Advanced General Aviation Transport Experiments

B – Basis Design Allowables for Epoxy – Based Prepreg

Newport Carbon Plain Weave Fabric 3K70P / NB321

AGATE-WP3.3-033051-095

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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.

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

<u>Superscripts</u>

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

<u>Subscripts</u>

12	in – plane shear
13	interlaminar shear (apparent)

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/Ep	carbon/epoxy
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
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

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
D2734-94	Void Content of Reinforced Plastics
D3171-90	Fiber Content of Resin – Matrix Composites by Matrix Digestion
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

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 3K70P plain weave 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.

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 D3171-90	One sample per panel			
Resin Volume	ASTM D3171-90	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 ± 5° F, moisture content = as fabricated, soak time at –65 was 10 min.)

2 RTD: Three prepreg lots of material tested (test temperature = 70 ± 10° F, moisture content = as fabricated)

3 ETW: Three prepreg lots of material tested (test temperature = 175 ± 5° 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 ± 5° F, moisture content = as fabricated, soak time at 175 was 10 min.)

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:

- 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.

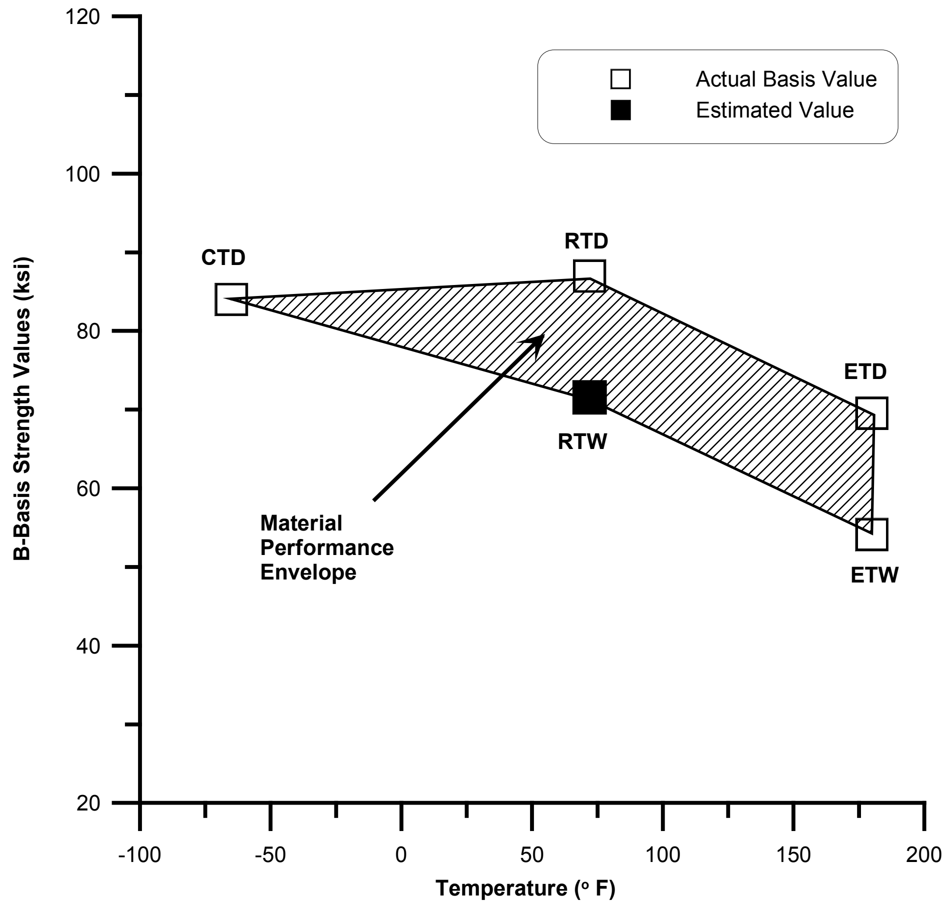


Figure 1.5.1 Material performance envelope.

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

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

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

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

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

$$\text{ETD} \quad : \quad B_{MOL} = 75.106 \text{ ksi}$$

$$\text{ETW} \quad : \quad B_{MOL} = 59.746 \text{ ksi}$$

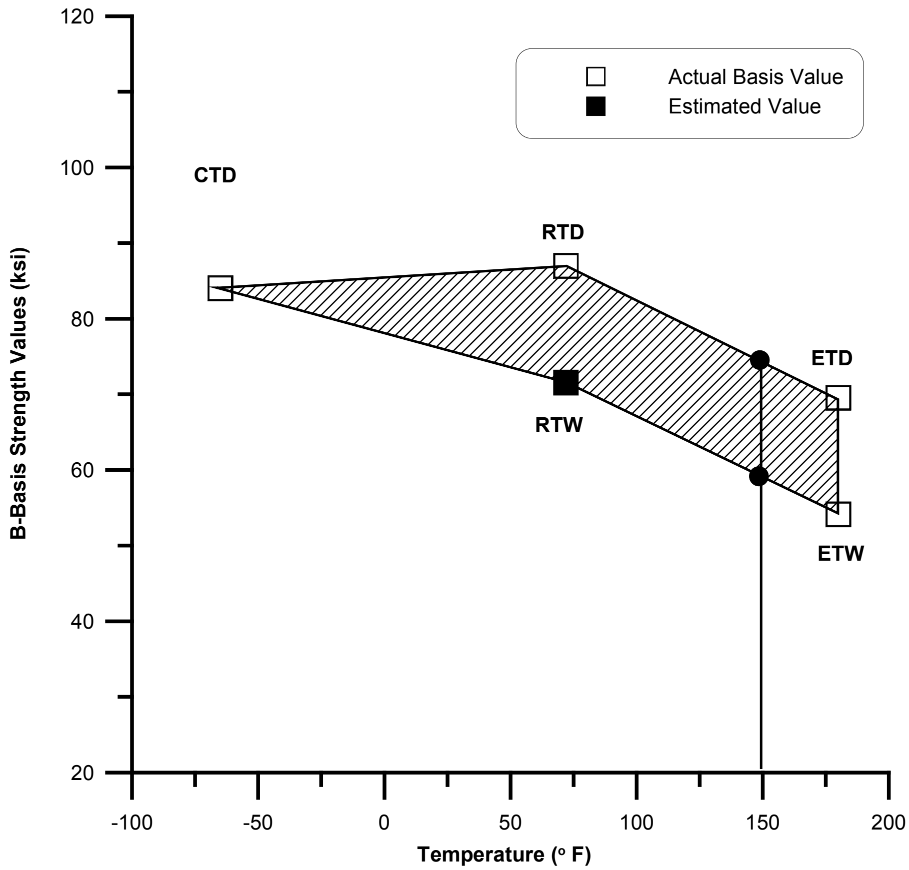


Figure 1.5.2 Example of 150° F interpolation for B-basis values.

