJ3115C	40.805	3.104	3	0.093	9	0.01031	42.926	3.266
MBJ3116C	40.380	3.018	3	0.093	9	0.01034	42.586	3.183
MBJ3117C	40.074	3.521	3	0.092	9	0.01018	41.619	3.656
MBJ4111C	39.512	3.250	4	0.091	9	0.01012	40.804	3.356
MBJ4112C	41.241	3.414	4	0.087	9	0.00969	40.797	3.377
MBJ4114C	36.602		4	0.091	9	0.01006	37.556	
MBJ4121C	38.208		4	0.087	9	0.00964	37.587	
MBJ4122C	37.682		4	0.088	9	0.00981	37.739	
MBJ4123C	38.493		4	0.090	9	0.01005	39.482	

Average	**42.556**	**3.402**	**$Average_{norm}$**	**0.00980**	**42.386**	**3.393**
Standard Dev.	**5.122**	**0.249**	**$Standard\ Dev._{norm}$**		**3.662**	**0.136**
Coeff. of Var. [%]	**12.035**	**7.334**	**$Coeff.\ of\ Var.\ [\%]_{norm}$**		**8.639**	**3.996**
Min. Value	**36.602**	**3.018**	**$Min.\ Value_{norm}$**	**0.0093**	**37.556**	**3.183**
Max. Value	**51.164**	**3.739**	**$Max.\ Value_{norm}$**	**0.0103**	**48.496**	**3.656**
Number	**20**	**12**	**$Number_{norm}$**		**20**	**12**

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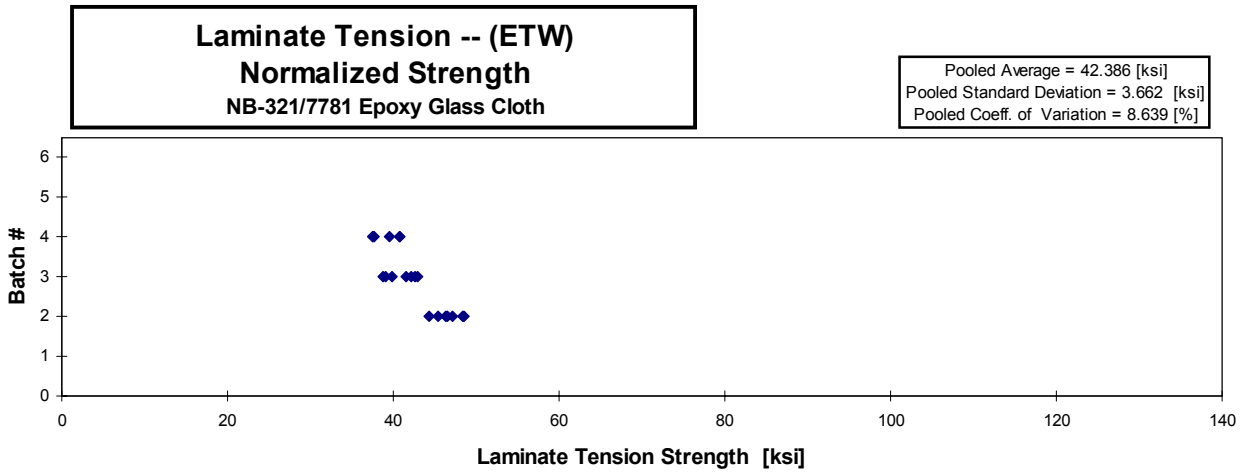

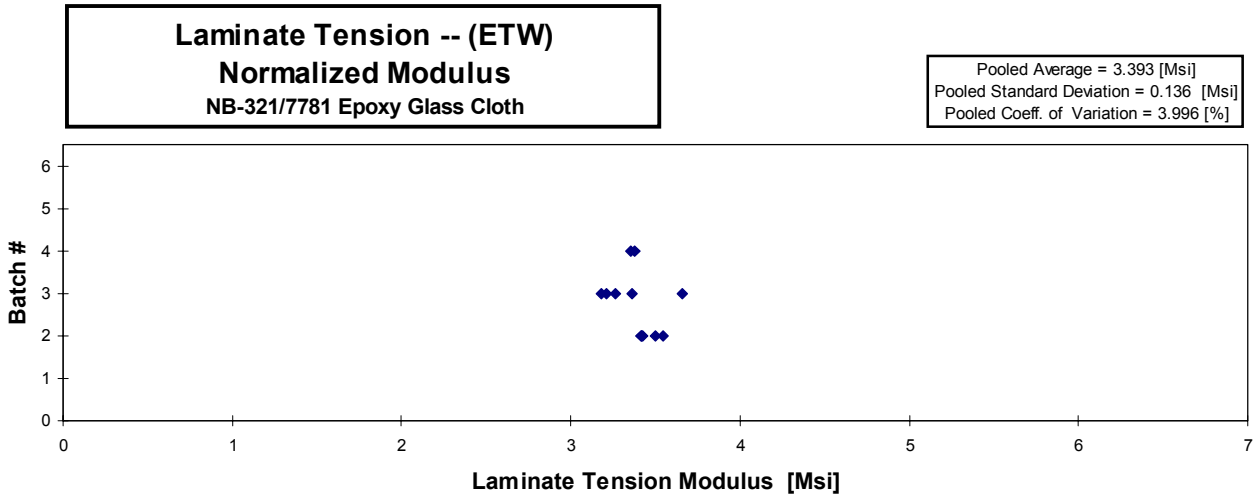

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Laminate Compression -- (RTD)
Strength & Modulus
NB-321/7781 Glass Cloth

normalizing t_{ply} [in]: 0.0098

Specimen Number	Strength [ksi]	Modulus [Msi]	Batch Number	Avg. Specimen Thickn. [in]	# Plies in Laminate	Avg. t_{ply} [in]	$Strength_{norm}$ [ksi]	$Modulus_{norm}$ [Msi]
MBK27A1A	74.816		2	0.116	12	0.0097	73.798	
MBK27A2A	78.099		2	0.115	12	0.0096	76.206	
MBK27A3A	78.758		2	0.114	12	0.0095	76.013	
MBK27A4A	79.452		2	0.115	12	0.0096	77.865	
MBK27A5A	81.217		2	0.116	12	0.0096	79.940	
MBK27A6A	78.148		2	0.117	12	0.0097	77.417	
MBK27A7A	80.829		2	0.117	12	0.0097	80.073	
MBK27A8A	79.289		2	0.115	12	0.0096	77.705	
MBK23A1A		4.017	2	0.117	12	0.0098		4.005
MBK23A2A		4.237	2	0.114	12	0.0095		4.089
MBK31A1A	73.215		3	0.119	12	0.0099	74.087	
MBK31A2A	78.418		3	0.119	12	0.0099	79.352	
MBK31A3A	75.540		3	0.121	12	0.0101	77.723	
MBK31A4A	81.177		3	0.120	12	0.0100	83.007	
MBK31A5A	82.100		3	0.119	12	0.0099	82.903	
MBK31A6A	78.427		3	0.122	12	0.0102	81.361	
MBK37A1A		3.766	3	0.119	12	0.0099		3.803
MBK37A2A		4.006	3	0.117	12	0.0098		3.986
MBK4111A	86.692		4	0.118	12	0.0098	86.802	
MBK4112A	69.454		4	0.116	12	0.0097	68.420	
MBK4113A	79.205		4	0.120	12	0.0100	81.023	
MBK4114A	73.269		4	0.116	12	0.0097	72.381	
MBK4131A	78.982		4	0.117	12	0.0098	78.781	
MBK4132A	78.042		4	0.118	12	0.0099	78.539	
MBL4115A		3.863	4	0.089	9	0.0099		3.895
MBL4116A		3.533	4	0.087	9	0.0096		3.477

Average	**78.256**	**3.904**	**$Average_{norm}$**	**0.00978**	**78.170**	**3.876**
Standard Dev.	**3.707**	**0.242**	**$Standard\ Dev._{norm}$**		**4.112**	**0.219**
Coeff. of Var. [%]	**4.738**	**6.194**	**$Coeff.\ of\ Var.\ [\%]_{norm}$**		**5.260**	**5.641**
Min. Value	**69.454**	**3.533**	**$Min.\ Value_{norm}$**	**0.0095**	**68.420**	**3.477**
Max. Value	**86.692**	**4.237**	**$Max.\ Value_{norm}$**	**0.0102**	**86.802**	**4.089**
Number	**20**	**6**	**$Number_{norm}$**		**20**	**6**

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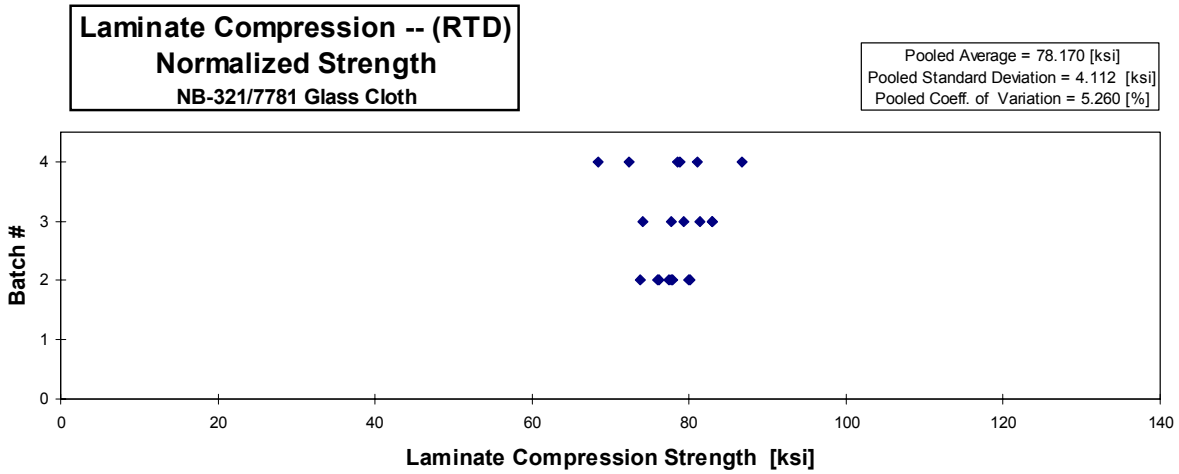

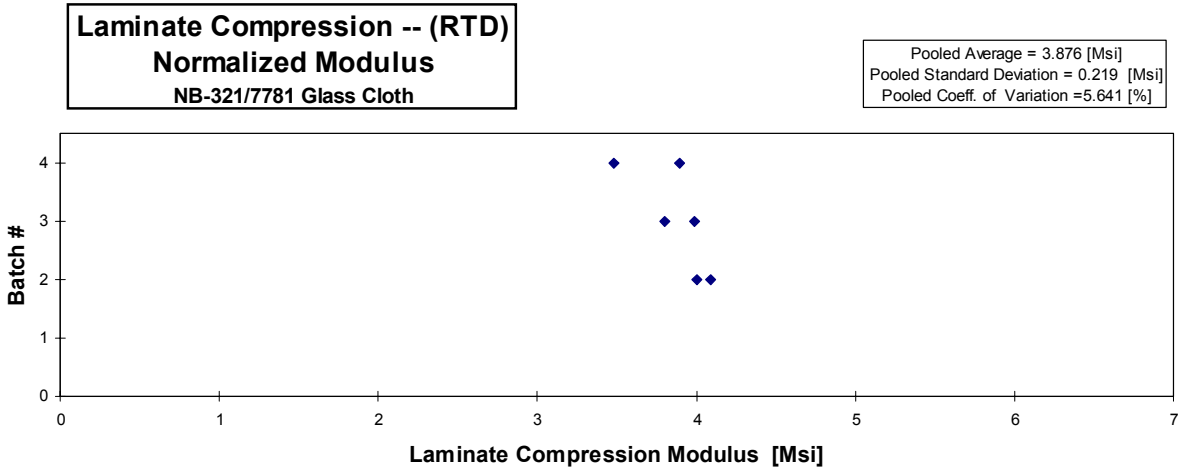

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Laminate Compression -- (CTD) Strength & Modulus

NB-321/7781 Glass Cloth

normalizing t_{ply} [in]: 0.0098

Specimen Number	Strength [ksi]	Modulus [Msi]	Batch Number	Avg. Specimen Thickn. [in]	# Plies in Laminate	Avg. t_{ply} [in]	$Strength_{norm}$ [ksi]	$Modulus_{norm}$ [Msi]
MBK4111B	95.711		4	0.117	12	0.0097	95.202	
MBK4112B	93.403		4	0.119	12	0.0099	94.634	
MBK4113B	98.485		4	0.119	12	0.0099	99.804	
MBK4114B	96.129		4	0.118	12	0.0098	96.211	
MBK4115B	97.696		4	0.117	12	0.0097	96.865	
MBK4121B	99.335		4	0.120	12	0.0100	101.130	
MBL4119B		3.931	4	0.087	9	0.0097		3.877
MBL411AB		4.040	4	0.088	9	0.0097		4.008

Average	**96.793**	**3.985**	**$Average_{norm}$**	**0.00981**	**97.308**	**3.943**
Standard Dev.	**2.156**	**0.077**	**$Standard\ Dev._{norm}$**		**2.601**	**0.092**
Coeff. of Var. [%]	**2.228**	**1.935**	**$Coeff.\ of\ Var.\ [\%]_{norm}$**		**2.673**	**2.340**
Min. Value	**93.403**	**3.931**	**$Min.\ Value_{norm}$**	**0.0097**	**94.634**	**3.877**
Max. Value	**99.335**	**4.040**	**$Max.\ Value_{norm}$**	**0.0100**	**101.130**	**4.008**
Number	**6**	**2**	**$Number_{norm}$**		**6**	**2**

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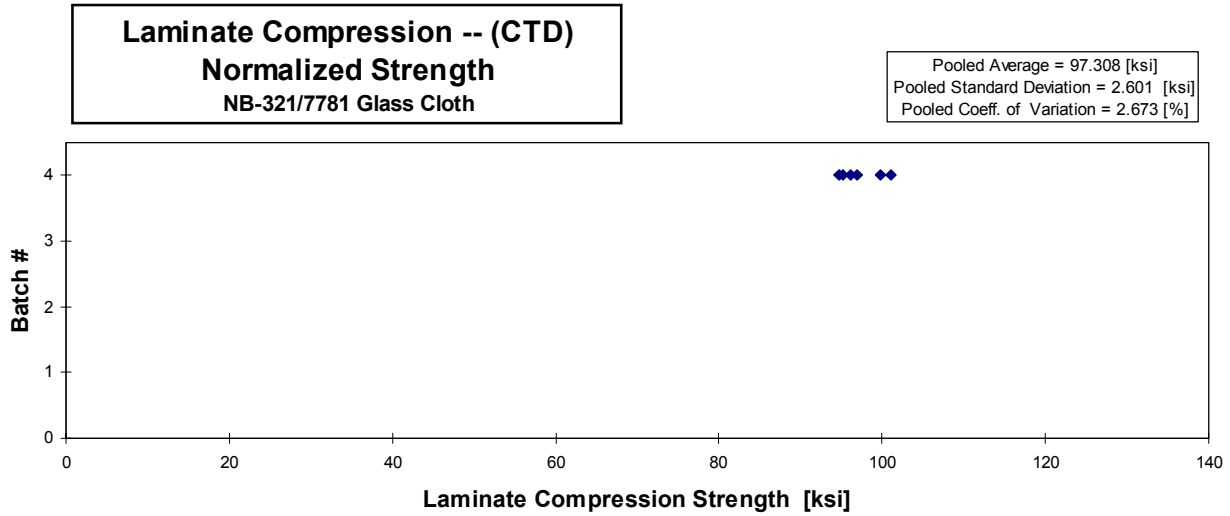

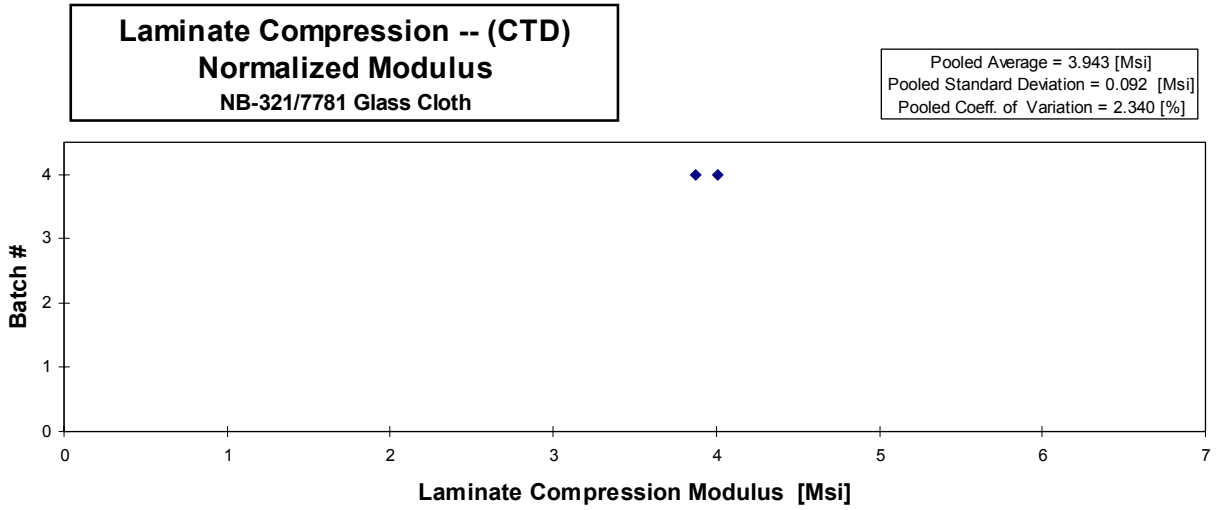

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Laminate Compression -- (ETW)
Strength & Modulus
NB-321/7781 Glass Cloth

normalizing t_{ply} [in]: 0.0098

Specimen Number	Strength [ksi]	Modulus [Msi]	Batch Number	Avg. Specimen Thickn. [in]	# Plies in Laminate	Avg. t_{ply} [in]	$Strength_{norm}$ [ksi]	$Modulus_{norm}$ [Msi]
MBK27A1C	64.107		2	0.116	12	0.0097	63.235	
MBK27A2C	60.202		2	0.116	12	0.0097	59.511	
MBK27A3C	62.614		2	0.114	12	0.0095	60.431	
MBK27A4C	58.000		2	0.117	12	0.0097	57.580	
MBK27A5C	56.963		2	0.117	12	0.0098	56.793	
MBK27A6C	60.498		2	0.114	12	0.0095	58.389	
MBK27A7C	62.069		2	0.114	12	0.0095	60.301	
MBK27A8C	53.453		2	0.114	12	0.0095	51.931	
MBK23A1C		4.062	2	0.115	12	0.0096		3.981
MBK23A2C		4.008	2	0.116	12	0.0097		3.953
MBK31A1C	55.720		3	0.115	12	0.0096	54.606	
MBK31A3C	59.763		3	0.117	12	0.0098	59.459	
MBK31A3C	60.590		3	0.119	12	0.0099	61.054	
MBK31A4C	55.040		3	0.118	12	0.0098	54.993	
MBK31A5C	58.821		3	0.118	12	0.0098	59.021	
MBK31A6C	52.747		3	0.120	12	0.0100	53.823	
MBK37A1C		3.868	3	0.118	12	0.0098		3.873
MBK37A2C		3.916	3	0.117	12	0.0097		3.879
MBK4121C	49.827		4	0.119	12	0.0099	50.272	
MBK4122C	51.907		4	0.117	12	0.0098	51.719	
MBK4123C	50.010		4	0.121	12	0.0101	51.488	
MBK4124C	52.586		4	0.120	12	0.0100	53.491	
MBK4131C	48.828		4	0.119	12	0.0100	49.585	
MBK4132C	48.027		4	0.119	12	0.0099	48.721	
MBL4113C		3.439	4	0.087	9	0.0097		3.387
MBL4114C		3.751	4	0.090	9	0.0100		3.810

Average	**56.089**	**3.841**	**$Average_{norm}$**	**0.00976**	**55.820**	**3.814**
Standard Dev.	**4.961**	**0.225**	**$Standard\ Dev._{norm}$**		**4.315**	**0.218**
Coeff. of Var. [%]	**8.845**	**5.856**	**$Coeff.\ of\ Var.\ [\%]_{norm}$**		**7.730**	**5.711**
Min. Value	**48.027**	**3.439**	**$Min.\ Value_{norm}$**	**0.0095**	**48.721**	**3.387**
Max. Value	**64.107**	**4.062**	**$Max.\ Value_{norm}$**	**0.0101**	**63.235**	**3.981**
Number	**20**	**6**	**$Number_{norm}$**		**20**	**6**