2.0 NEWPORT 3K70P / NB 321 PREPREG PROPERTIES

2.1 Prepreg Documentation by Prepreg Lot

Prepreg Documentation	**Prepreg Manufacturer & Product ID: Newport NB321-3K70P** **Impregnation Method: Hot Melt - Direct Coating**		
Prepreg Batch or Lot #	4426A	4601 B	4632 B
Batch # as Labeled on Specimens	1	2	3
Date of Manufacture	4/24/96	7/20/96	8/2/96
Expiration Date	4/25/97	1/23/97	2/5/97
Resin Content [%]	42±3%		
Reinforcement Areal Weight & Test Method	0.040 lb/ft^2 NACTM 013		
Resin Flow & Test Conditions	25.8% 275°F/25 psi	20.6% 275°F/25 psi	26.4% 275°F/25 psi
Gel Time & Test Conditions	7min 35sec @ 275°F	6min 21sec @ 275°F	6min 2sec @ 275°F
Volatile Content	Not Tested (less than 0.5% typical)		
Reinforcement Documentation	**Fiber/Fabric Manufacturer & Product ID: Hercules AS4C-M** **Precursor Type: HI SPAN Precursor 3K PAN** **Nominal Filament Count: 3000** **Finish/Sizing Type and %: 1.0-1.4%** **Nominal tow or yarn count/inch:12.0 X 12.0**		
Fabric Batch or Lot #	D1073-5D	D1073-5D	D1370-6C
Date of Manufacture	8/8/95	8/8/95	5/26/96
Average Fiber Density per Lot & Test Method	1.79 g/cm^3 ASTM D792		
Matrix Documentation	**Resin Manufacturer & Product ID: Newport NB321**		
Matrix Batch or Lot #	4426A	4601B	4632B
Date of Manufacture	4/24/96	7/20/96	8/2/96
Average Neat Resin Density by Lot & Test Method	1.20 g/cm^3 ASTM D792		

Note: The fabric was woven without a selvage edge resulting in excessive fiber misalignment.

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.

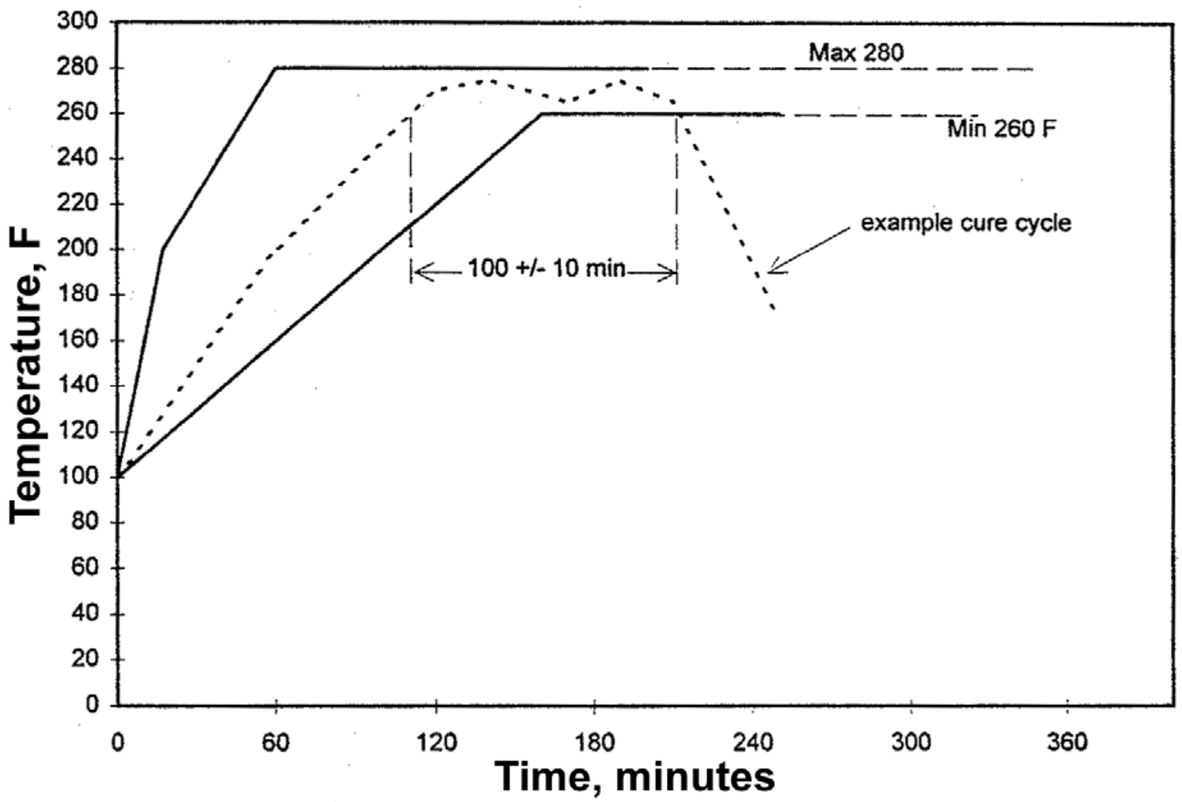


Figure 2.2: Sample prepreg cure cycle 3K70P / NB321 carbon fabric.
Figure courtesy of Pacific Aviation Composites, USA LLC.

3.0 NEWPORT 3K70P / NB 321 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 <u>lamina</u> properties of the prepreg. Therefore, the term <u>laminate</u> is used throughout the document for clarity.