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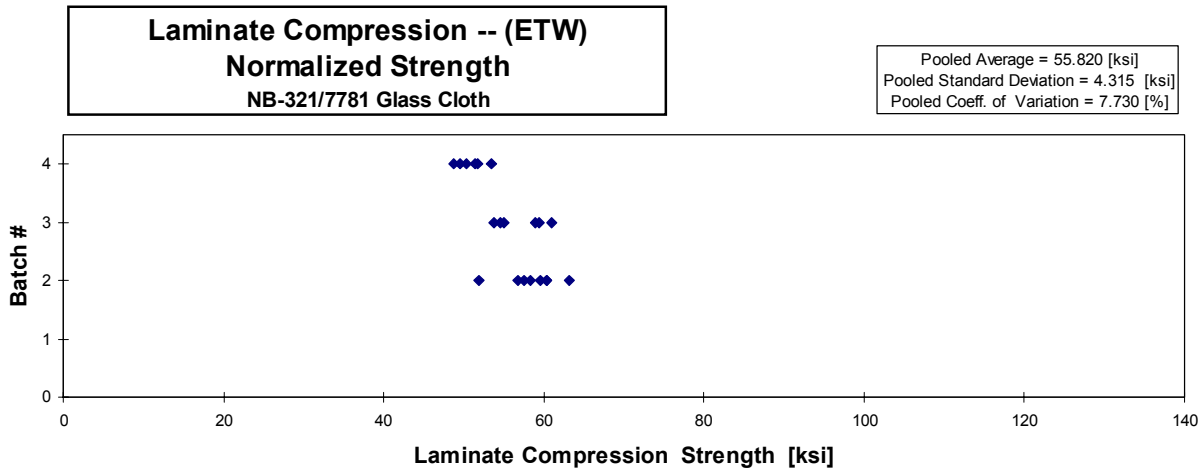

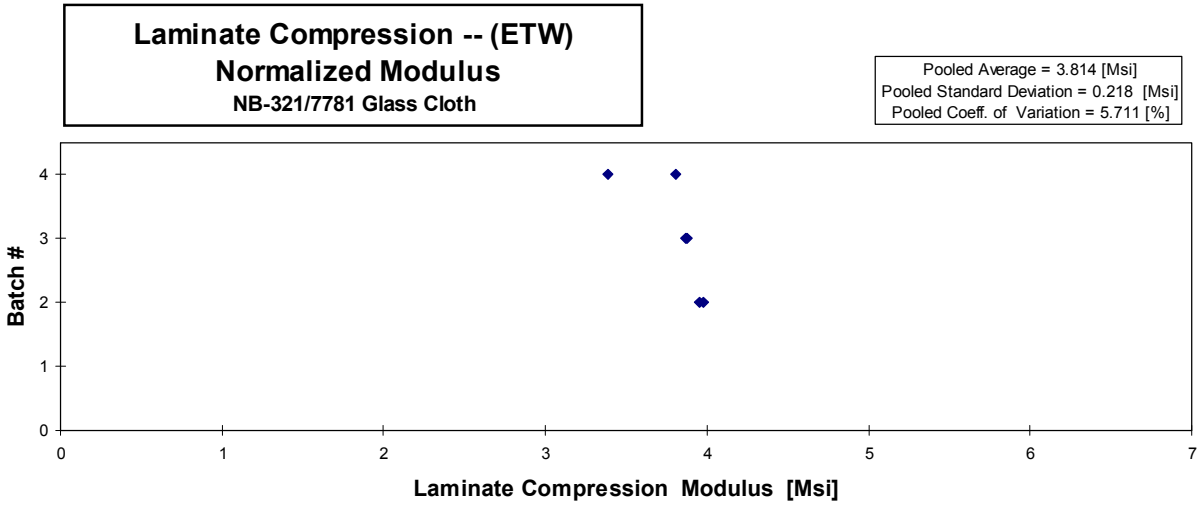

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Laminate Compression -- (ETD) Strength

NB-321/7781 Epoxy Glass Cloth

normalizing t_{ply} [in]: 0.0098

Specimen Number	Strength [ksi]	Batch Number	Avg. Specimen Thickn. [in]	# Plies in Laminate	Avg. t_{ply} [in]	$Strength_{norm}$ [ksi]
MBK27A1E	72.860	2	0.114	12	0.0095	70.475
MBK27A2E	68.028	2	0.114	12	0.0095	66.090
MBK27A3E	69.709	2	0.114	12	0.0095	67.575
MBK27A4E	70.192	2	0.115	12	0.0096	68.790
MBK27A5E	62.279	2	0.114	12	0.0095	60.240
MBK27A6E	61.922	2	0.114	12	0.0095	60.027
MBK27A7E	61.313	2	0.115	12	0.0095	59.696
MBK27A8E	59.921	2	0.115	12	0.0096	58.723
MBK31A1E	68.907	3	0.119	12	0.0099	69.874
MBK31A2E	66.487	3	0.120	12	0.0100	67.561
MBK31A3E	70.819	3	0.119	12	0.0099	71.512
MBK31A4E	67.470	3	0.119	12	0.0099	68.130
MBK31A5E	71.647	3	0.120	12	0.0100	72.957
MBK31A6E	70.744	3	0.120	12	0.0100	71.887
MBK4121E	67.361	4	0.118	12	0.0098	67.633
MBK4122E	65.866	4	0.123	12	0.0102	68.694
MBK4123E	61.073	4	0.125	12	0.0104	64.799
MBK4124E	67.693	4	0.119	12	0.0099	68.600
MBK4131E	63.941	4	0.120	12	0.0100	65.423

Average	**66.749**	**$Average_{norm}$**	**0.00980**	**66.773**
Standard Dev.	**3.965**	**$Standard\ Dev._{norm}$**		**4.310**
Coeff. of Var. [%]	**5.940**	**$Coeff.\ of\ Var.\ [\%]_{norm}$**		**6.455**
Min. Value	**59.921**	**$Min.\ Value_{norm}$**	**0.0095**	**58.723**
Max. Value	**72.860**	**$Max.\ Value_{norm}$**	**0.0104**	**72.957**
Number	**19**	**$Number_{norm}$**		**19**

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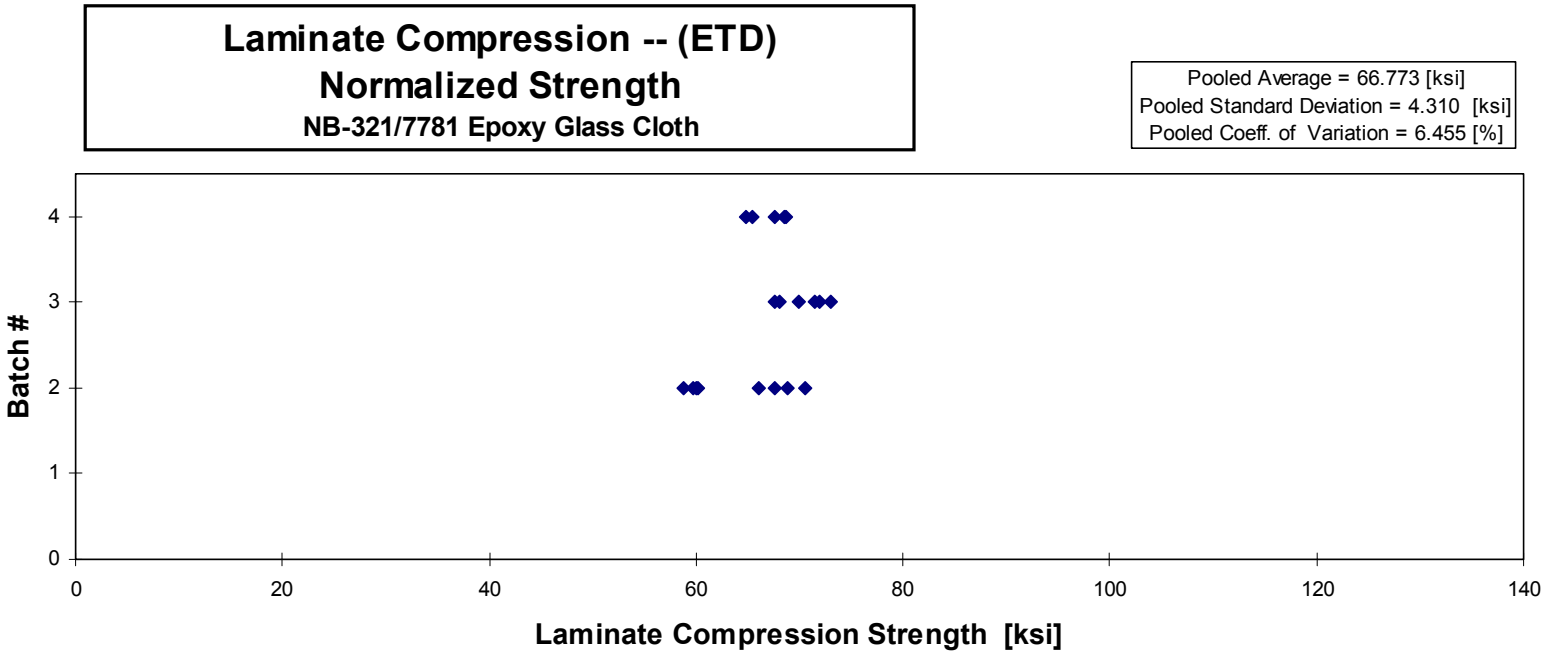

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In-Plane Shear -- (RTD)
Strength & Modulus
NB-321/7781 Glass Cloth

Specimen Number	Strength [ksi]	Modulus [Msi]	Batch Number	Avg. Specimen Thickn. [in]	# Plies in Laminate	Avg. t_{ply} [in]
MBN24A1A	19.282		2	0.091	10	0.0091
MBN24A2A	19.332		2	0.092	10	0.0092
MBN24A3A	18.234	0.733	2	0.093	10	0.0093
MBN24A4A	18.788		2	0.094	10	0.0094
MBN24A5A	19.388		2	0.093	10	0.0093
MBN24A6A	18.797	0.685	2	0.092	10	0.0092
MBN31A1A	19.350		3	0.099	10	0.0099
MBN31A2A	19.545		3	0.103	10	0.0103
MBN31A3A	19.140		3	0.103	10	0.0103
MBN31A4A	18.992		3	0.096	10	0.0096
MBN31A5A	19.555	0.566	3	0.100	10	0.0100
MBN31A6A	19.412	0.576	3	0.101	10	0.0101
MBN4121A	17.416	0.564	4	0.100	10	0.0100
MBN4122A	18.211	0.532	4	0.100	10	0.0100
MBN4123A	20.063		4	0.098	10	0.0098
MBN4124A	20.280		4	0.097	10	0.0097
MBN4125A	19.861		4	0.097	10	0.0097
MBN4126A	18.243		4	0.099	10	0.0099

Average	**19.105**	**0.609**		
Standard Dev.	**0.725**	**0.080**		
Coeff. of Var. [%]	**3.797**	**13.095**		
Min.	**17.416**	**0.532**	**Min.**	**0.0091**
Max.	**20.280**	**0.733**	**Max.**	**0.0103**
Number of Spec.	**18**	**6**		

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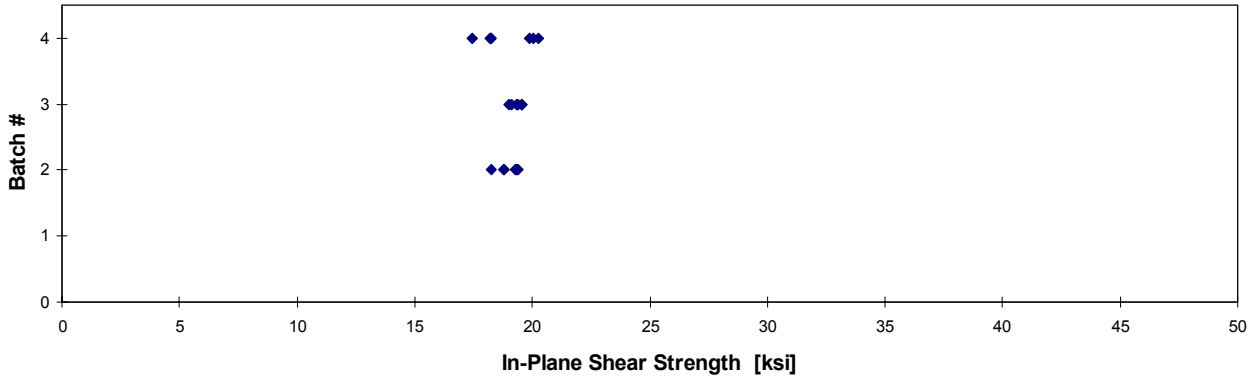
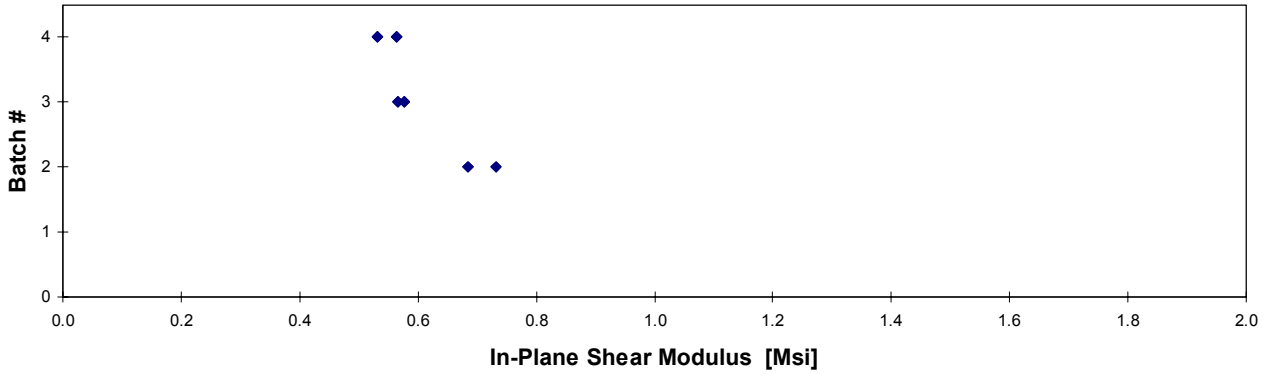
In-Plane Shear -- (RTD)
Measured Strength
NB-321/7781 Glass Cloth

Pooled Average = 19.105 [ksi]
Pooled Standard Deviation = 0.725 [ksi]
Pooled Coeff. of Variation = 3.797 [%]



In-Plane Shear -- (RTD)
Measured Modulus
NB-321/7781 Glass Cloth

Pooled Average = 0.609 [Msi]
Pooled Standard Deviation = 0.080 [Msi]
Pooled Coeff. of Variation = 13.095 [%]



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In-Plane Shear -- (CTD)
Strength & Modulus
NB-321/7781 Glass Cloth

Specimen Number	Strength [ksi]	Modulus [Msi]	Batch Number	Avg. Specimen Thickn. [in]	# Plies in Laminate	Avg. t_{ply} [in]
MBN4111B	23.303	0.762	4	0.103	10	0.0103
MBN4112B	21.729	0.674	4	0.102	10	0.0102
MBN4113B	23.697		4	0.101	10	0.0101
MBN4114B	23.396		4	0.103	10	0.0103
MBN4115B	26.547		4	0.098	10	0.0098
MBN4116B	21.440		4	0.102	10	0.0102

Average	**23.352**	**0.718**		
Standard Dev.	**1.824**	**0.062**		
Coeff. of Var. [%]	**7.809**	**8.612**		
Min.	**21.440**	**0.674**	**Min.**	**0.0098**
Max.	**26.547**	**0.762**	**Max.**	**0.0103**
Number of Spec.	**6**	**2**		

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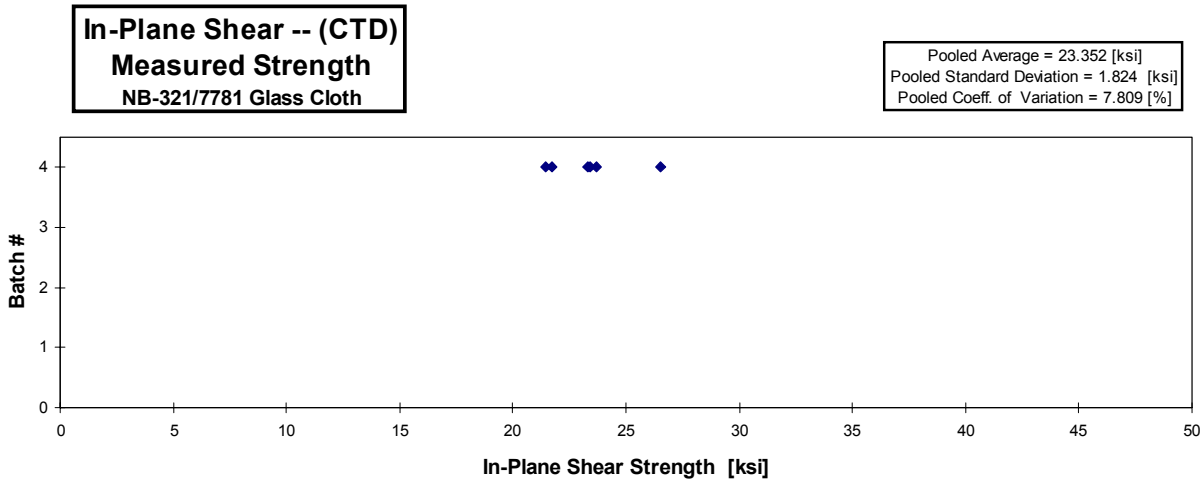

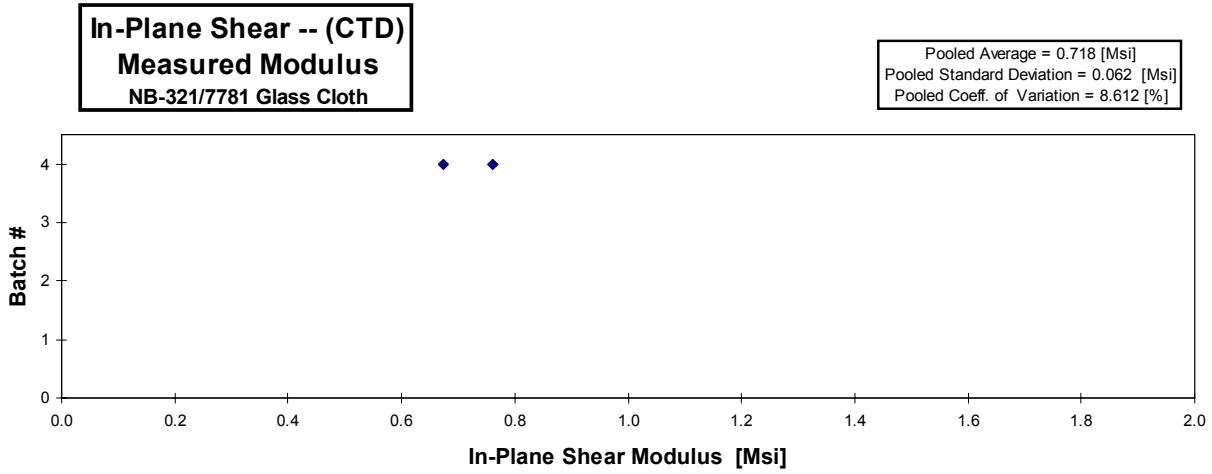

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In-Plane Shear -- (ETW)
Strength & Modulus
NB-321/7781 Glass Cloth

Specimen Number	Strength [ksi]	Modulus [Msi]	Batch Number	Avg. Specimen Thickn. [in]	# Plies in Laminate	Avg. t_{ply} [in]
MBN23A1C	14.740	0.430	2	0.095	10	0.0095
MBN23A2C	13.421	0.504	2	0.094	10	0.0094
MBN23A3C	14.239		2	0.094	10	0.0094
MBN23A4C	14.107		2	0.092	10	0.0092
MBN23A5C	14.161		2	0.094	10	0.0094
MBN23A6C	13.825		2	0.095	10	0.0095
MBN34A1C	12.800	0.389	3	0.103	10	0.0103
MBN34A3C	12.480		3	0.102	10	0.0102
MBN34A4C	12.670		3	0.104	10	0.0104
MBN34A5C	12.900		3	0.103	10	0.0103
MBN34A6C	12.620		3	0.101	10	0.0101
MBN34A8C	12.880	0.364	3	0.102	10	0.0102
MBN4131C	11.561		4	0.098	10	0.0098
MBN4132C	12.133	0.386	4	0.096	10	0.0096
MBN4141C	12.084	0.313	4	0.097	10	0.0097
MBN4142C	11.400		4	0.099	10	0.0099
MBN4143C	11.878		4	0.098	10	0.0098
MBN4144C	11.574		4	0.100	10	0.0100

Average	**12.860**	**0.398**		
Standard Dev.	**1.022**	**0.065**		
Coeff. of Var. [%]	**7.945**	**16.241**		
Min.	**11.400**	**0.313**	**Min.**	**0.0092**
Max.	**14.740**	**0.504**	**Max.**	**0.0104**
Number of Spec.	**18**	**6**		

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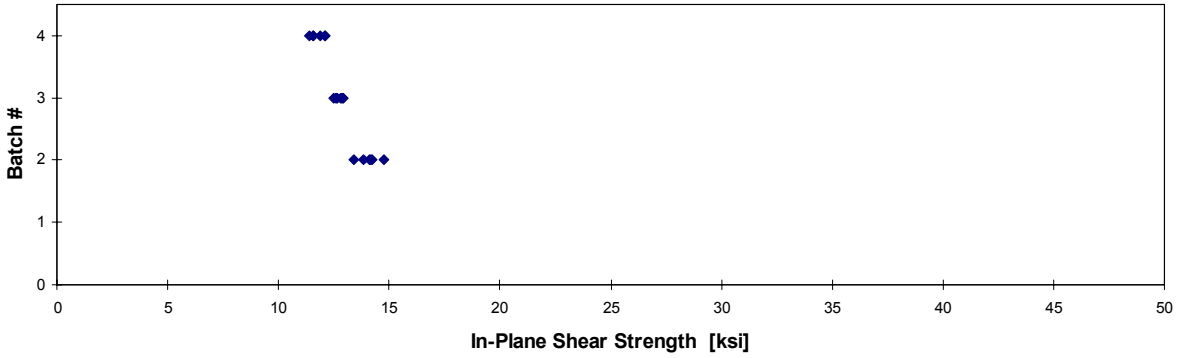
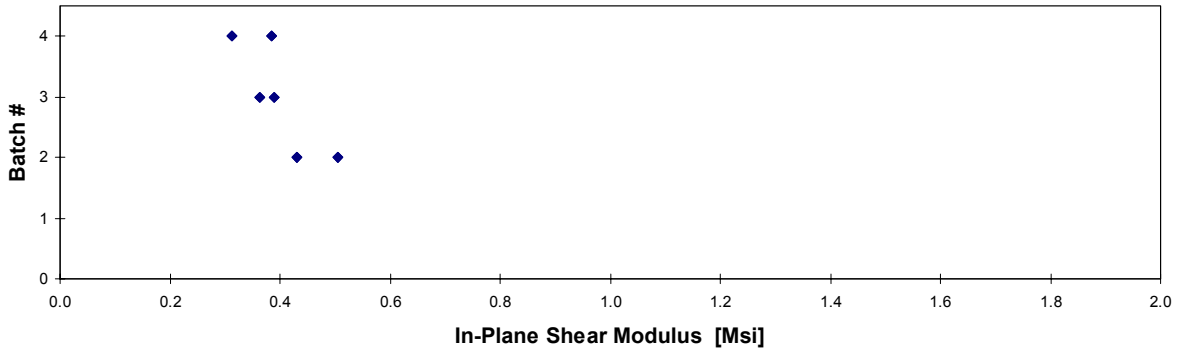
In-Plane Shear -- (ETW)
Measured Strength
NB-321/7781 Glass Cloth

Pooled Average = 12.860 [ksi]
Pooled Standard Deviation = 1.022 [ksi]
Pooled Coeff. of Variation = 7.945 [%]



In-Plane Shear -- (ETW)
Measured Modulus
NB-321/7781 Glass Cloth

Pooled Average = 0.398 [Msi]
Pooled Standard Deviation = 0.065 [Msi]
Pooled Coeff. of Variation = 16.241 [%]



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In-Plane Shear -- (ETD) Strength

NB-321/7781 Epoxy Glass Cloth

Specimen Number	Strength [ksi]	Batch Number	Avg. Specimen Thickn. [in]	# Plies in Laminate	Avg. t_{ply} [in]
MBN23A1E	16.266	2	0.094	10	0.0094
MBN23A2E	16.123	2	0.095	10	0.0095
MBN23A3E	17.385	2	0.094	10	0.0094
MBN23A4E	16.600	2	0.094	10	0.0094
MBN23A6E	16.685	2	0.094	10	0.0094
MBN23A7E	17.023	2	0.094	10	0.0094
MBN23A8E	16.520	2	0.094	10	0.0094
MBN31A2E	17.270	3	0.102	10	0.0102
MBN31A3E	16.198	3	0.098	10	0.0098
MBN31A4E	15.880	3	0.100	10	0.0100
MBN31A5E	16.416	3	0.103	10	0.0103
MBN31A6E	15.775	3	0.098	10	0.0098
MBN31A8E	15.262	3	0.098	10	0.0098
MBN4131E	14.629	4	0.098	10	0.0098
MBN4132E	16.769	4	0.098	10	0.0098
MBN4133E	15.400	4	0.098	10	0.0098
MBN4134E	15.572	4	0.097	10	0.0097
MBN4135E	16.975	4	0.099	10	0.0099
MBN4111E	14.066	4	0.105	10	0.0105

Average	**16.148**		
Standard Dev.	**0.878**		
Coeff. of Var. [%]	**5.436**		
Min.	**14.066**	**Min.**	**0.0094**
Max.	**17.385**	**Max.**	**0.0105**
Number	**19**		

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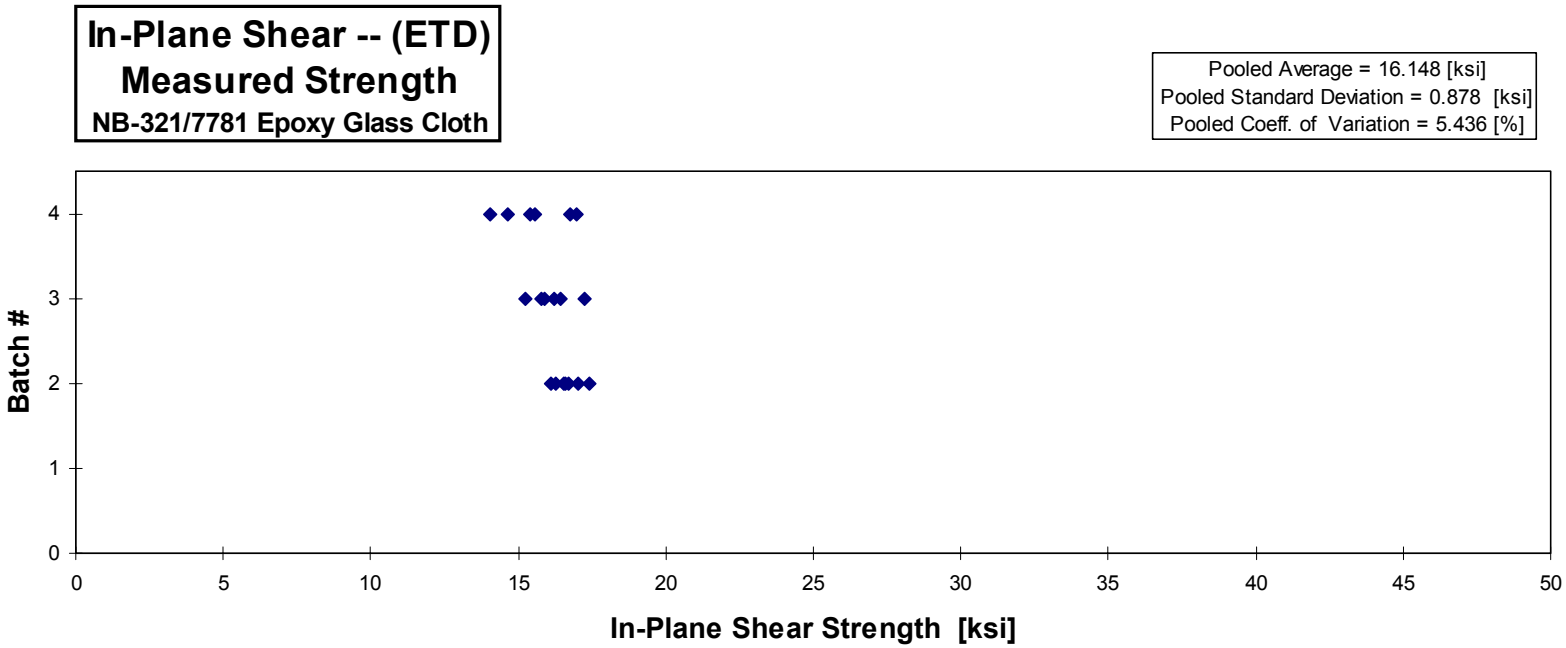

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Apparent Interlaminar Shear -- (RTD) Strength

NB-321/7781 Glass Cloth

Specimen Number	Strength [ksi]	Batch Number	Avg. Specimen Thickn. [in]	# Plies in Laminate	Avg. tply [in]
MBQ22A1A	9.121	2	0.083	9	0.0092
MBQ22A2A	8.781	2	0.083	9	0.0093
MBQ22A3A	8.680	2	0.084	9	0.0094
MBQ22A4A	9.180	2	0.084	9	0.0093
MBQ22A5A	9.339	2	0.084	9	0.0093
MBQ22A6A	9.145	2	0.084	9	0.0093
MBQ31A1A	9.650	3	0.085	9	0.0094
MBQ31A2A	9.690	3	0.084	9	0.0093
MBQ31A3A	9.695	3	0.085	9	0.0094
MBQ31A4A	9.620	3	0.084	9	0.0093
MBQ31A5A	9.729	3	0.084	9	0.0093
MBQ31A6A	9.750	3	0.083	9	0.0093
MBQ4111A	8.971	4	0.084	9	0.0093
MBQ4114A	9.529	4	0.083	9	0.0092
MBQ4115A	9.758	4	0.086	9	0.0095
MBQ4116A	9.065	4	0.085	9	0.0094
MBQ4117A	9.941	4	0.086	9	0.0095
MBQ4118A	8.872	4	0.084	9	0.0093
MBQ4119A	9.448	4	0.082	9	0.0091
MBQ411AA	9.490	4	0.085	9	0.0094

Average	**9.373**		
Standard Dev.	**0.371**		
Coeff. of Var. [%]	**3.959**		
Min.	**8.680**	**Min.**	**0.0091**
Max.	**9.941**	**Max.**	**0.0095**
Number	**20**		

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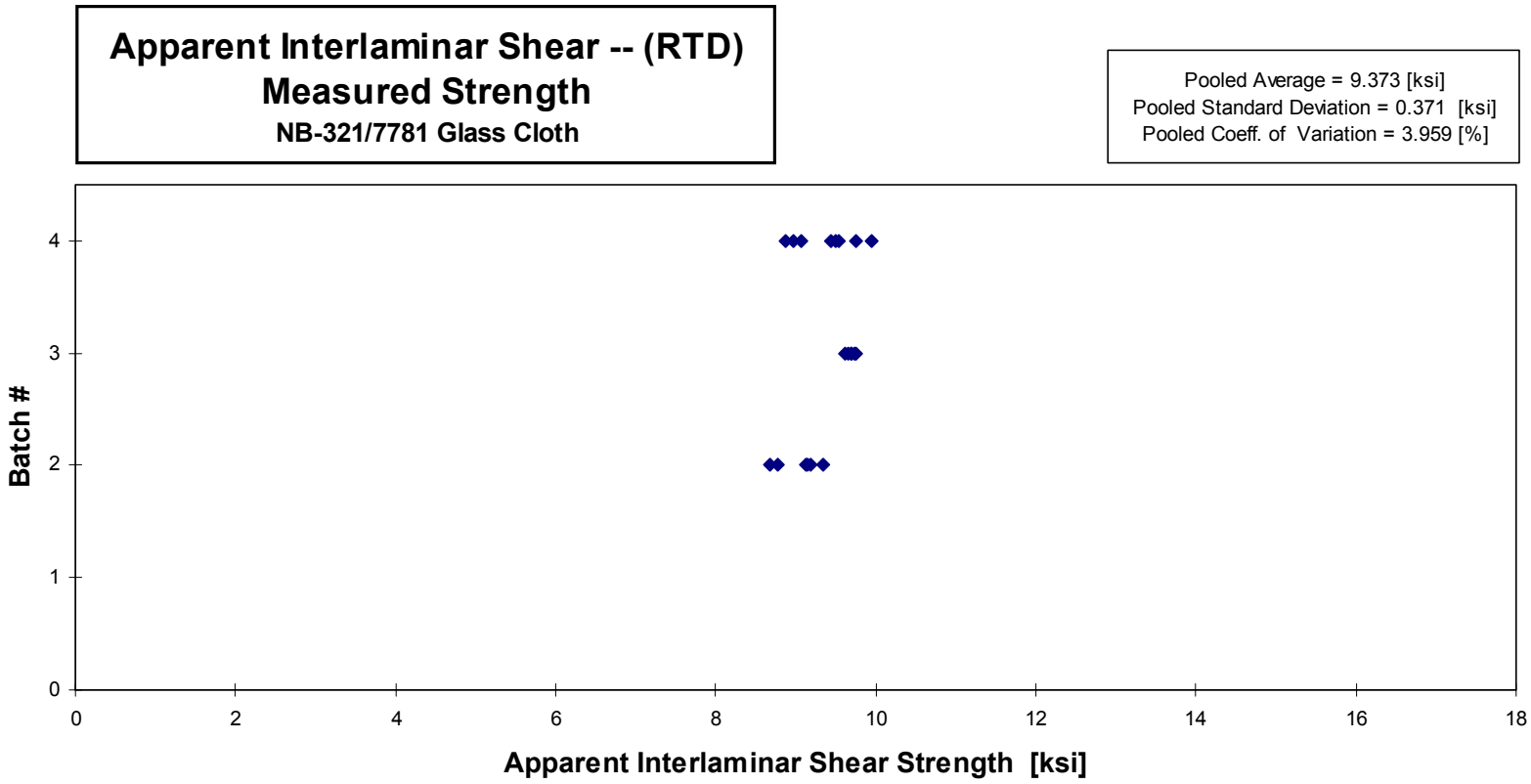

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3.2.2 Representative Shear Stress-Strain Curve

The following stress-strain curve is representative of the 7781 E-Glass / NB 321 prepreg system. The tension and compression stress-strain curves are not presented in graphical form. If strain design allowables from these tests are required, simple one-dimensional linear stress-strain relationships may be used to obtain corresponding strain design values. This process should approximate tensile and compressive strain behavior relatively well but may produce extremely conservative strain values in shear due to the nonlinear behavior. A more realistic approach for shear strain design allowables is to use a maximum strain value of 5% (reference MIL-HDBK-17-1E, section 5.7.6). If a nonlinear analysis of the material's shear behavior is required, the curve-fit of the shear stress-strain curve may be used. The representative shear stress-strain curve was obtained by taking the average of all the sample shear curves and determining the best-fit line through the data. The actual data points also presented on the chart to demonstrate material variability.

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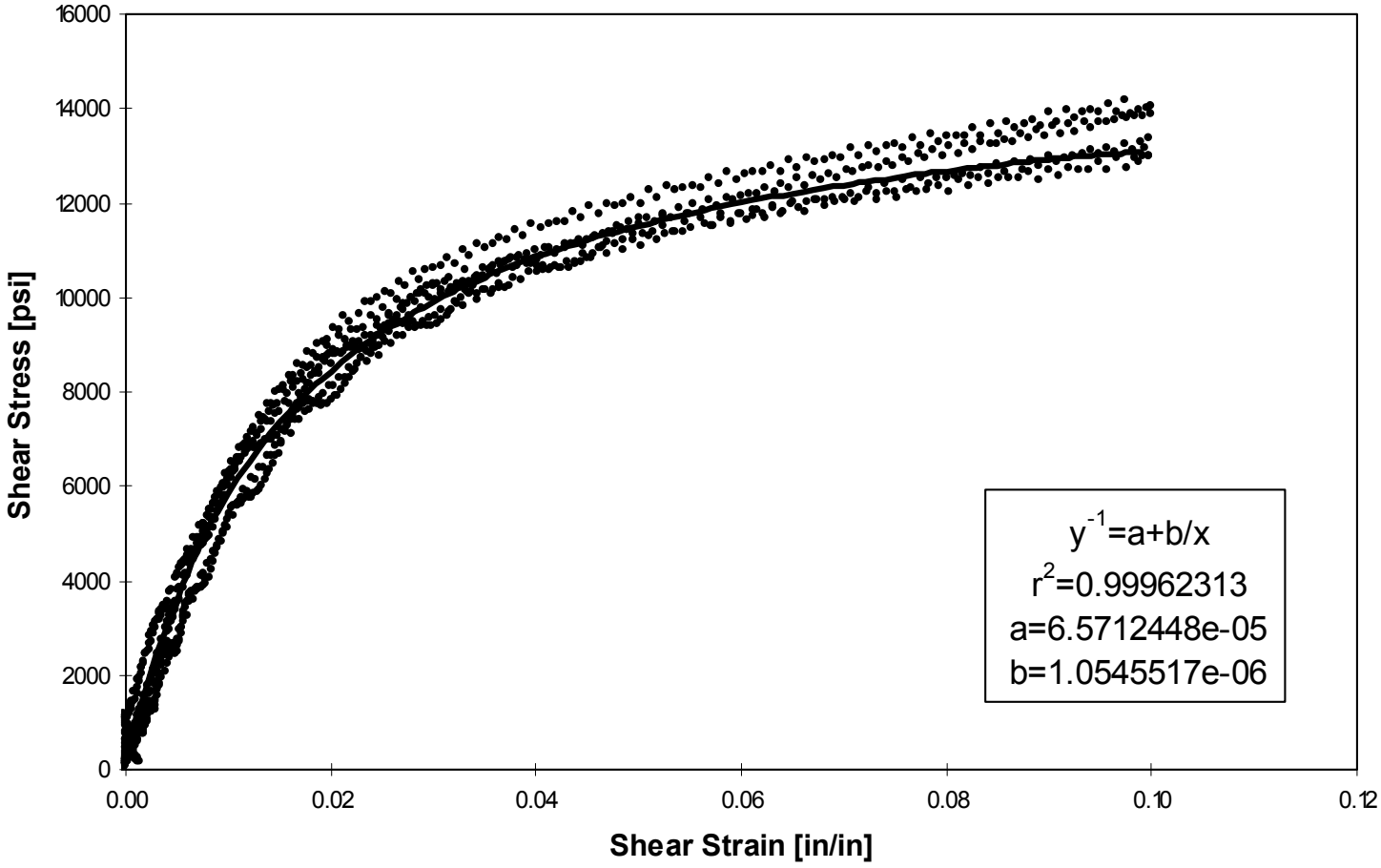
Shear Stress vs. Shear Strain, RTD



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3.3.1 Plot by Condition

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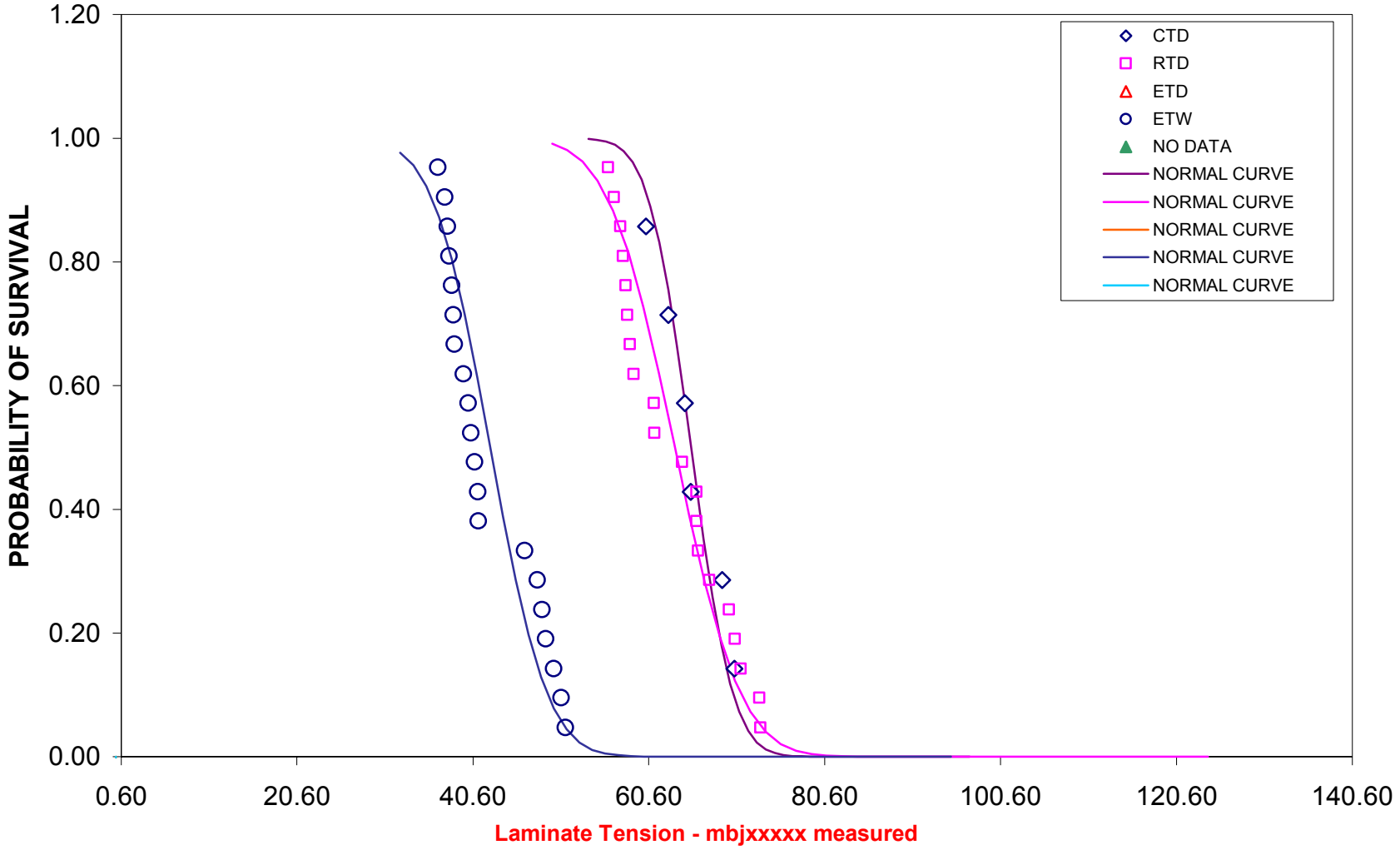
Lancair