3.1 Test Results

3.1.1 Summary

MATERIAL:	NB321/3K70P Carbon Cloth		**NB321/3K70P Summary**
PREPREG:	Newport NB321/3K70P Carbon Cloth (1.1% sizing)		
FIBER:	Hexcel AS4C-M 3K	**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	8/95 -- 5/96	**Date of testing**	12/96 -- 4/97
Date of resin manufacture	4/96 – 8/96	**Date of data submittal**	4/98
Date of prepreg manufacture	4/96 -- 8/96	**Date of analysis**	12/96 -- 5/97
Date of composite manufacture	5/96 – 10/96		

LAMINATE MECHANICAL PROPERTY SUMMARY
Data Reported as: Measured
(Normalized by CPT=0.0085 in)

	CTD		RTD		ETD		ETW	
	B-Basis	Mean	B-Basis	Mean	B-Basis	Mean	B-Basis	Mean
F_1^{tu} (ksi)	64.26 (63.26)	83.28 (80.93)	72.41 (71.16)	89.95 (87.45)	---	---	61.51 (60.14)	76.41 (73.90)
E_1^t (Msi)	---	8.15 (7.92)	---	9.62 (9.28)	---	---	---	8.39 (8.16)
ν_{12}^{tu}	---	---	---	0.058	---	---	---	---
F_1^{cu} (ksi)	59.00 (60.41)	74.67 (78.74)	56.78 (57.01)	69.23 (71.21)	34.18 (33.97)	41.78 (42.55)	45.87 (45.99)	55.78 (57.27)
E_1^c (Msi)	---	7.33 (7.75)	---	7.91 (8.24)	---	---	---	8.14 (8.42)
F_{12}^{su} (ksi)	14.60	18.00	13.88	16.67	10.85	13.02	9.20	11.06
G_{12}^s (Msi)	---	0.72	---	0.62	---	---	---	0.43
F_{13}^{su**} (ksi)	---	---	7.16	8.77	---	---	---	---

** *Apparent* interlaminar shear strength

3.1.2 Individual Test Summaries

3.1.2.1 Tension, Laminate

Tension, Laminate
C/Ep
Newport NB321/3K70P
$[0_f/90_f/0_f/90_f/0_f/90_f/0_f/90_f/0_f]$

Material: Newport NB321/3K70P carbon cloth

Resin content: 38 - 44 wt. % **Comp. density:** 1.46 - 1.50 g/cc
Fiber volume: 46 - 52 % **Void content:** 0.6 - 2.6 %
Ply thickness: 0.0080-0.0087 in.
Ply range: 9 ply

Test method: D3039-95 **Modulus calculation:** linear fit from 1000 - 3000 $\mu\varepsilon$

Normalized by: 0.0085 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		MCJXXXXB		MCJXXXXA				MCJXXXXC					
		Normalized	**Measured**	**Normalized**	**Measured**	**Normalized**	**Measured**	**Normalized**	**Measured**	**Normalized**	**Measured**	**Normalized**	**Measured**
	Mean	80.93	83.28	87.45	89.95			73.90	76.41				
	Minimum	75.94	77.92	69.63	72.40			52.82	53.54				
	Maximum	85.69	90.09	104.03	106.51			84.77	89.90				
	C.V.(%)	4.72	5.82	9.41	9.23			13.12	14.08				
F^{tu}													
(ksi)	**B-value**	63.26	64.26	71.16	72.41			60.14	61.51				
	A-value	53.30	53.52	60.00	60.40			50.70	51.30				
	No. Specimens	6		22				22					
	No. Prepreg Lots	1		3				3					
	Mean	7.92	8.15	9.28	9.62			8.16	8.39				
	Minimum	7.67	7.74	8.16	8.22			7.47	7.53				
	Maximum	8.32	8.45	10.47	10.92			8.66	8.97				
E^t	**C.V.(%)**	2.71	3.70	10.08	11.17			5.06	6.08				
(Msi)													
	No. Specimens	6		14				9					
	No. Prepreg Lots	1		3				3					
	Mean				0.058								
ν_{12}^t	**No. Specimens**			3									
	No. Prepreg Lots			3									

3.1.2.2 Compression, Laminate

Compression,Laminate
C/Ep
Newport NB321/3K70P
$[0_f/90_f]_{3s}$

Material: Newport NB321/3K70P carbon cloth

Resin content: 42 - 45 wt. %
Comp. density: 1.47 - 1.49 g/cc
Fiber volume: 45 - 48 %
Void content: 0.1 - 2.0 %
Ply thickness: 0.0083 - 0.0095 in.
Ply range: 12 ply

Test method: SRM 1-94, D695-91 (mod)
Modulus calculation: linear fit from 1000 - 3000 $\mu\varepsilon$

Normalized by: 0.0085 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		MCKXXXXB		MCKXXXXA		MCKXXXXE		MCKXXXXC					
		Normalized	Measured	Normalized	Measured	Normalized	Measured	Normalized	Measured	Normalized	Measured	Normalized	Measured
F^{cu} (ksi)	**Mean**	78.74	74.67	71.21	69.23	42.55	41.78	57.27	55.78				
	Minimum	70.47	68.46	53.10	52.97	37.92	36.29	43.51	42.06				
	Maximum	85.29	81.12	84.14	77.44	52.03	50.30	75.41	71.22				
	C.V.(%)	7.11	6.70	11.74	9.66	9.91	9.63	13.87	12.71				
	B-value	60.41	59.00	57.01	56.78	33.97	34.18	45.99	45.87				
	A-value	50.19	50.26	47.50	48.45	28.31	29.17	38.32	39.14				
	No. Specimens	6		20		18		23					
	No. Prepreg Lots	1		3		3		3					
E^c (Msi)	**Mean**	7.75	7.33	8.24	7.91			8.42	8.14				
	Minimum	7.51	7.06	7.53	7.17			7.78	7.57				
	Maximum	7.99	7.59	8.58	8.39			8.63	8.38				
	C.V.(%)	4.36	5.18	5.72	6.55			3.80	3.65				
	No. Specimens	2		6				6					
	No. Prepreg Lots	1		3				3					

3.1.2.3 Shear, 12 axis

Shear, 12-axis
C/Ep
Newport NB321/3K70P
$[(0_f/90_f)_2/0_f]_s$

Material: Newport NB321/3K70P carbon cloth

Resin content: 38 - 43 wt. % **Comp. density:** 1.44 - 1.49 g/cc
Fiber volume: 48 - 50 % **Void content:** 0.4 - 3.6 %
Ply thickness: 0.0080-0.0090 in.
Ply range: 10 ply

Test method: D5379-93 **Modulus calculation:** linear fit from 1000 - 6000 $\mu\varepsilon$

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		MCNXXXXB		MCNXXXXA		MCNXXXXE		MCNXXXXC					
		Normalized	Measured	Normalized	Measured	Normalized	Measured	Normalized	Measured	Normalized	Measured	Normalized	Measured
F_{12}^{su} (ksi)	Mean		18.00		16.67		13.02		11.06				
	Minimum		17.44		14.32		10.72		9.63				
	Maximum		18.77		19.94		15.12		12.84				
	C.V.(%)		2.71		11.33		10.09		9.40				
	B-value		14.60		13.88		10.85		9.20				
	A-value		12.65		12.03		9.40		7.98				
	No. Specimens	6		18		19		18					
	No. Prepreg Lots	1		3		3		3					
G_{12}^{s} (Msi)	Mean		0.72		0.62				0.43				
	Minimum		0.72		0.55				0.32				
	Maximum		0.73		0.73				0.51				
	C.V.(%)		0.60		11.23				17.97				
	No. Specimens	2		6				6					
	No. Prepreg Lots	1		3				3					

3.1.2.4 Shear, 13 axis

Shear, 13-axis
C/Ep
Newport NB321/3K70P
$[0_f/90_f/0_f/90_f/0_f/90_f/0_f/90_f/0_f]$

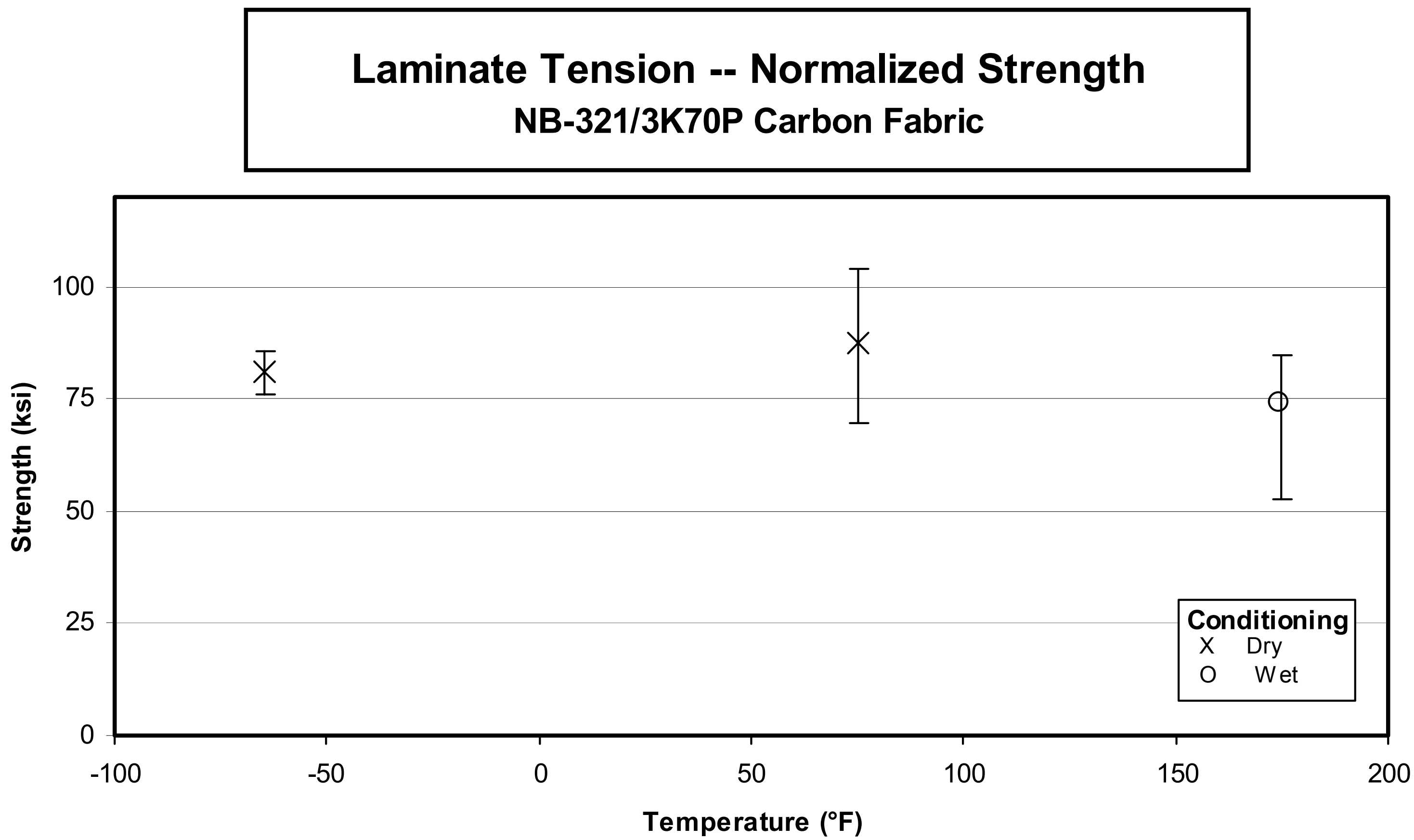
Material:	Newport NB321/3K70P carbon cloth
Resin content:	39 - 44 wt. %
Comp. density:	1.47 - 1.50 g/cc
Fiber volume:	46 - 51 %
Void content:	0.4 - 2.1 %
Ply thickness:	0.0078 - 0.0089 in.
Ply range:	9 ply
Test method:	D2344-89
Modulus calculation:	N/A
Normalized by:	N/A

		CTD		RTD		ETD		ETW					
Test Temperature [°F]				70									
Moisture Conditioning				dry									
Equilibrium at T, RH				as fabricated									
Source code				MCQXXXXA									
		Normalized	Measured	Normalized	Measured	Normalized	Measured			Normalized	Measured	Normalized	Measured
	Mean				8.77								
	Minimum				7.55								
	Maximum				10.48								
	C.V.(%)				10.17								
F_{13}^{su}													
(ksi)	**B-value**				7.16								
	A-value				5.99								
	No. Specimens				28								
	No. Prepreg Lots				3								

Note(s):
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.