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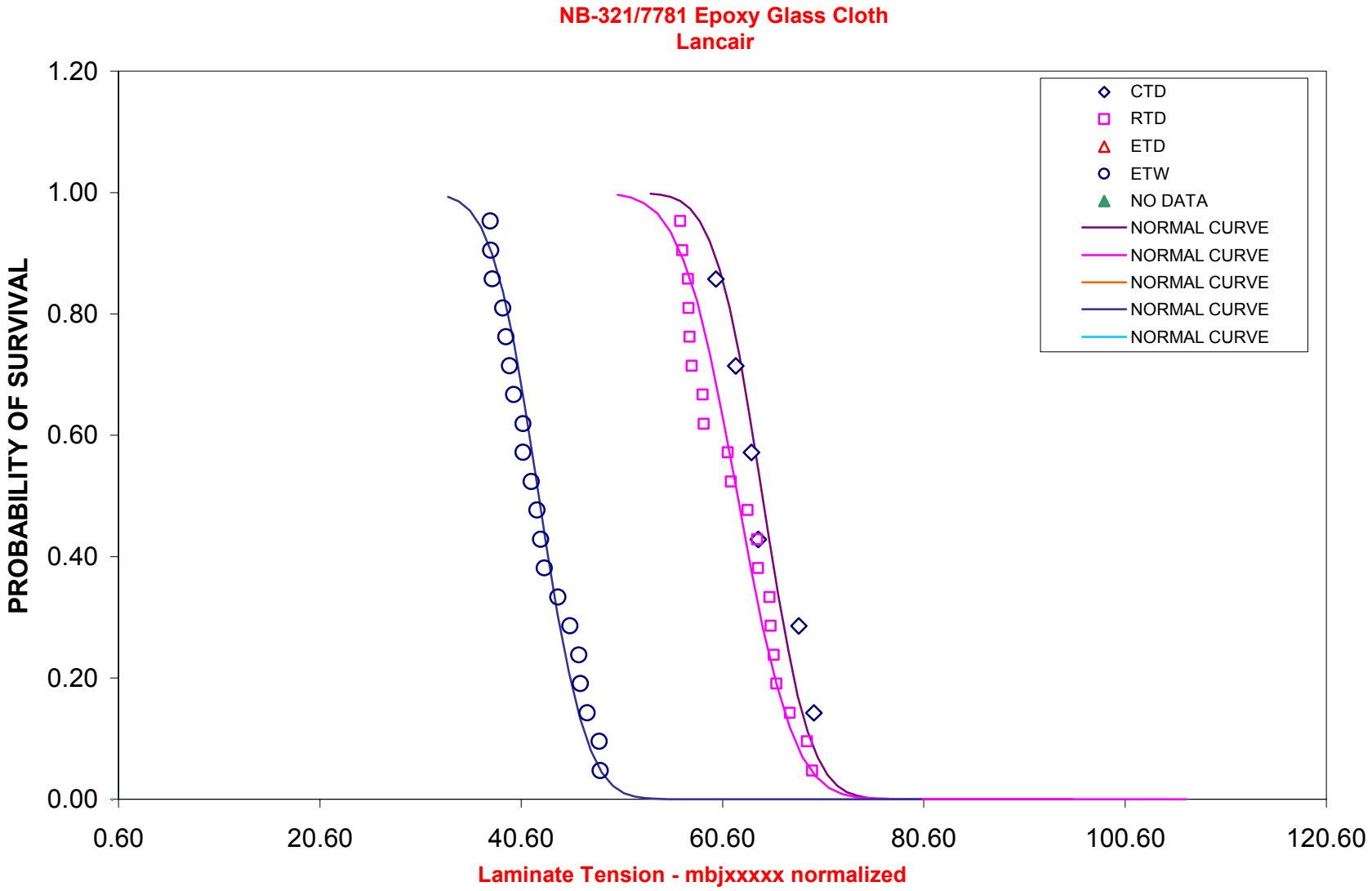

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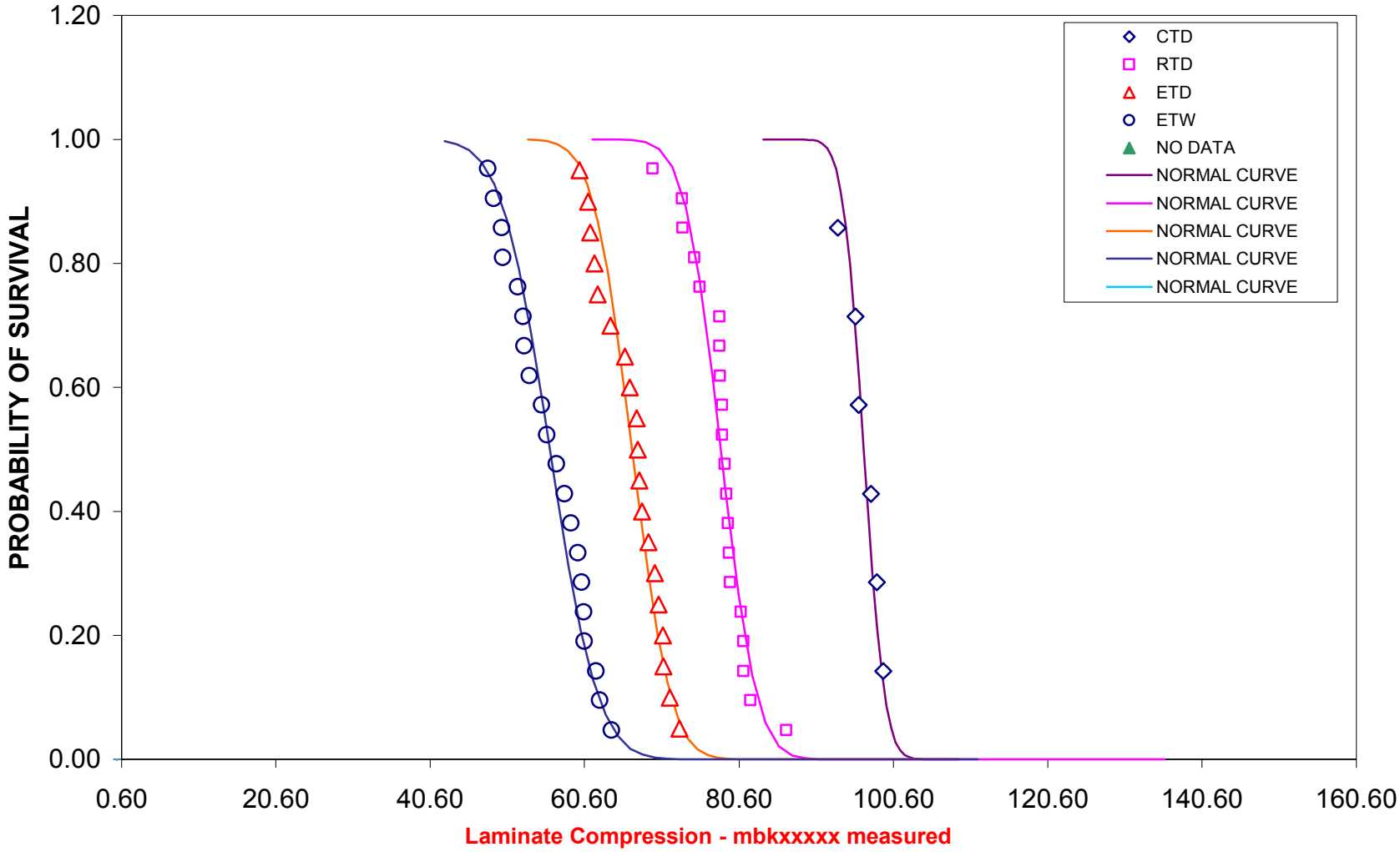

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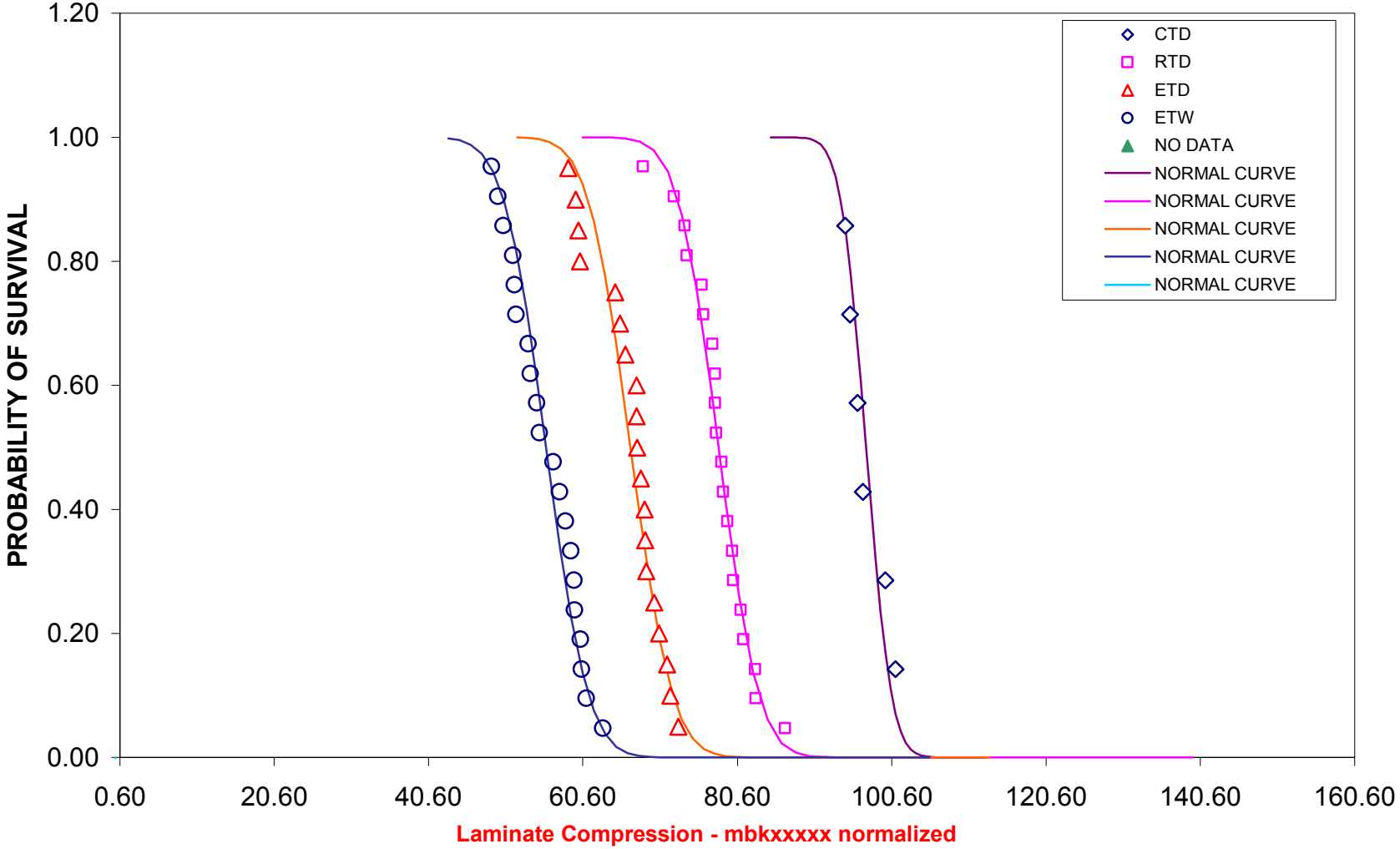

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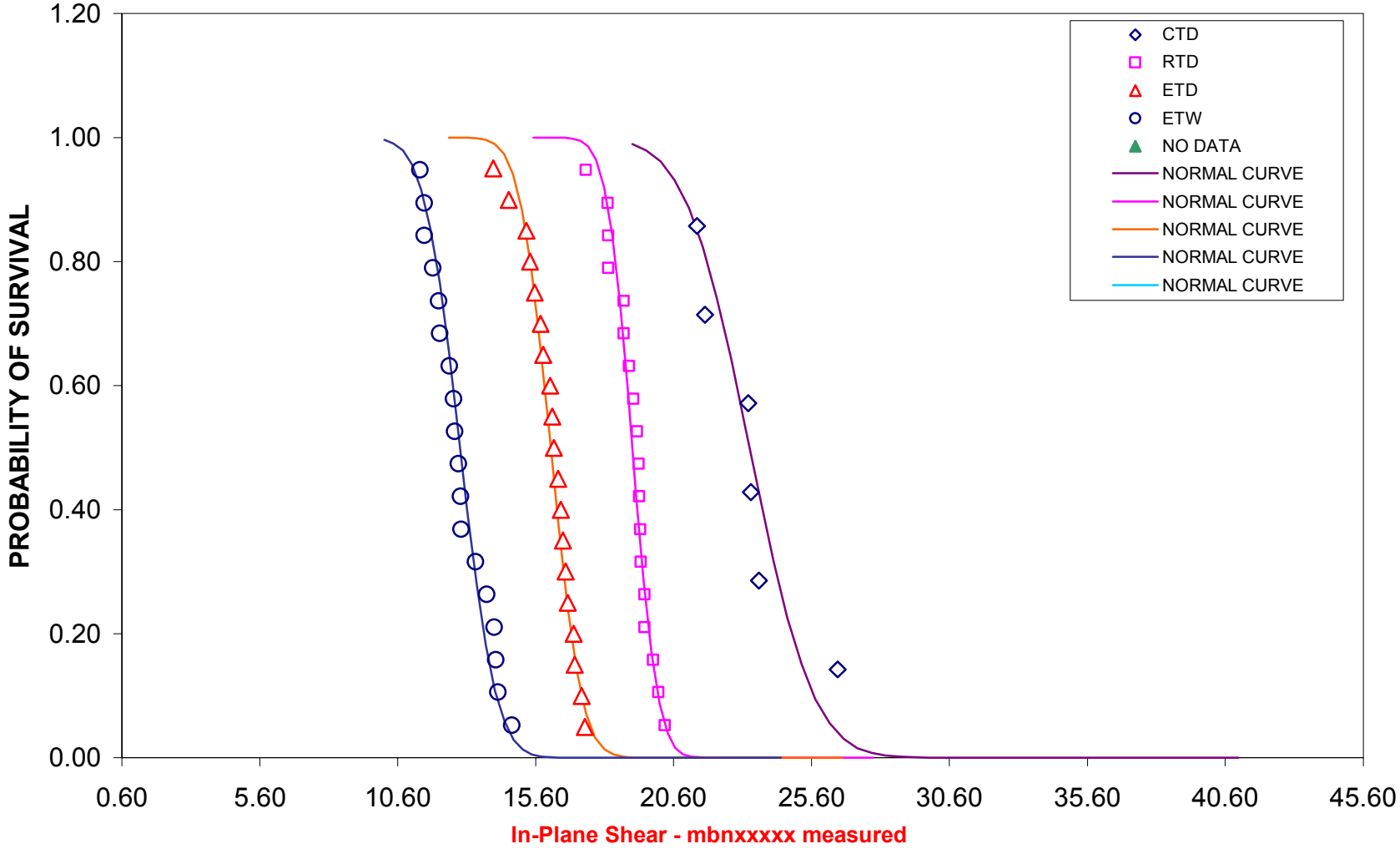

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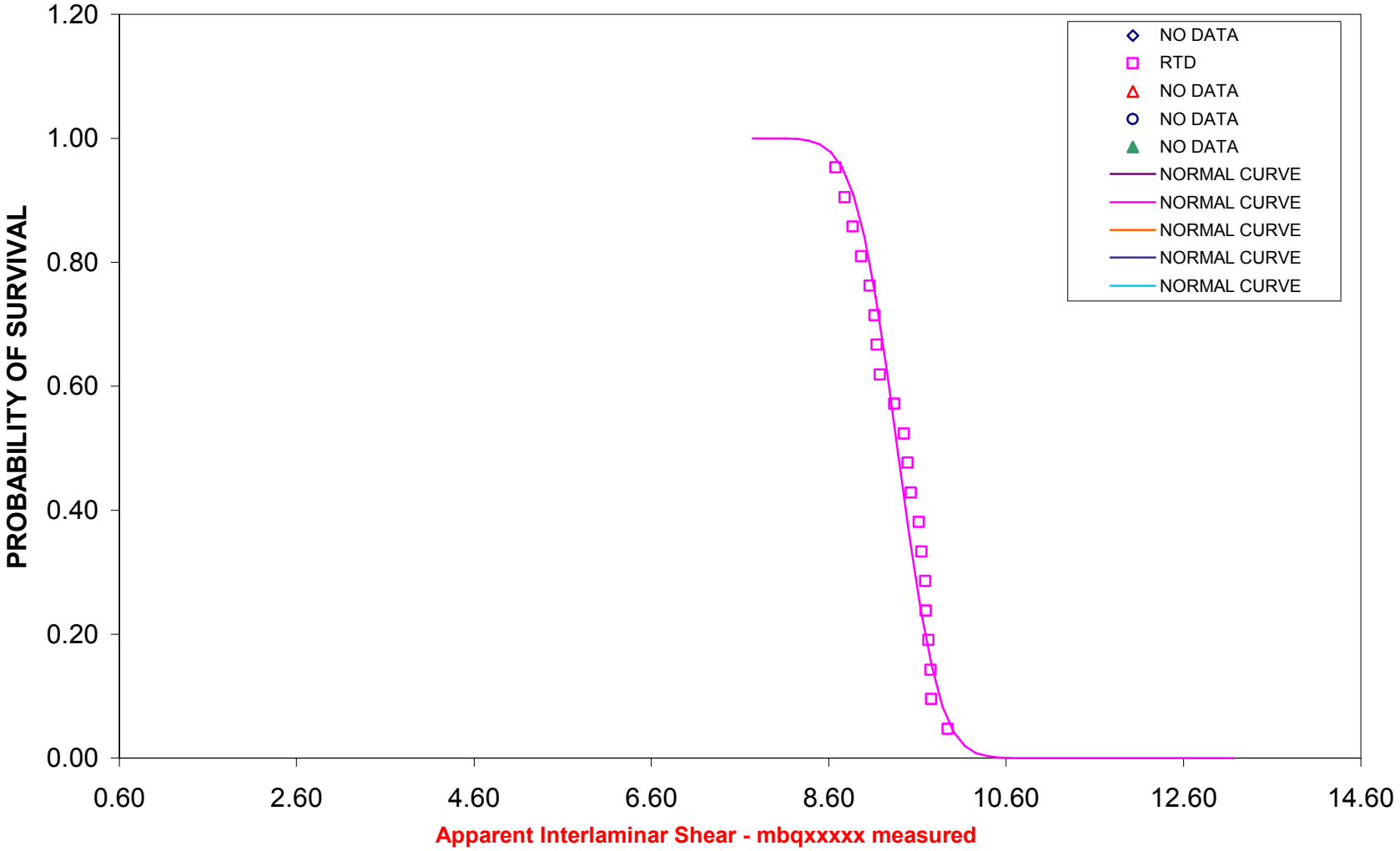