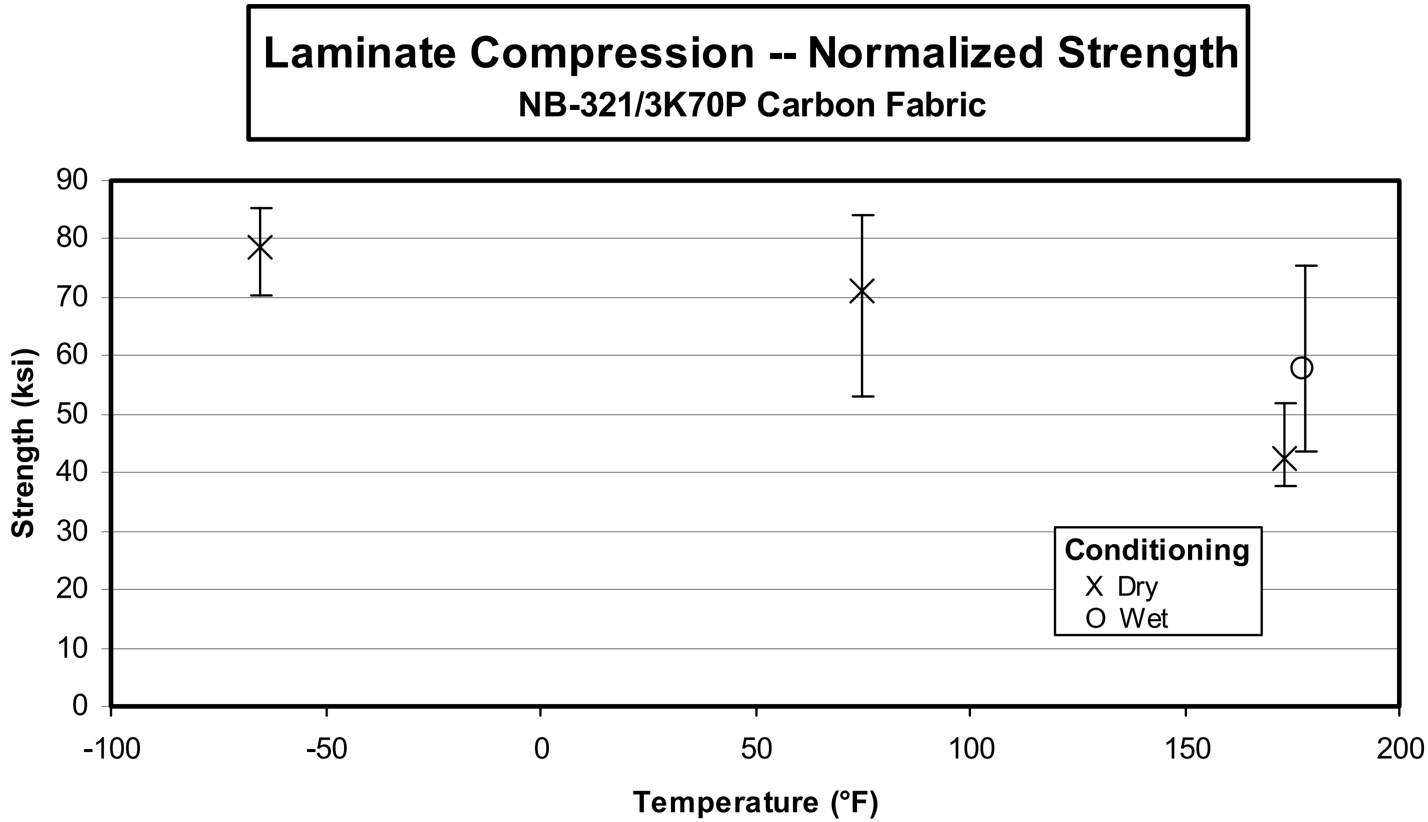
3.1.3 Individual Test Charts

3.1.3.1 Tension, Laminate



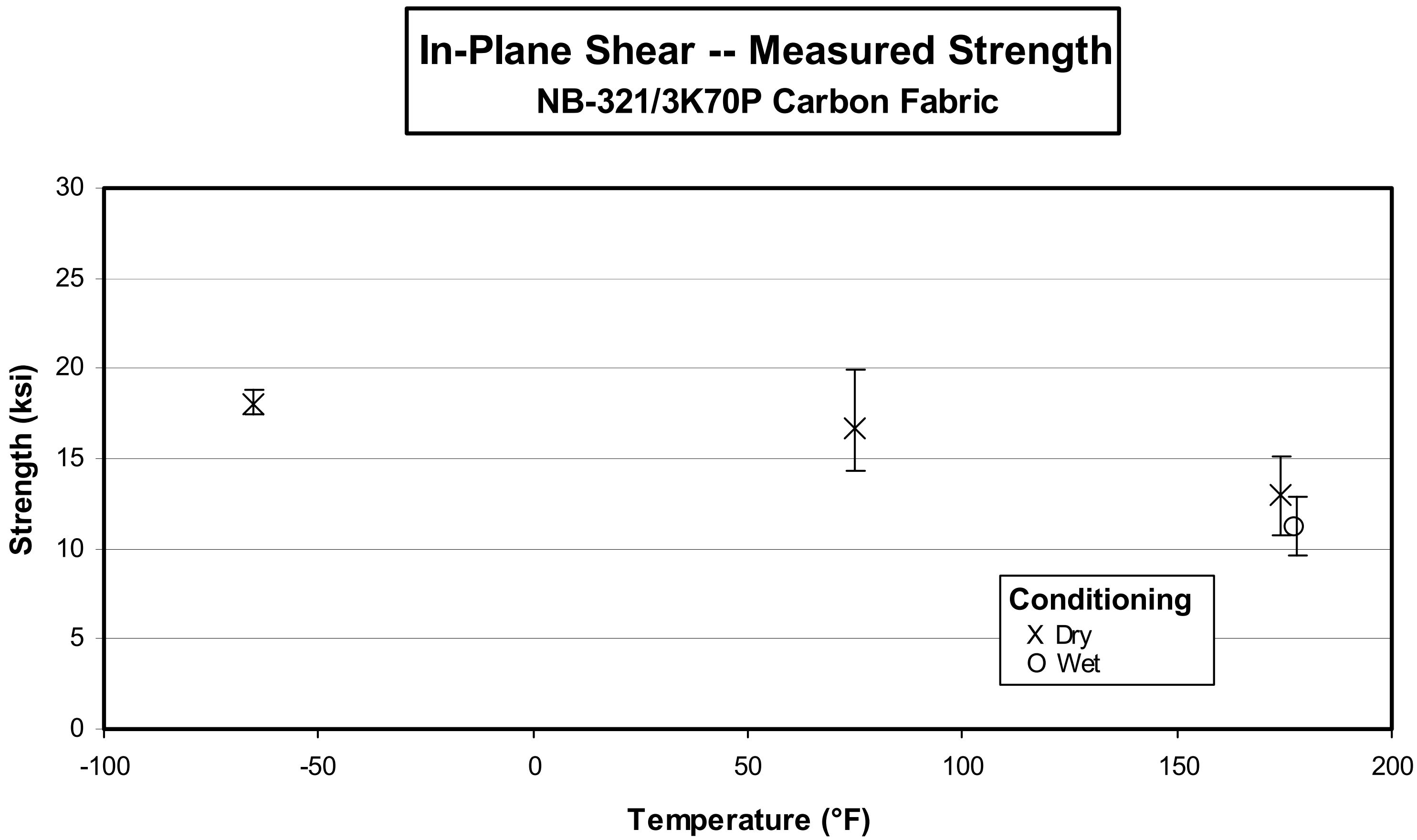
Note: The symbols represent the 'pooled' average of all tests, and the bars represent the upper & lower limit of the data.

3.1.3.2 Compression, Laminate



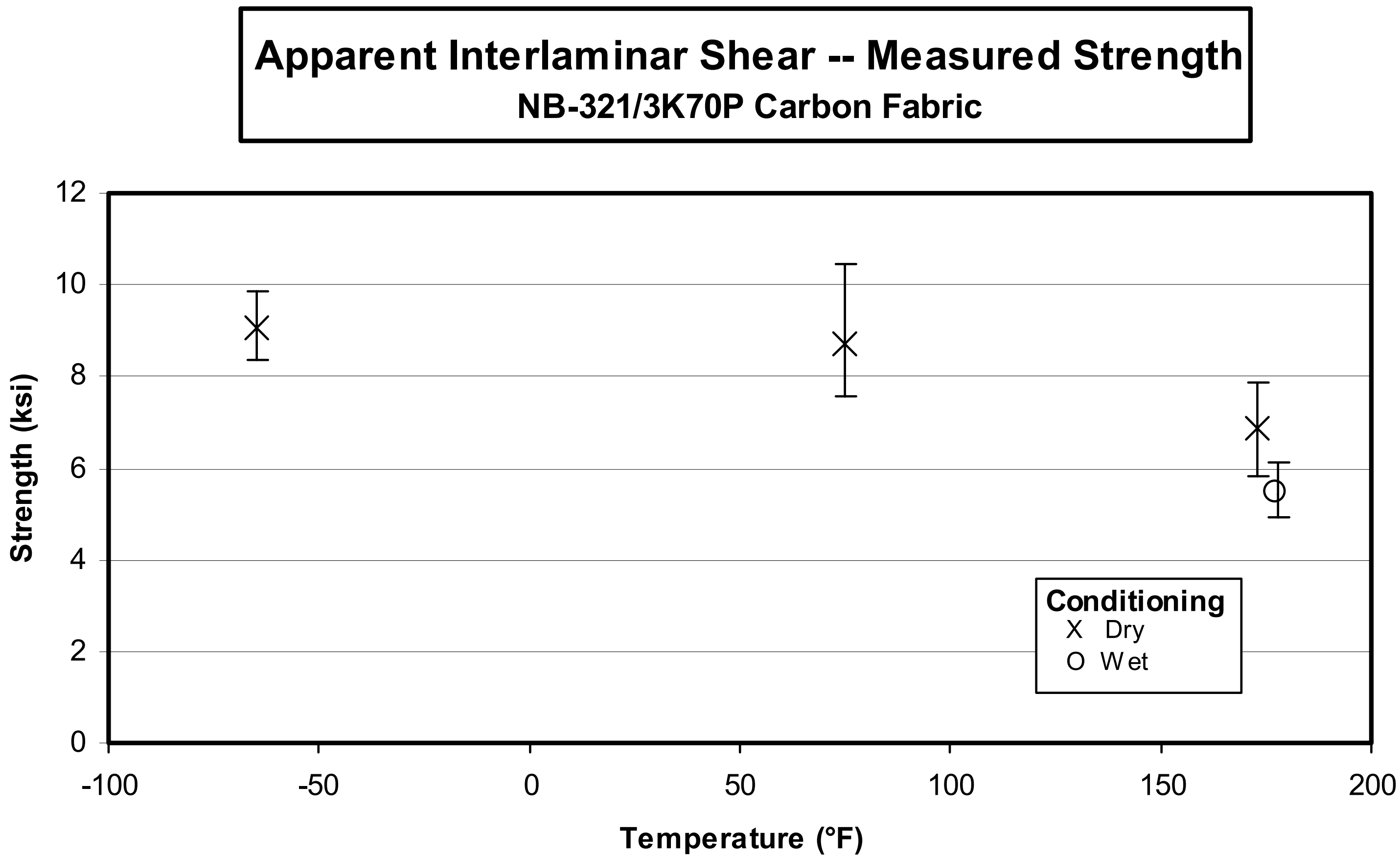
Note: The symbols represent the 'pooled' average of all tests, and the bars represent the upper & lower limit of the data. The 175° dry and wet data has been scattered for clarity.

3.1.3.3 Shear, 12 axis



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

3.1.3.4 Shear. 13 axis



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

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 C J 2 1 2 5 C

1st Character: Fabricator
'M' designates Lancair

2nd Character: Material System
'C' designates 3K70P / 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.