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3.3.2 Plot of Pooled Data

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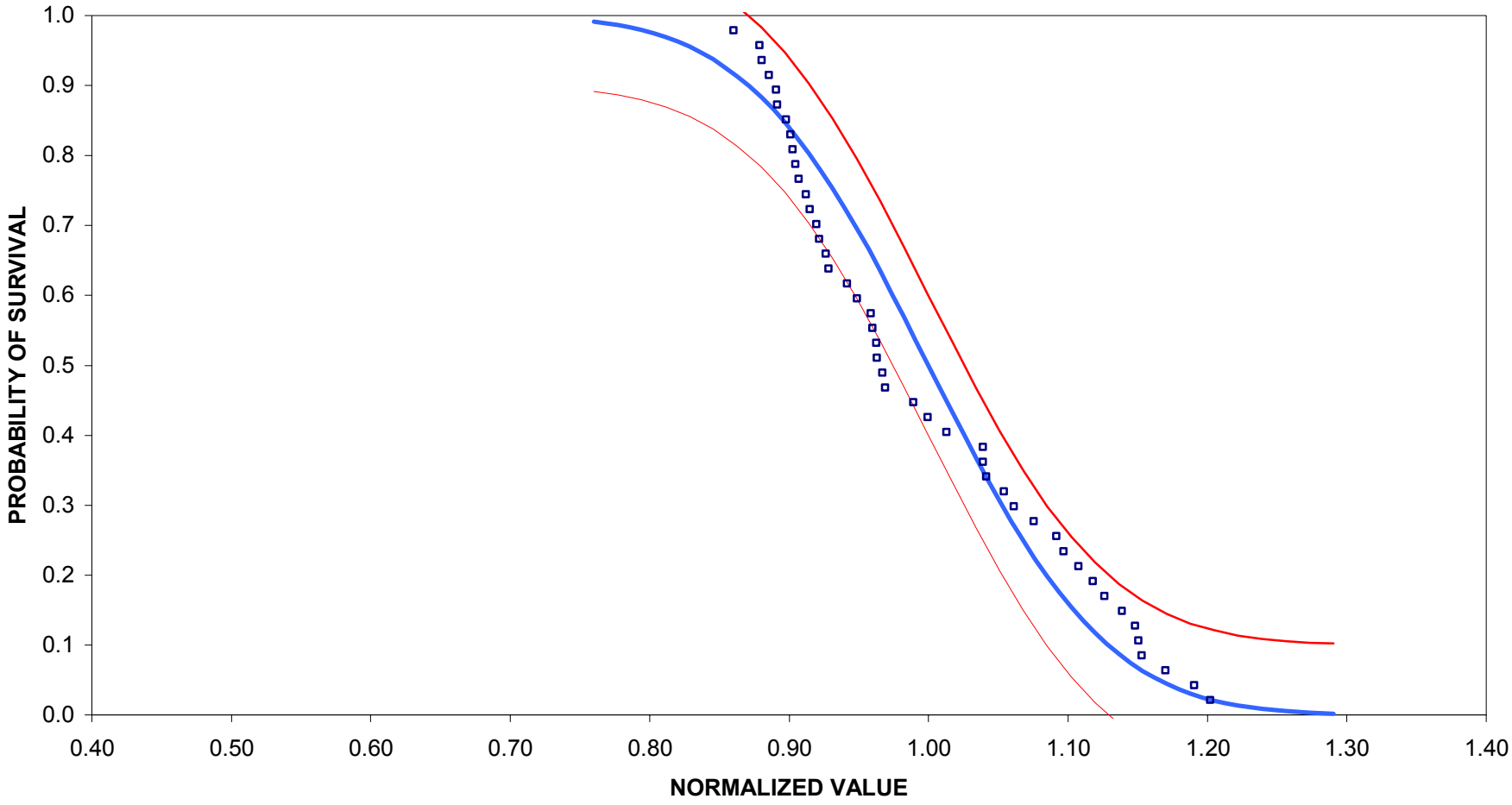
Laminate Tension - mbjxxxxx measured



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NB-321/7781 Epoxy Glass Cloth

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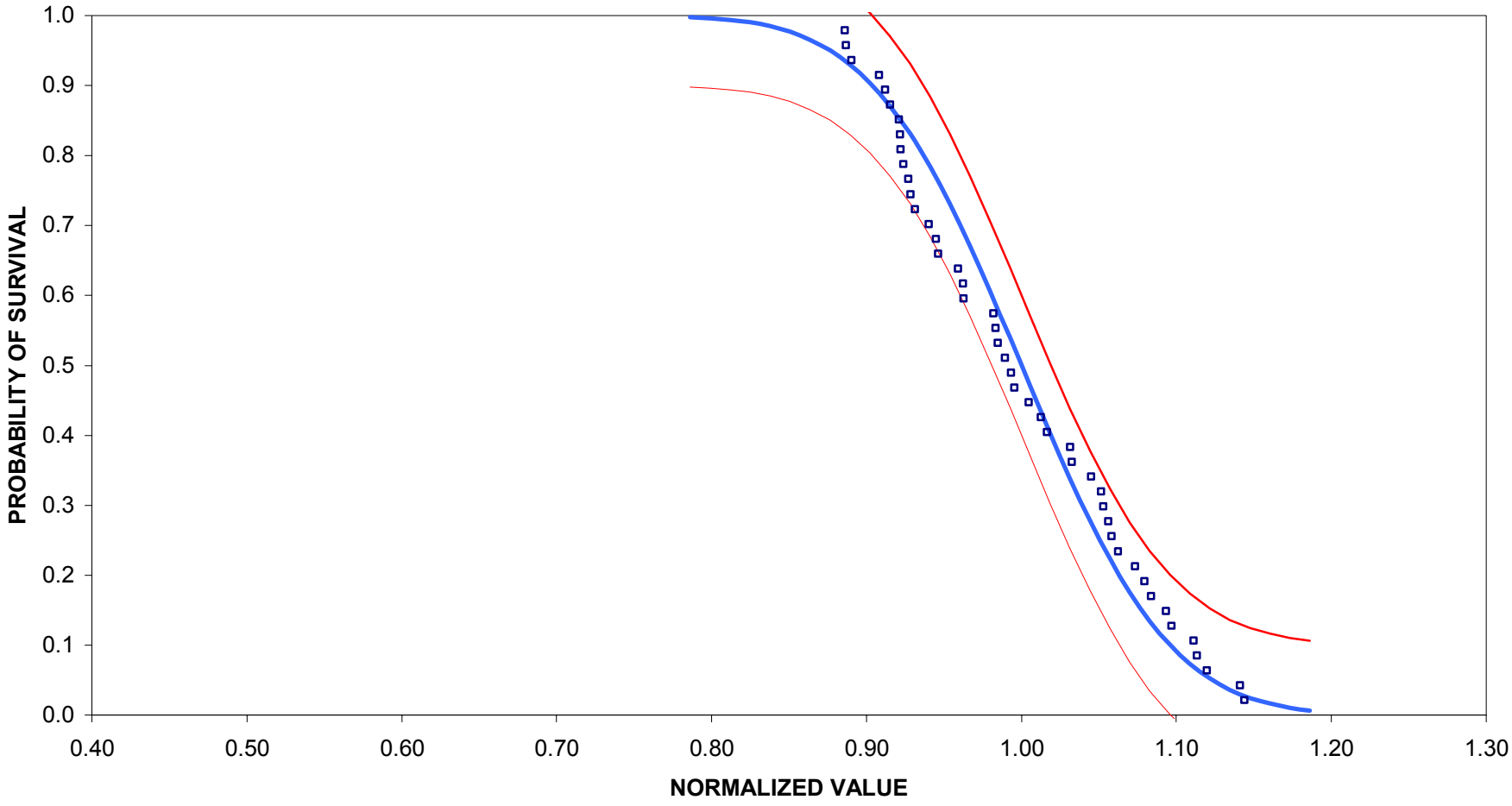
Laminate Tension - mbjxxxxx normalized



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NB-321/7781 Epoxy Glass Cloth

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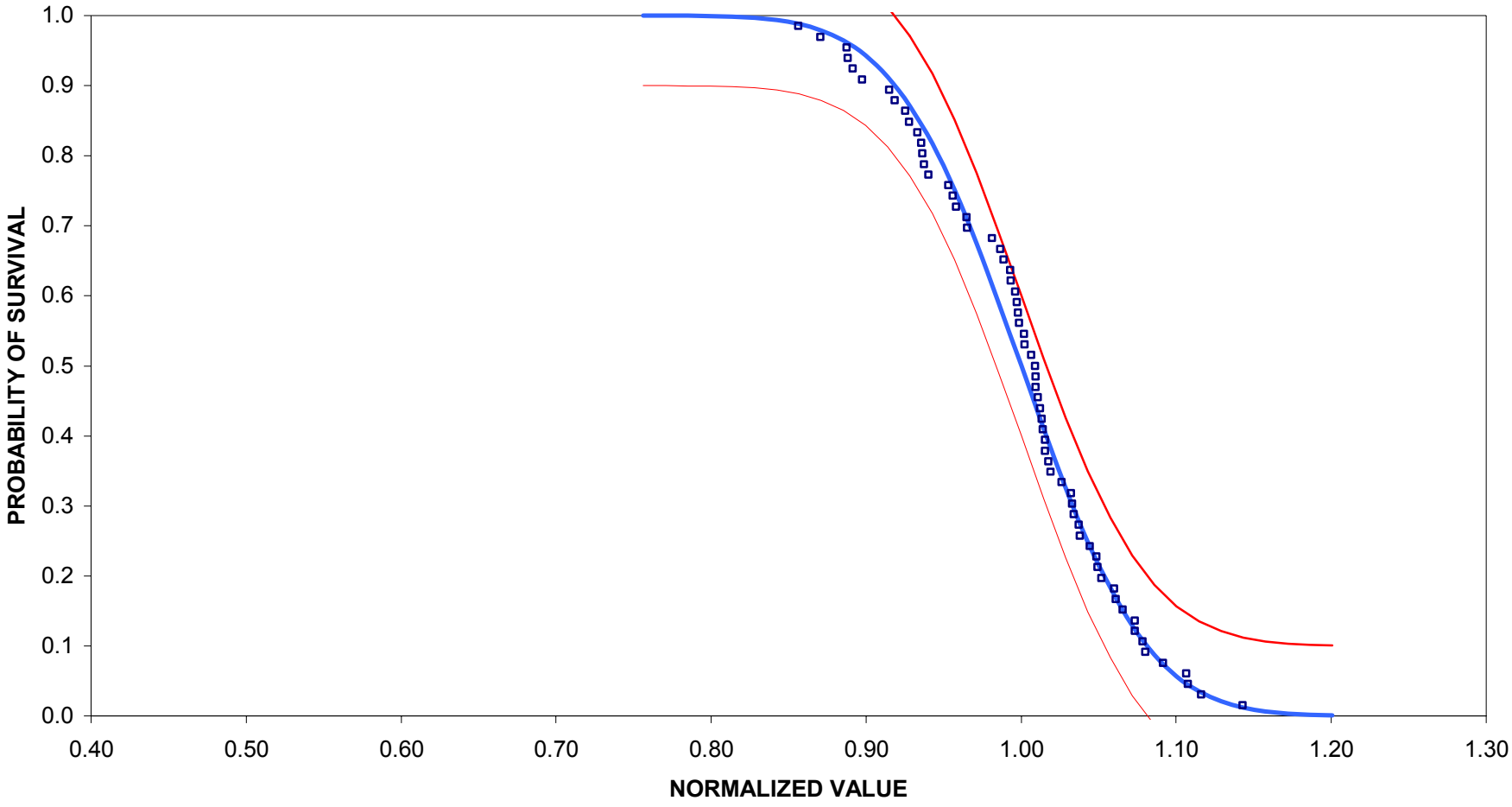
Laminate Compression - mbkxxxxx measured



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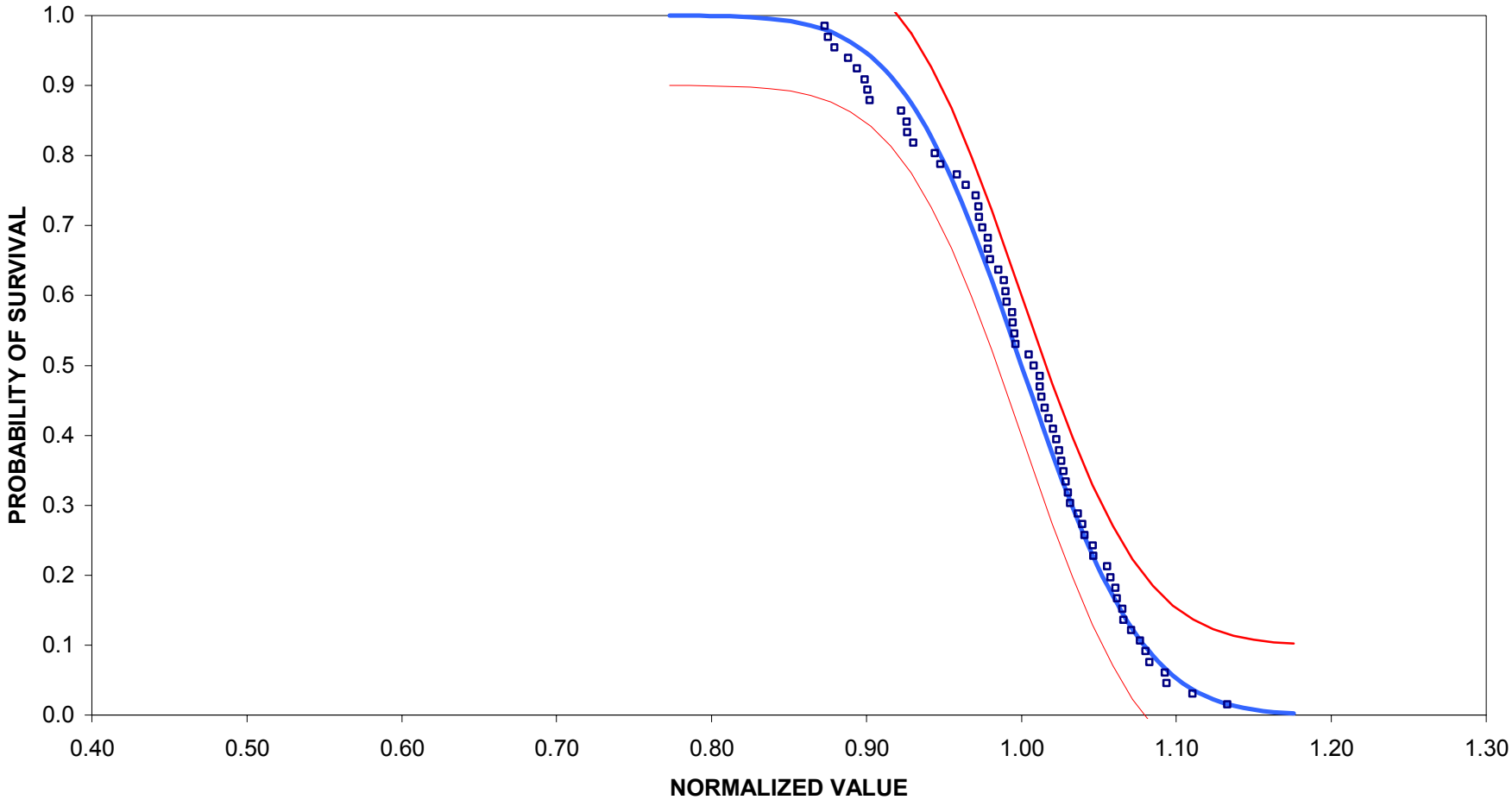
NB-321/7781 Epoxy Glass Cloth

Lancair

Laminate Compression - mbkxxxxx normalized



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NB-321/7781 Epoxy Glass Cloth

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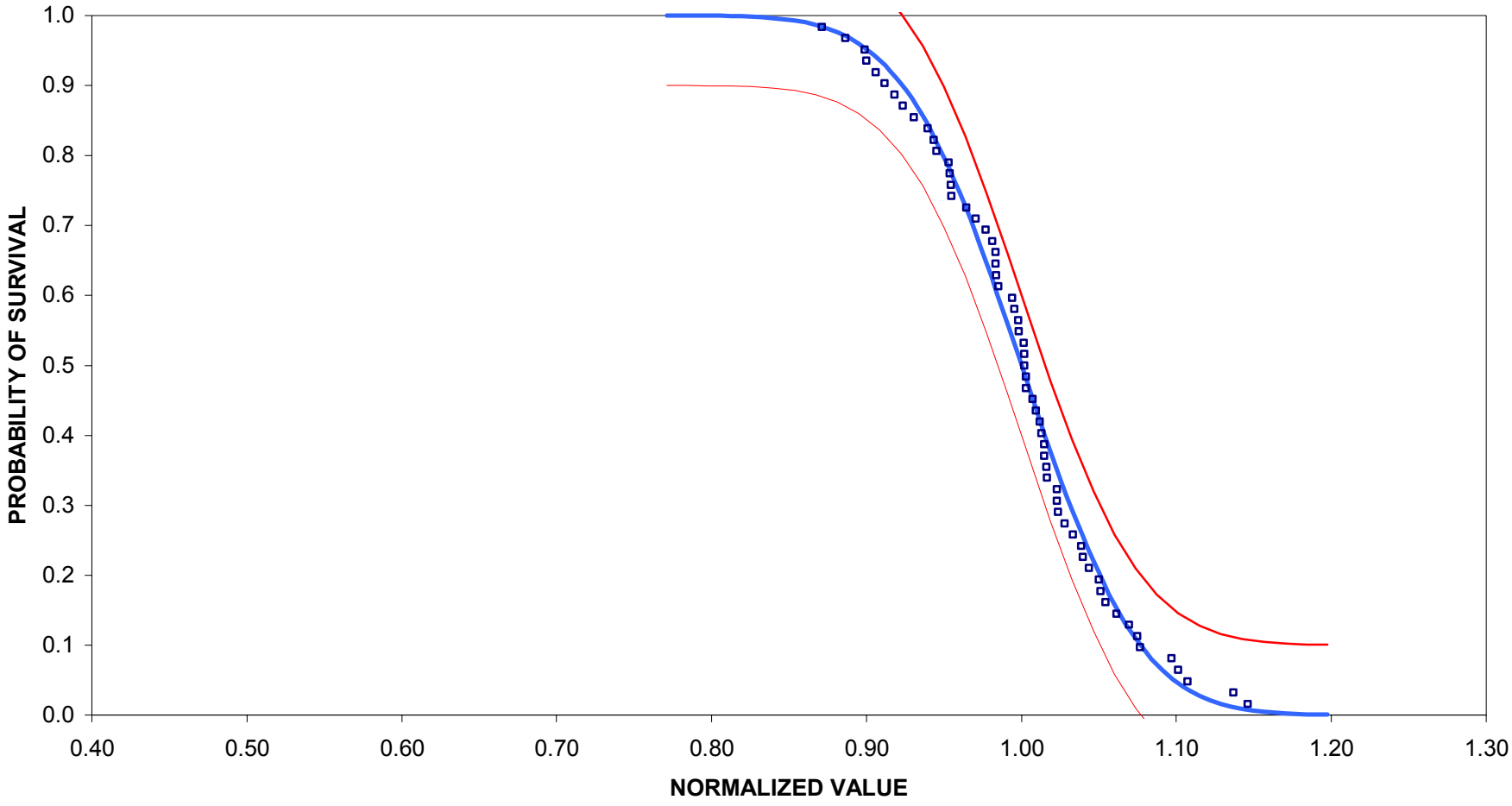
In-Plane Shear - mbnxxxxx measured



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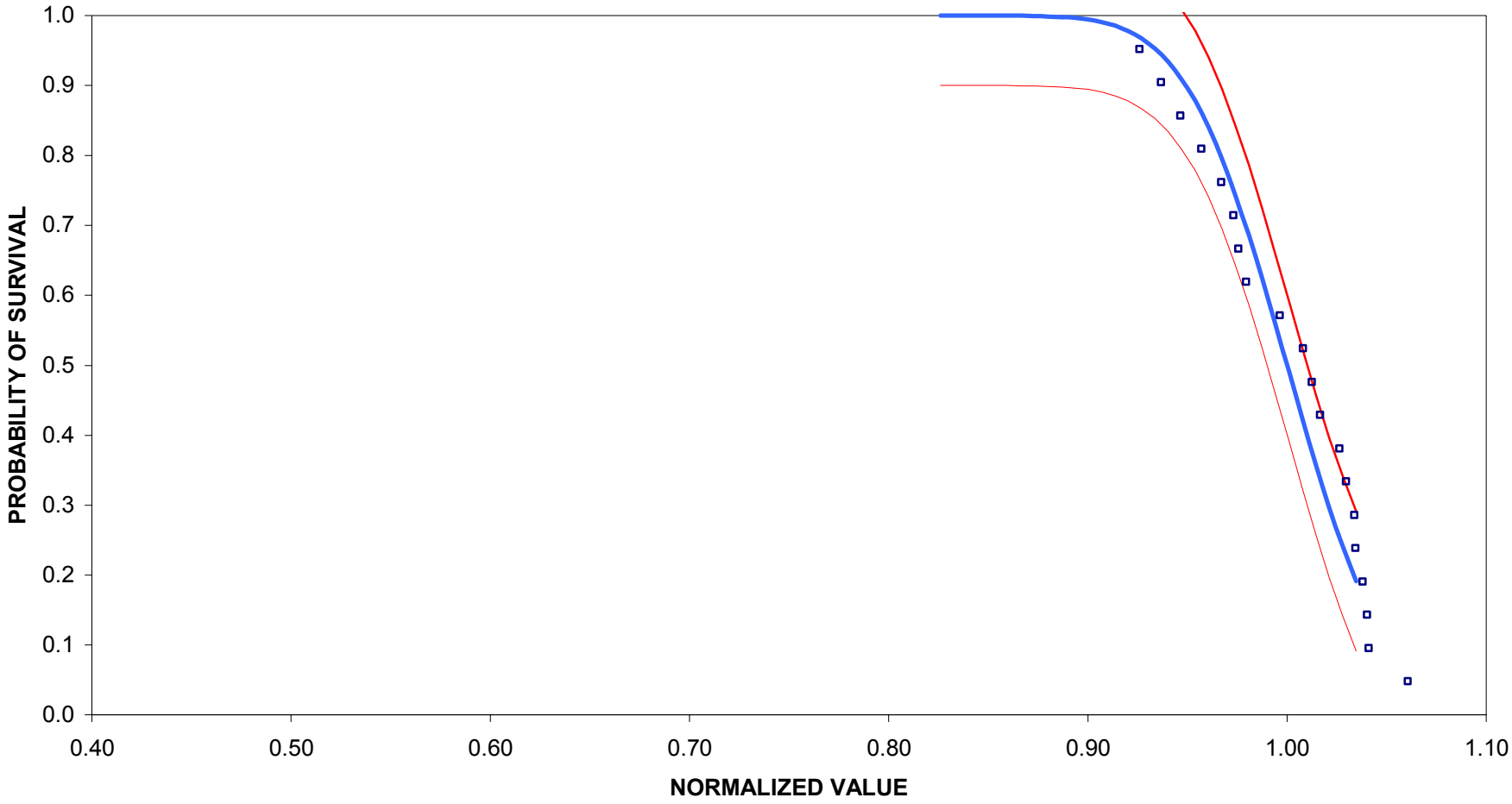
Apparent Interlaminar Shear - mbqxxxxx measured