3.2.1 Raw Data Spreadsheets and Scatter Charts

Laminate Tension -- (RTD)
Strength & Modulus
NB-321/3K70P Carbon Fabric

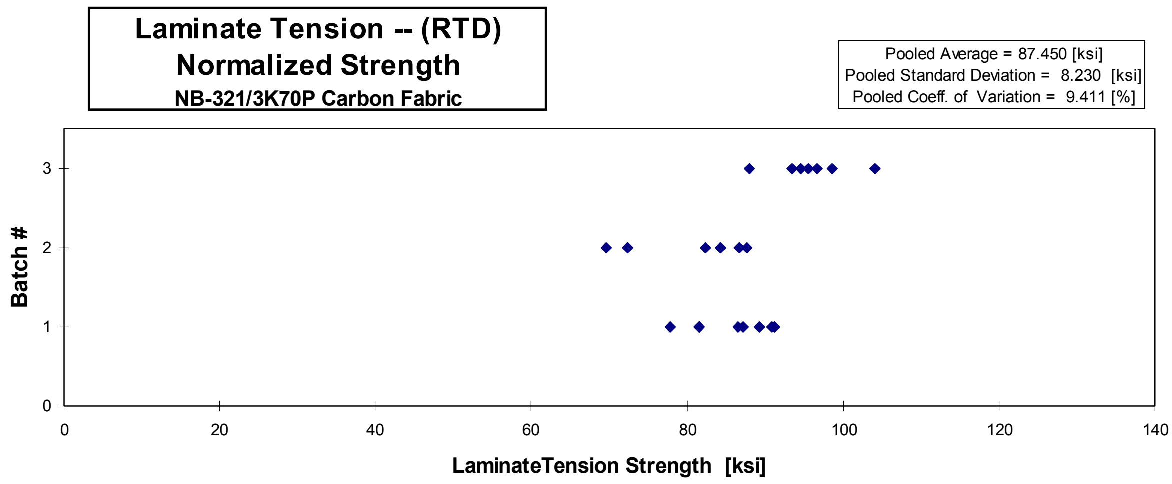
normalizing t_{ply} [in]: 0.0085

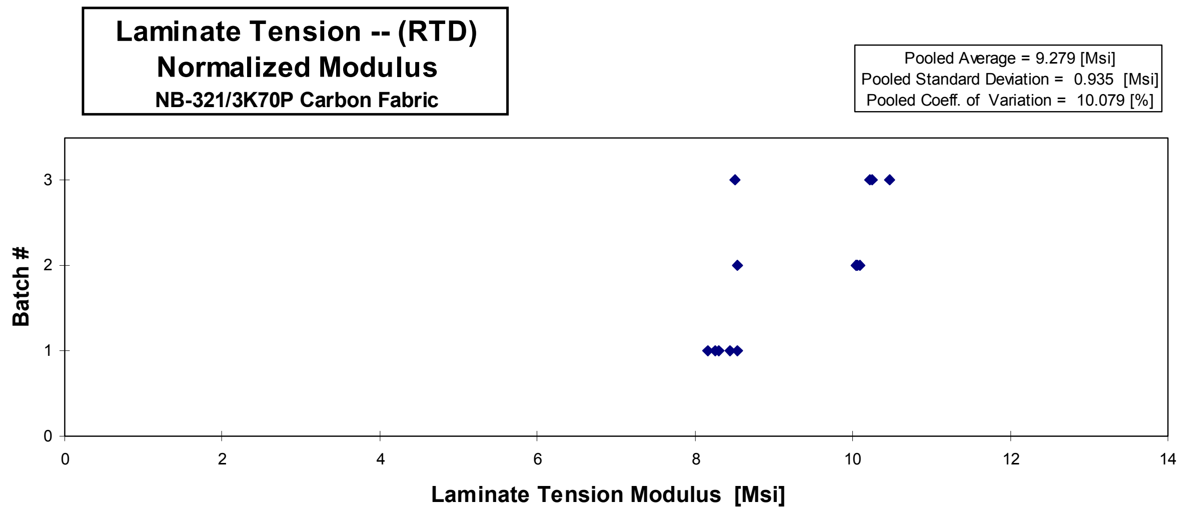
Specimen Number	Strength [ksi]	Modulus [Msi]	Poisson's Ratio	Batch Number	Avg. Specimen Thickn. [in]	# Plies in Laminate	Avg. t_{ply} [in]	$Strength_{norm}$ [ksi]	$Modulus_{norm}$ [Msi]
MCJ13A1A	83.727			1	0.075	9	0.0083	81.575	
MCJ13A2A	88.705			1	0.079	9	0.0087	91.198	
MCJ11A3A	82.759			1	0.072	9	0.0080	77.819	
MCJ11A4A	91.042	8.681		1	0.073	9	0.0081	86.500	8.248
MCJ11A5A	95.159	8.701		1	0.073	9	0.0081	90.847	8.307
MCJ11A6A	93.550	8.856		1	0.073	9	0.0081	89.189	8.444
MCJ11A7A	82.175	8.598		1	0.076	9	0.0084	81.531	8.530
MCJ13A1B(A)**	87.864	8.220	0.057	1	0.076	9	0.0084	87.197	8.158
MCJ22A1A	89.181	10.329		2	0.074	9	0.0083	86.714	10.043
MCJ22A2A	72.403	10.502		2	0.074	9	0.0082	69.627	10.099
MCJ22A3A	89.752	10.699		2	0.072	9	0.0080	84.336	10.053
MCJ22A4A	73.380	10.195		2	0.075	9	0.0084	72.325	10.049
MCJ23A1A	84.647			2	0.076	9	0.0085	84.241	
MCJ23A2A	90.255			2	0.074	9	0.0083	87.601	
MCJ23A6A	84.885	8.801	0.064	2	0.074	9	0.0082	82.333	8.537
MCJ31A5A	98.780	10.835		3	0.072	9	0.0080	93.507	10.256
MCJ32A6A	98.607	10.918		3	0.073	9	0.0081	94.525	10.466
MCJ31A7A	93.749	10.890		3	0.072	9	0.0080	87.948	10.216
MCJ33A1A	106.514			3	0.075	9	0.0083	104.031	
MCJ33A2A	98.973			3	0.075	9	0.0083	96.687	
MCJ33A3A	98.165			3	0.077	9	0.0085	98.572	
MCJ33A4A	94.544	8.407	0.052	3	0.077	9	0.0086	95.594	8.500

	Strength	Modulus	Poisson's Ratio
Average	**89.946**	**9.617**	**0.058**
Standard Dev.	**8.300**	**1.074**	**0.006**
Coeff. of Var. [%]	**9.228**	**11.171**	**10.604**
Min. Value	**72.403**	**8.220**	**0.052**
Max. Value	**106.514**	**10.918**	**0.064**
Number	**22**	**14**	**3**

	Avg. t_{ply}	$Strength_{norm}$	$Modulus_{norm}$
$Average_{norm}$	**0.00827**	**87.450**	**9.279**
Standard $Dev._{norm}$		**8.230**	**0.935**
Coeff. of Var. $[\%]_{norm}$		**9.411**	**10.079**
Min. $Value_{norm}$	**0.0080**	**69.627**	**8.158**
Max. $Value_{norm}$	**0.0087**	**104.031**	**10.466**
$Number_{norm}$		**22**	**14**

** NOTE: This sample was an extra from CTD testing and is identical to the other samples in every way except for the 'B' suffix.