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3.4 Moisture Conditioning History Charts

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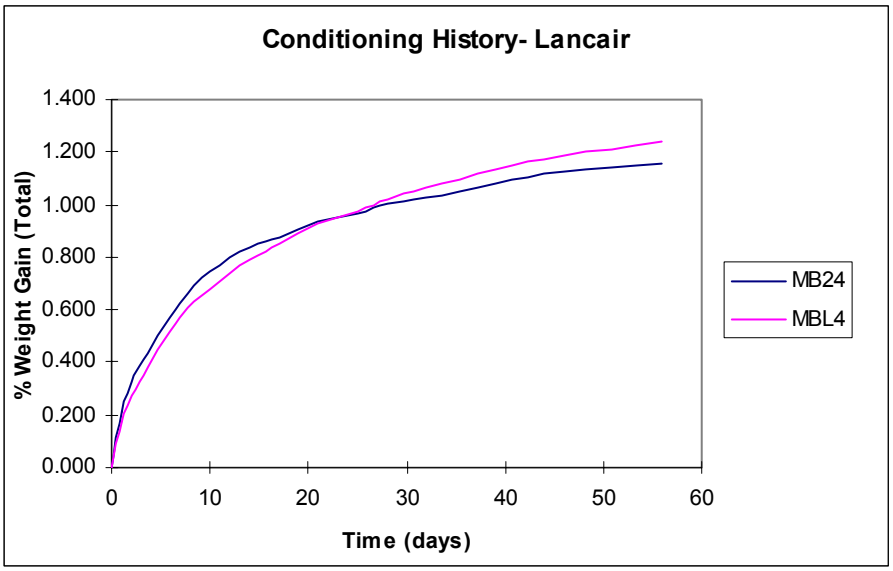

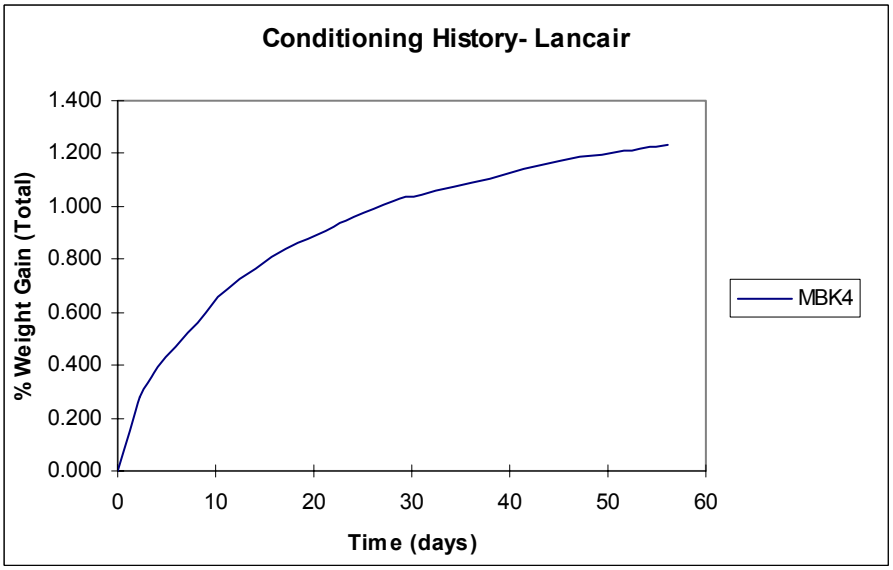

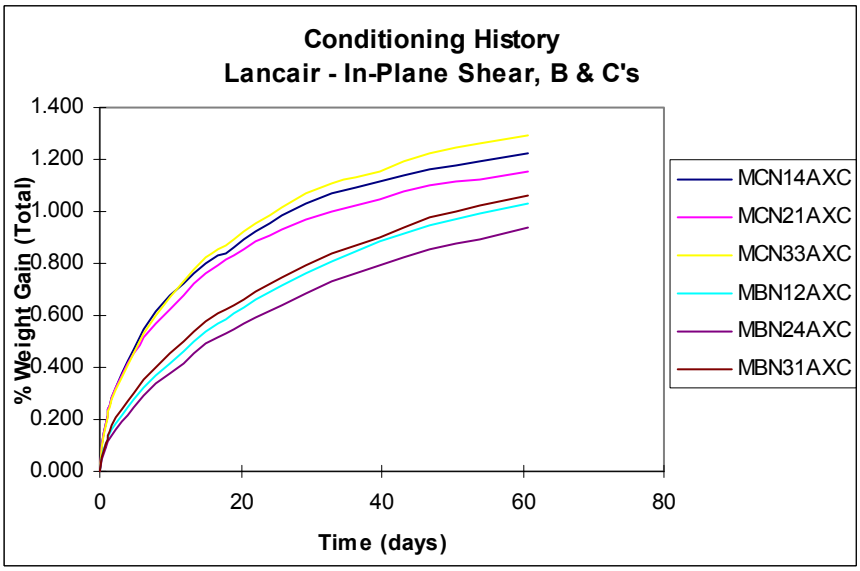

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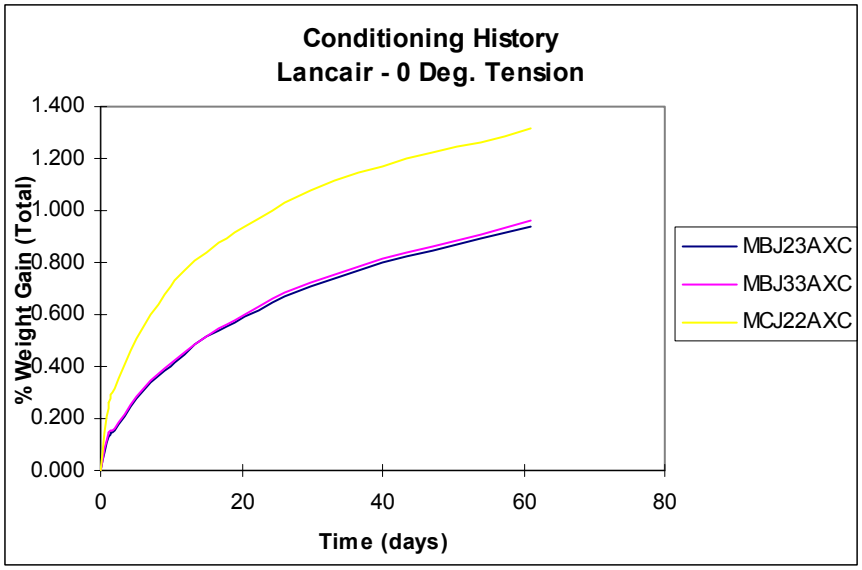

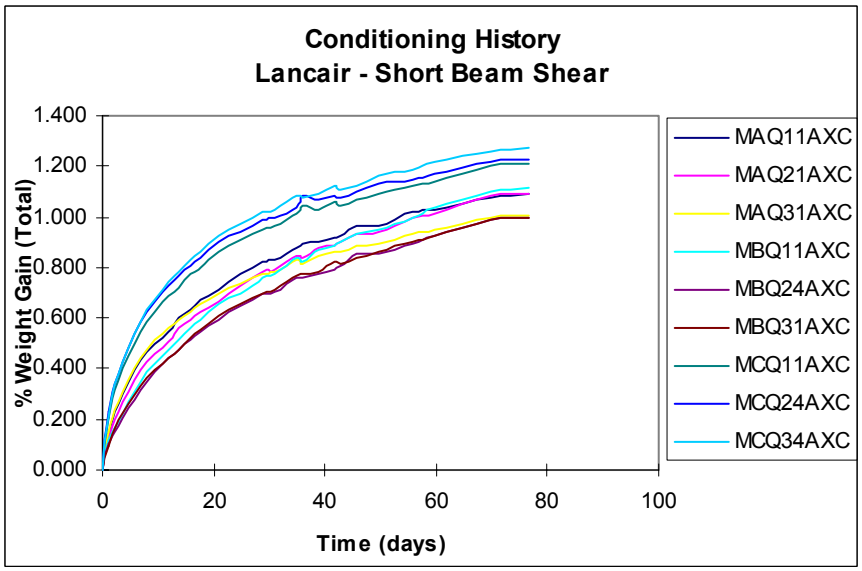

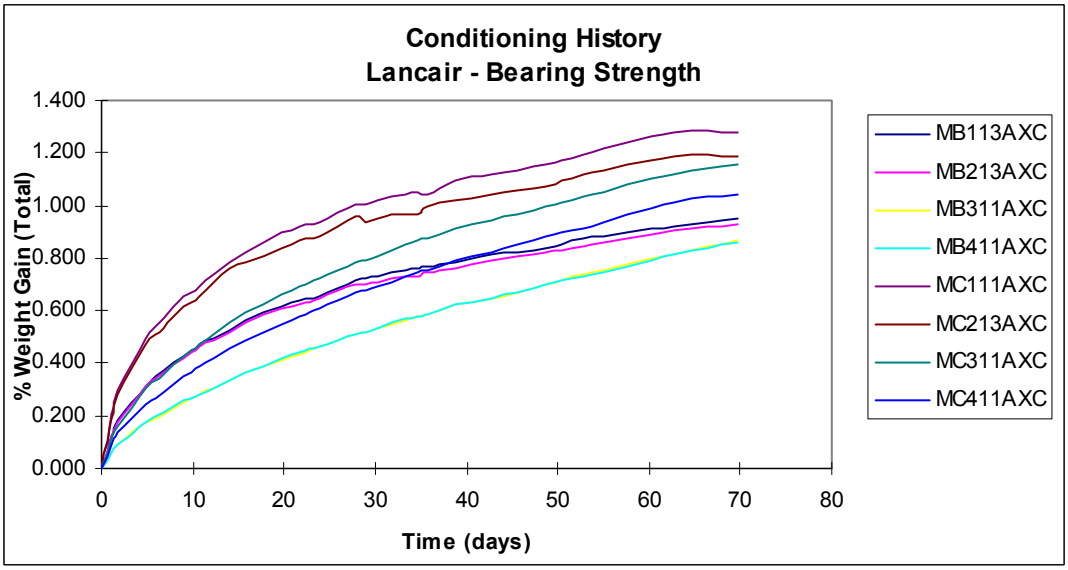

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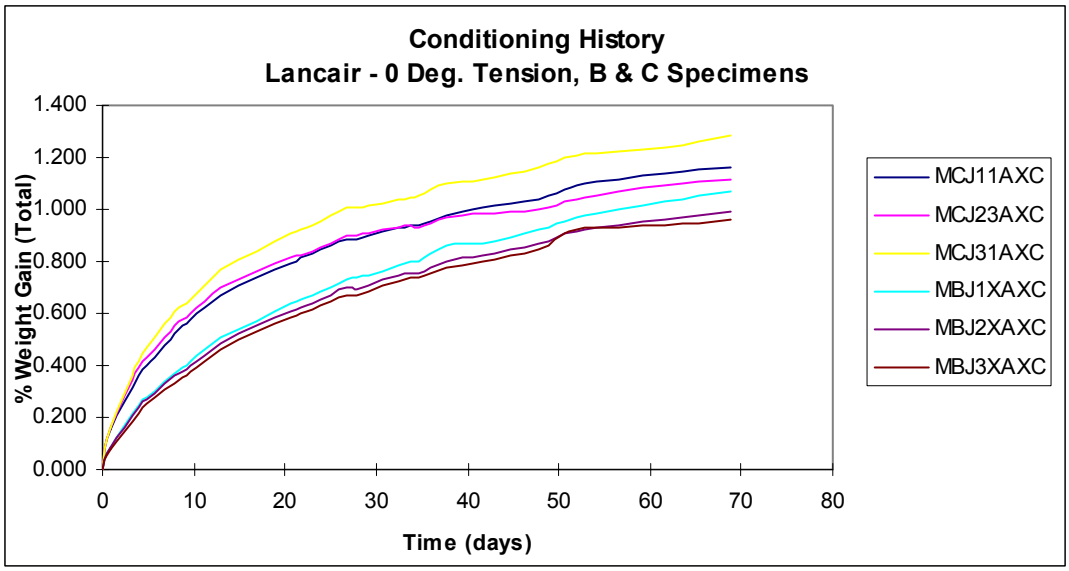

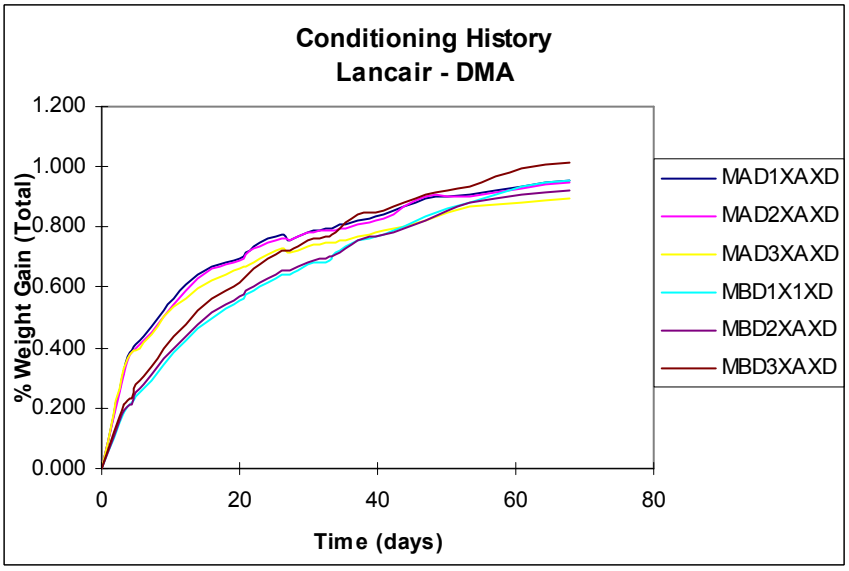

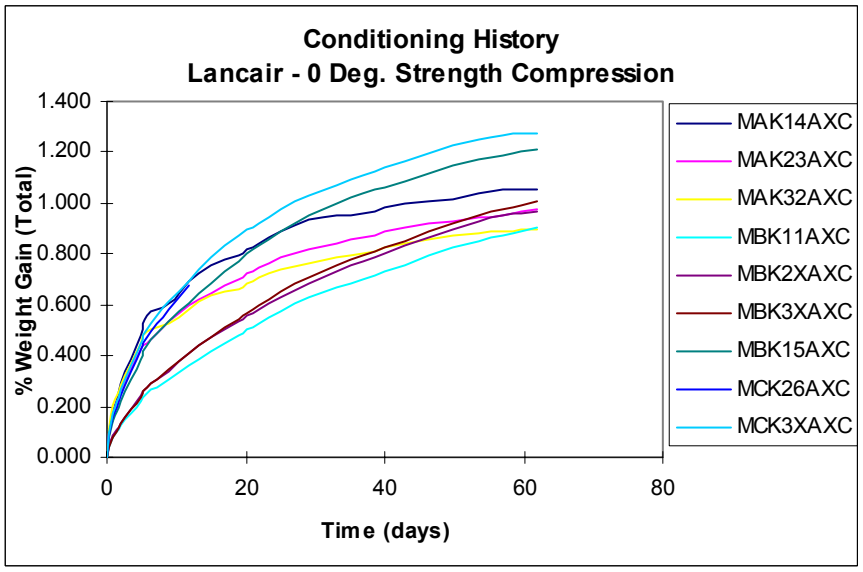

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3.5 DMA Results

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DMA Results

Sample	Tg Onset of Storage Modulus (°C)	Tg Maxima of Loss Modulus (°C)	Tg Maxima of Tan δ (°C)
1 wet	105.8	117.6	124.7
2 wet	107.2	116.2	122.8
3 wet	100.7	111.6	118.7
4 wet	108.7	126.5	135.5
5 wet	110.4	127.0	136.7
6 wet	104.0	126.0	134.8
Average wet	*106.2*	*120.8*	*128.9*

Sample	Tg Onset of Storage Modulus (°C)	Tg Maxima of Loss Modulus (°C)	Tg Maxima of Tan δ (°C)
1 dry	126.4	149.1	160.0
2 dry	135.5	142.4	151.6
3 dry	118.6	138.6	151.8
4 dry	114.5	145.0	162.0
5 dry	109.4	154.4	169.2
6 dry	124.0	156.1	168.6
Average dry	*121.4*	*147.6*	*160.5*

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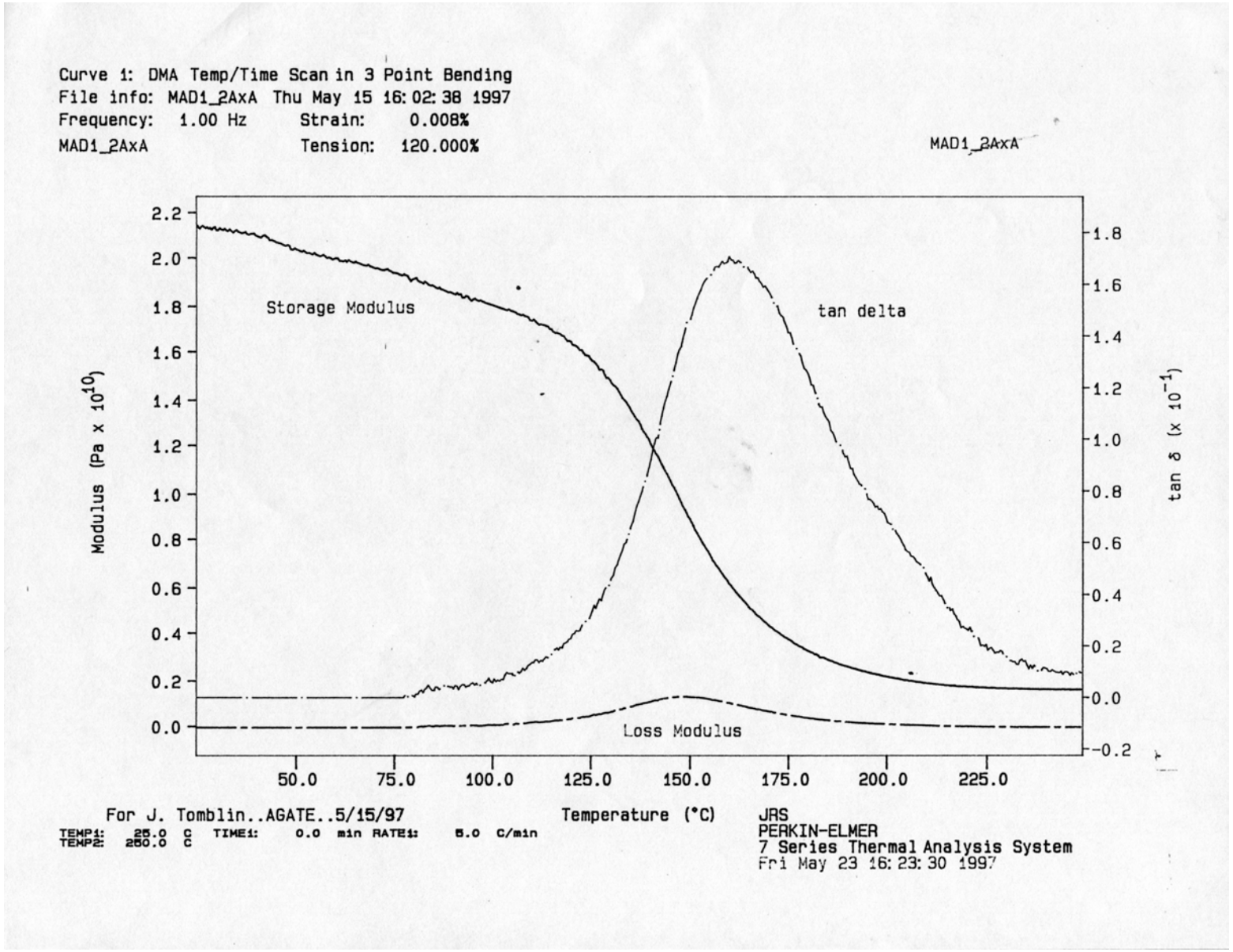

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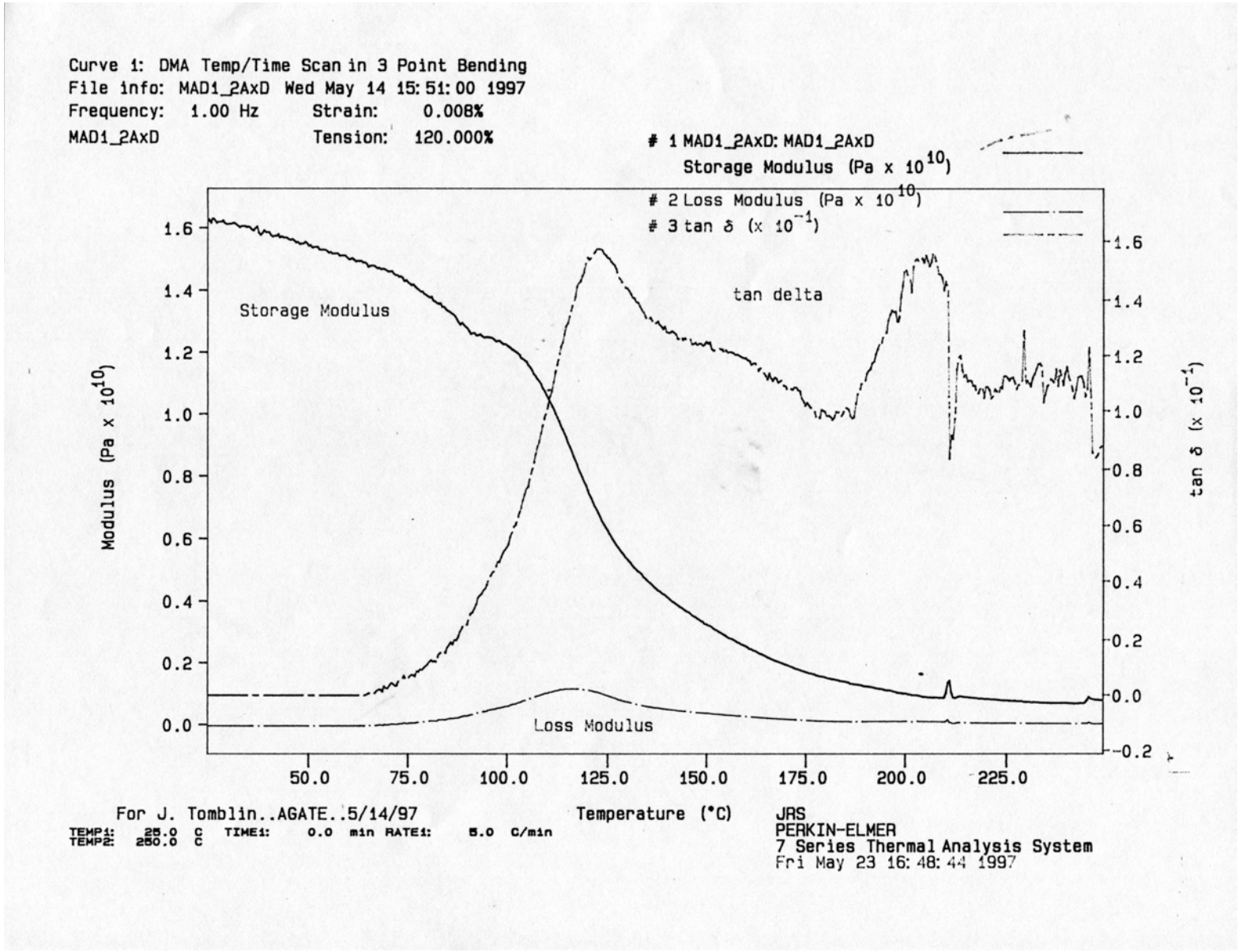

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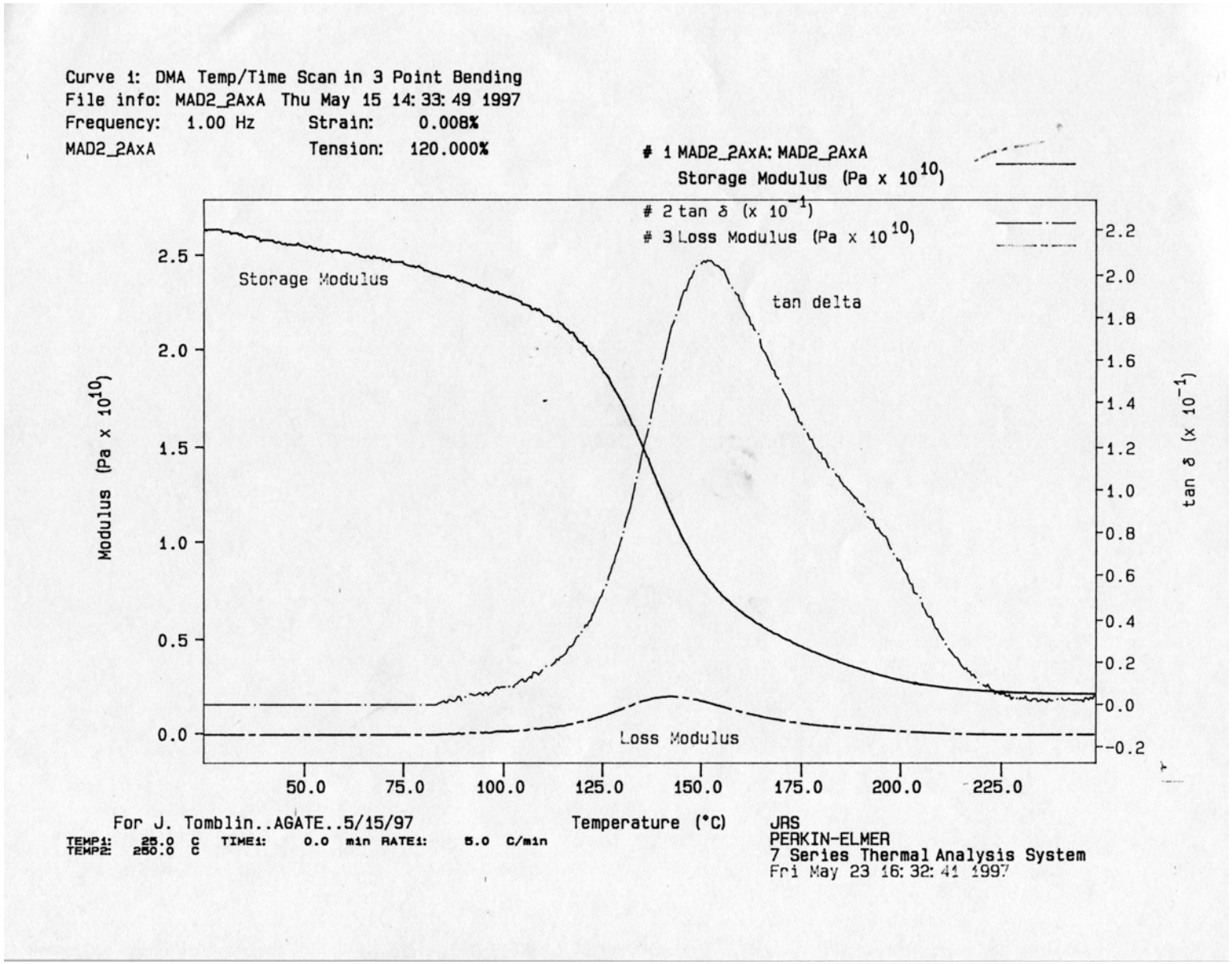

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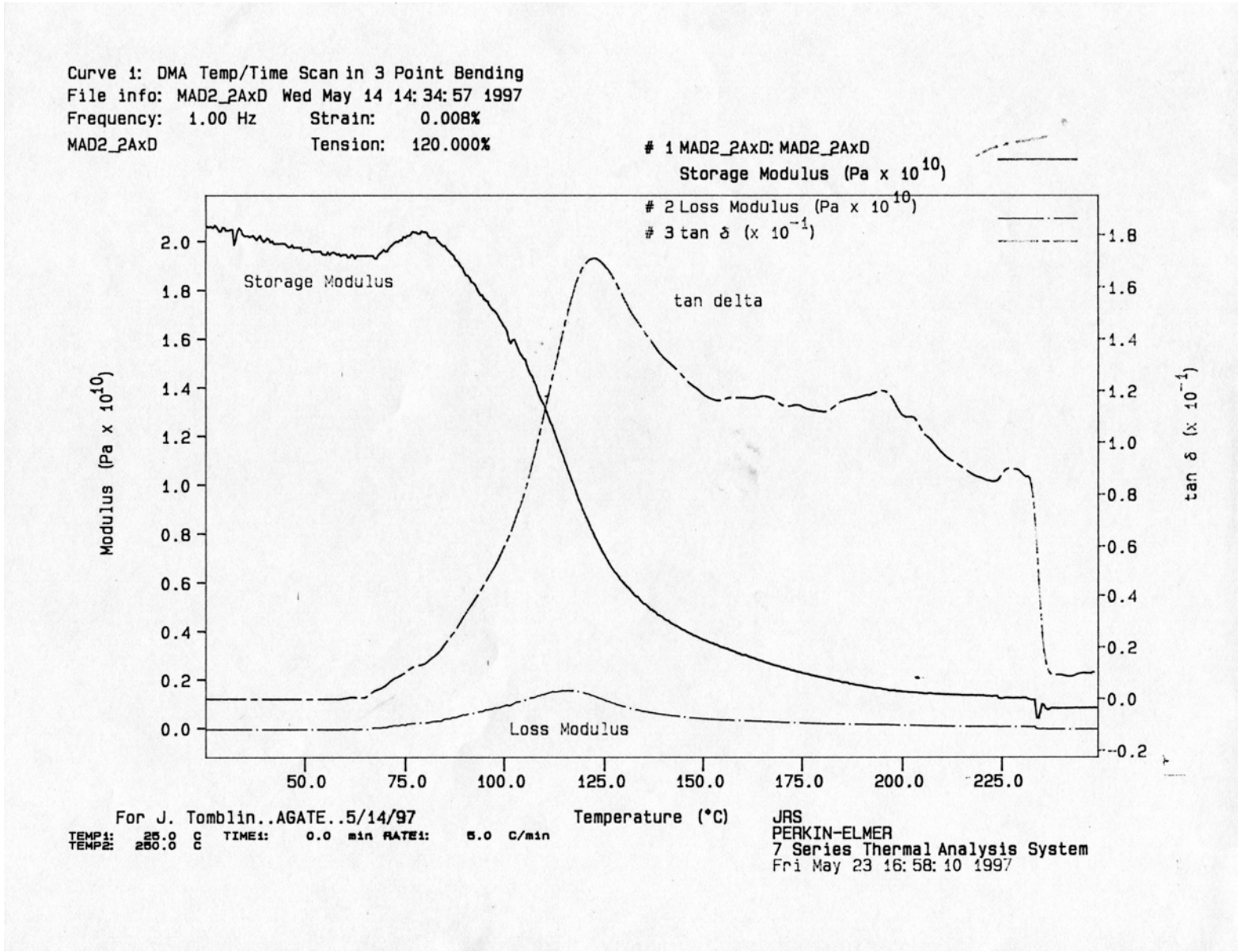

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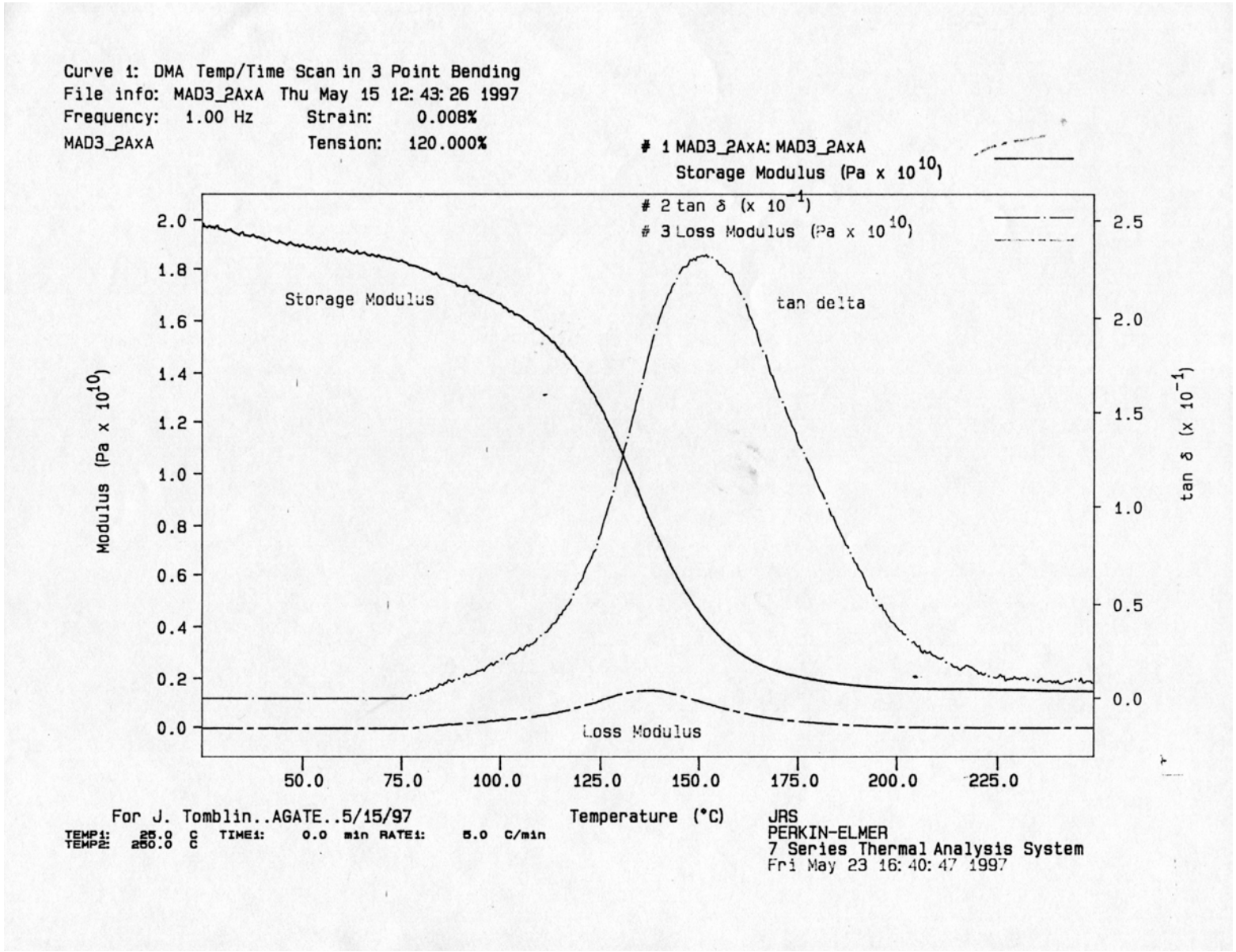

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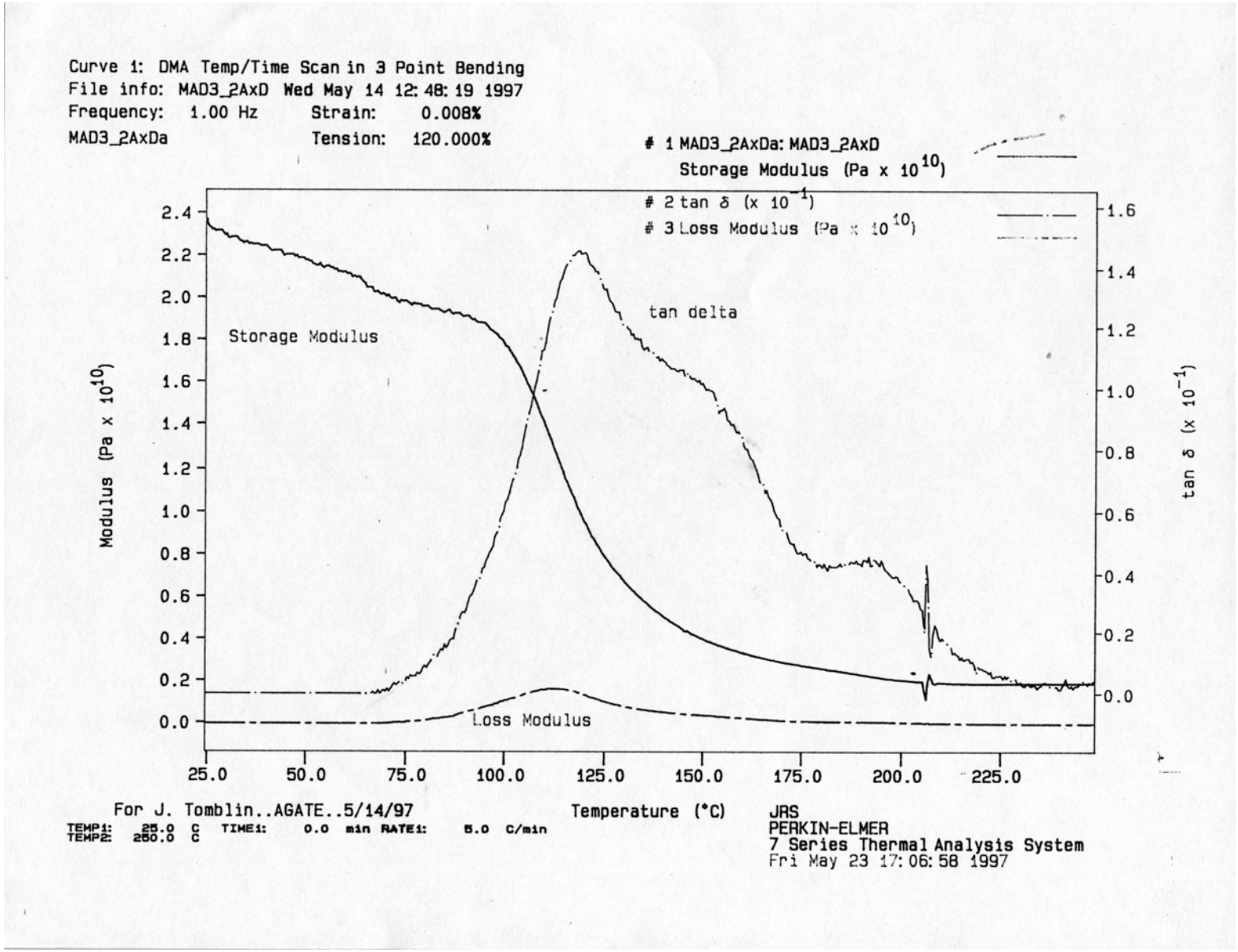

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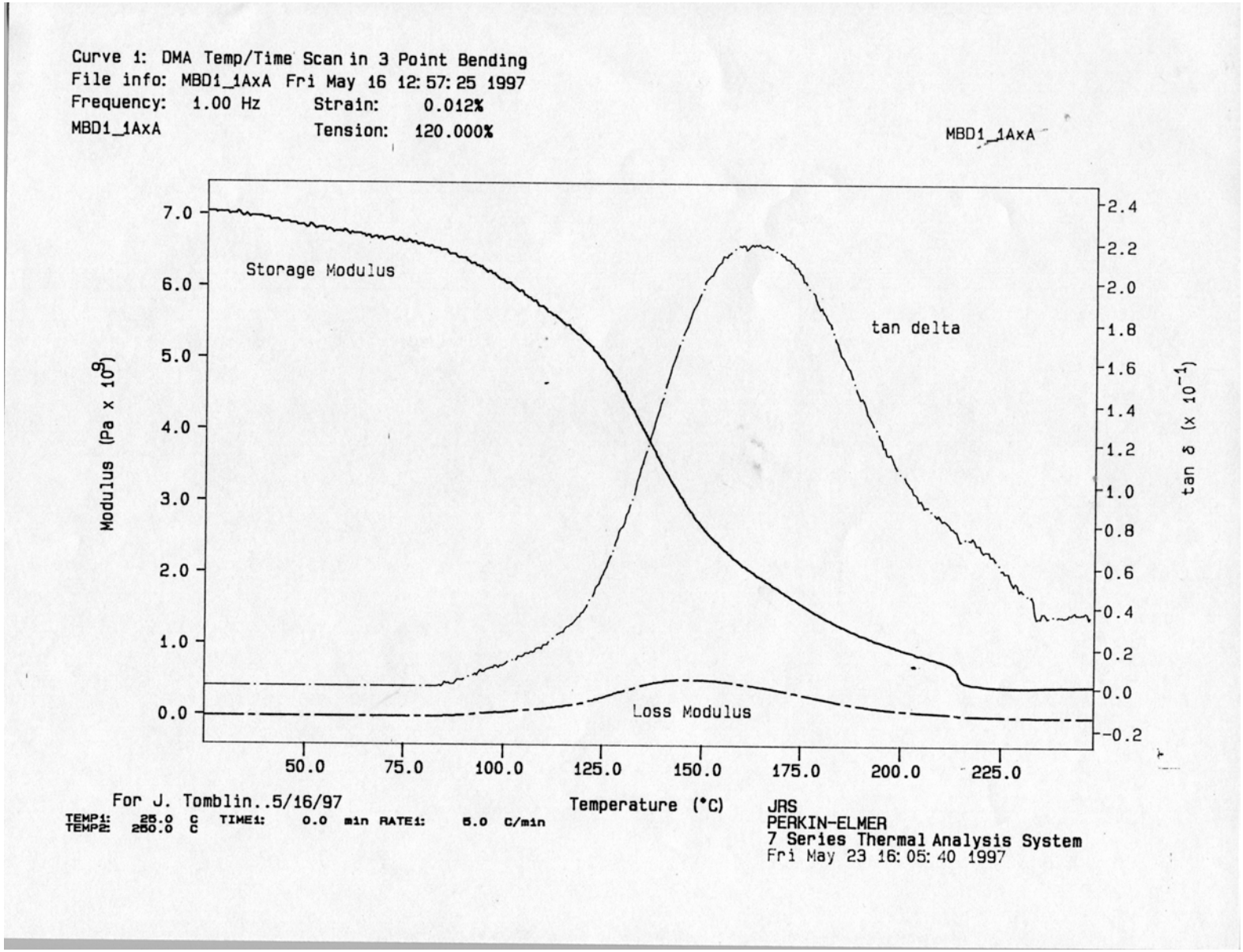

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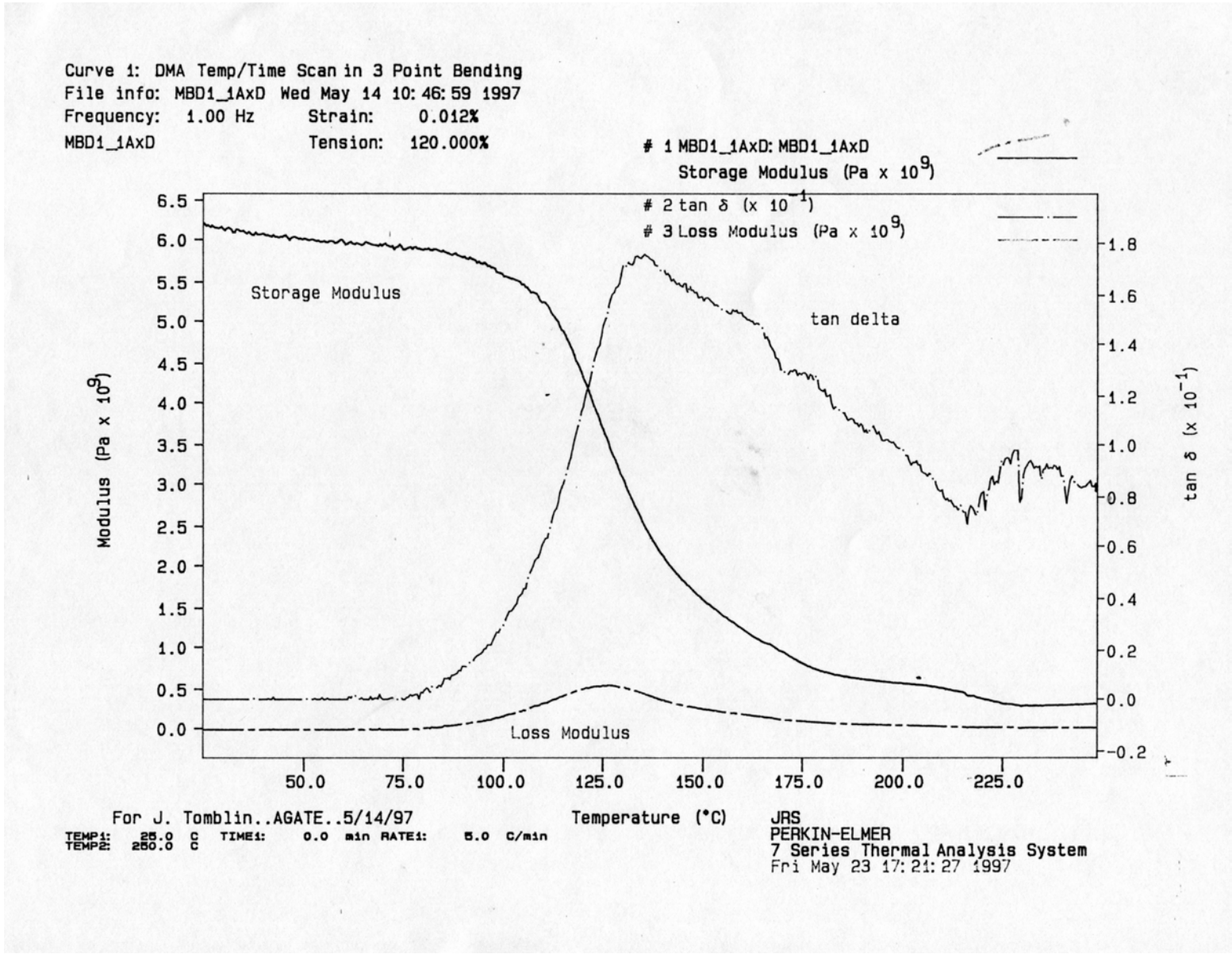

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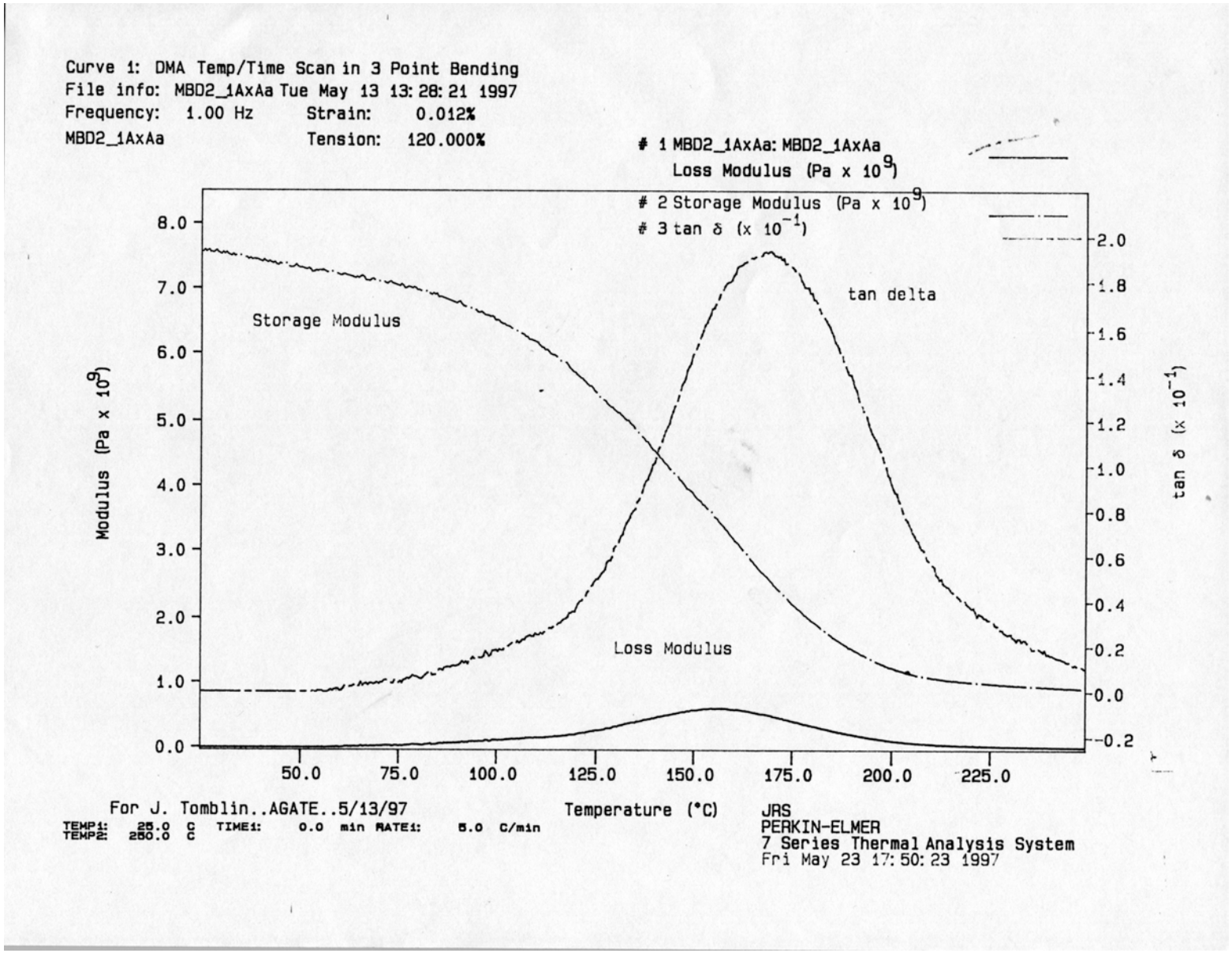

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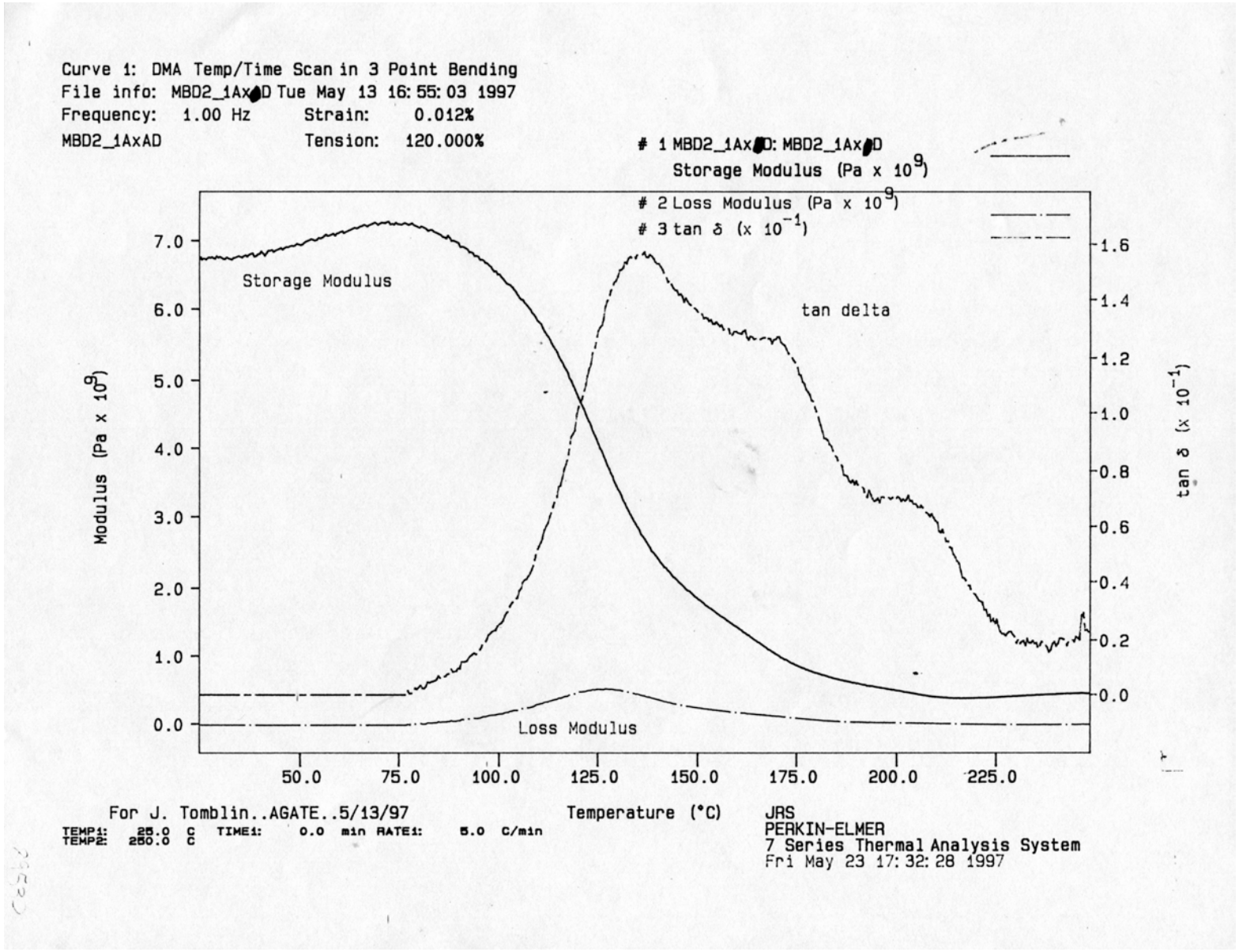

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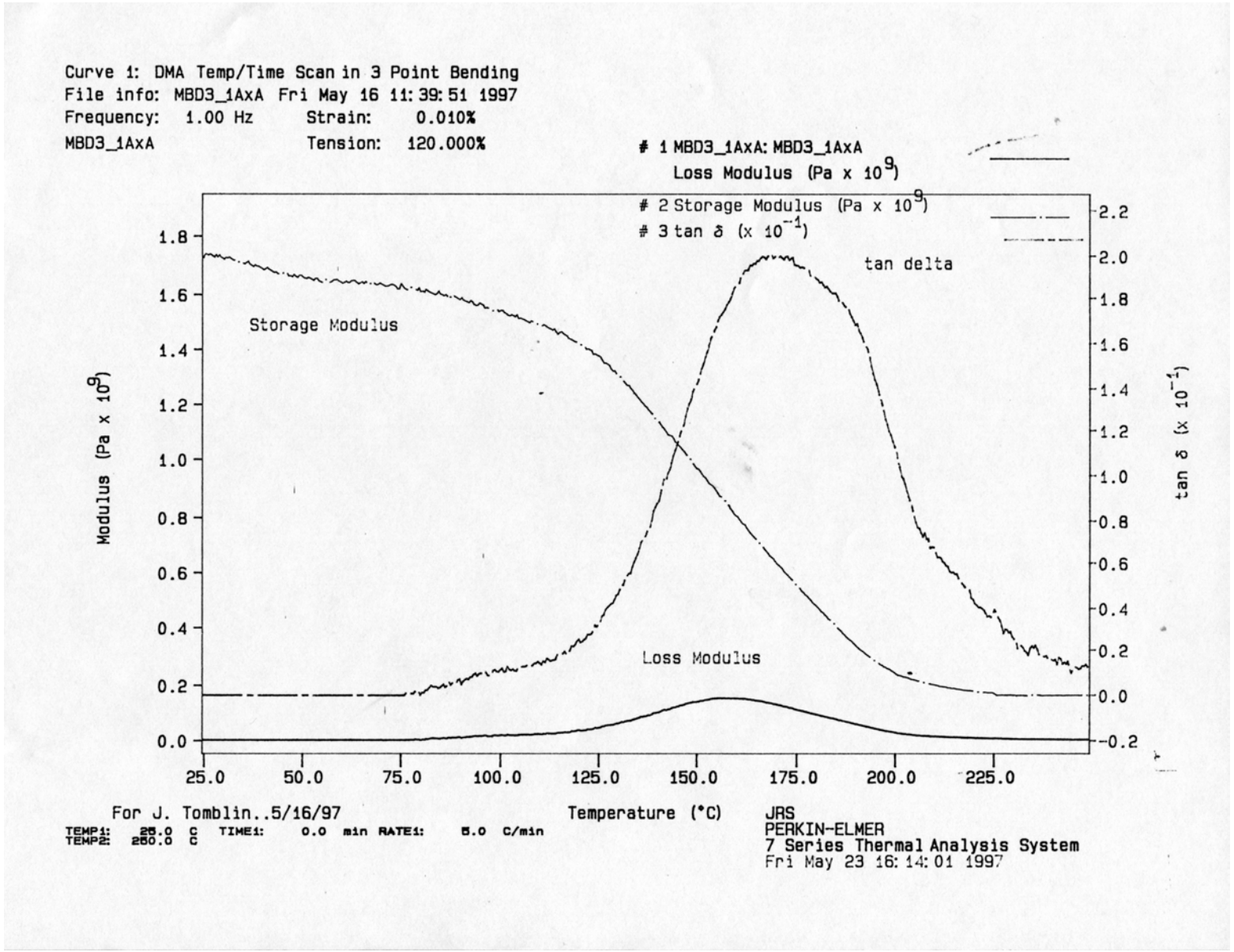

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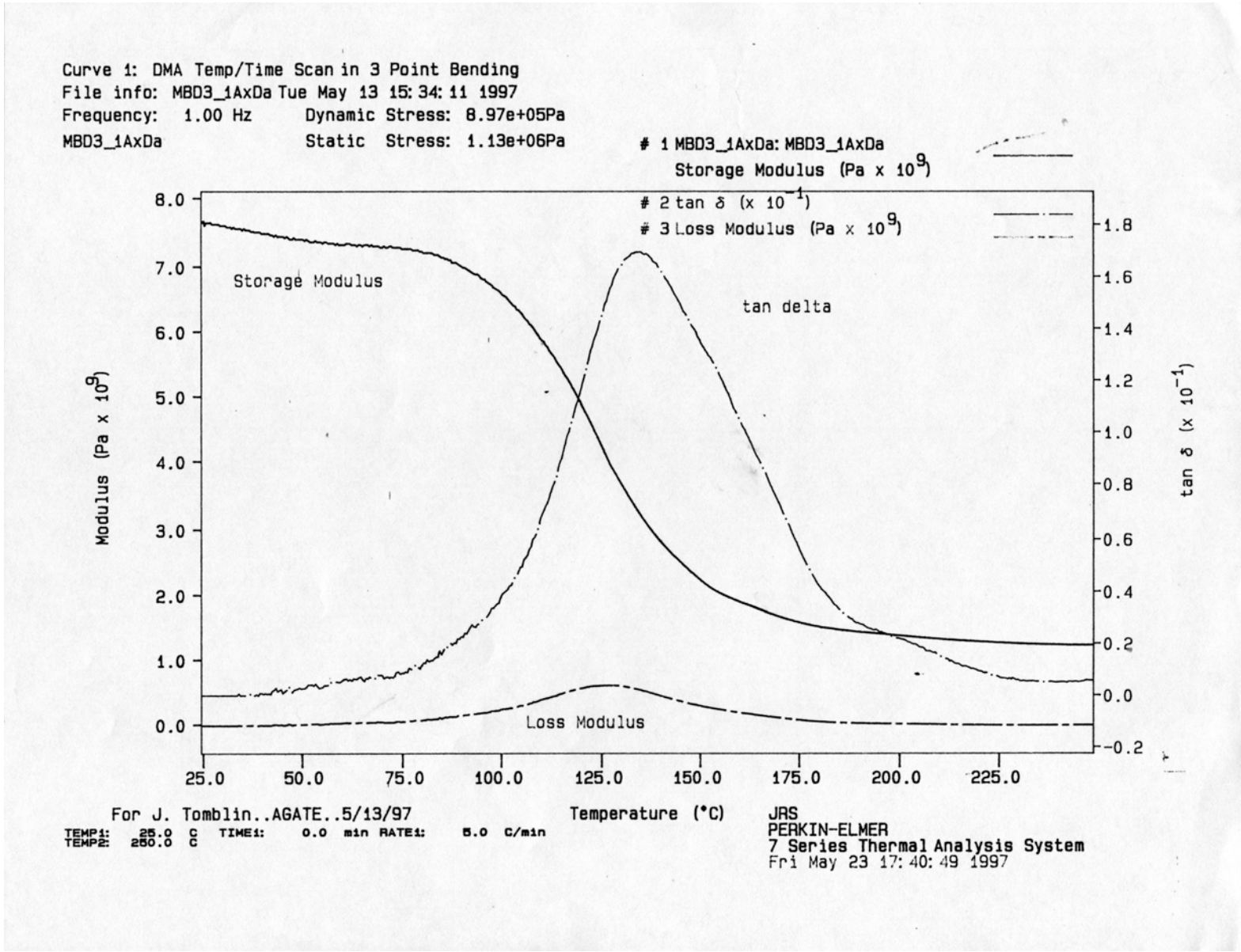

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