Laminate Tension -- (RTD)
Normalized Strength
NB-321/3K70P Carbon Fabric
Pooled Average = 87.450 [ksi]
Pooled Standard Deviation = 8.230 [ksi]
Pooled Coeff. of Variation = 9.411 [%]
Batch #
0
1
2
3
0
20
40
60
80
100
120
140
LaminateTension Strength [ksi]


Laminate Tension -- (RTD)
Normalized Modulus
NB-321/3K70P Carbon Fabric
Pooled Average = 9.279 [Msi]
Pooled Standard Deviation = 0.935 [Msi]
Pooled Coeff. of Variation = 10.079 [%]
Batch #
0
1
2
3
0
2
4
6
8
10
12
14
Laminate Tension Modulus [Msi]

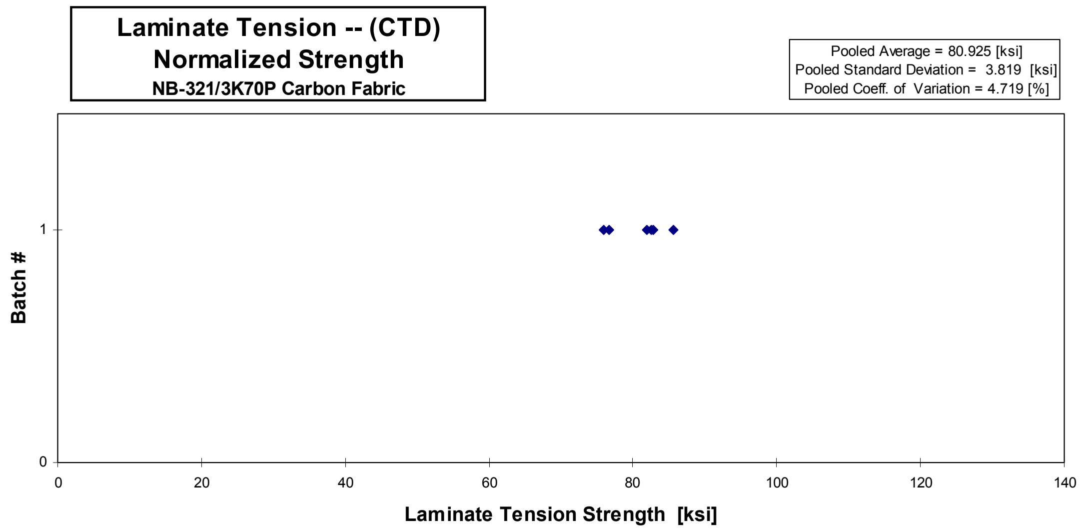
Laminate Tension -- (CTD)
Strength & Modulus
NB-321/3K70P Carbon Fabric

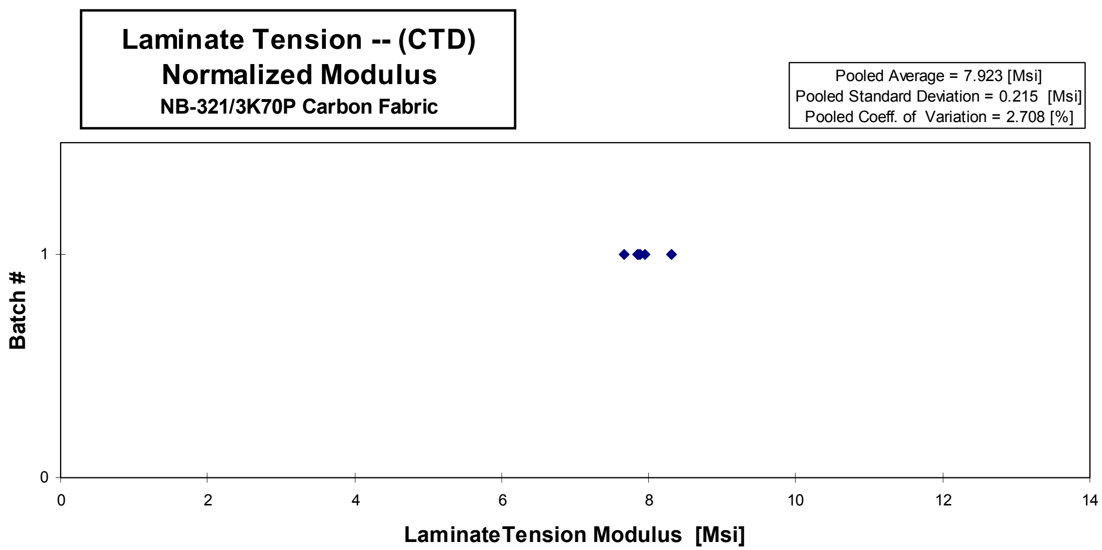
normalizing t_{ply} [in]: 0.0085

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]
MCJ11A1B	90.087	8.260	1	0.073	9	0.0081	85.691	7.857
MCJ11A2B	87.394	8.411	1	0.072	9	0.0080	82.539	7.944
MCJ13A3B	84.555	7.826	1	0.075	9	0.0083	82.842	7.667
MCJ13A4B	80.302	7.735	1	0.078	9	0.0087	81.876	7.887
MCJ13A5B	79.436	8.227	1	0.073	9	0.0081	75.940	7.865
MCJ13A2B	77.919	8.453	1	0.075	9	0.0084	76.663	8.317

	Strength	Modulus
Average	**83.282**	**8.152**
Standard Dev.	**4.843**	**0.302**
Coeff. of Var. [%]	**5.815**	**3.702**
Min. Value	**77.919**	**7.735**
Max. Value	**90.087**	**8.453**
Number	**6**	**6**

	Avg. t_{ply}	$Strength_{norm}$	$Modulus_{norm}$
$Average_{norm}$	**0.00827**	**80.925**	**7.923**
$Standard\ Dev._{norm}$		**3.819**	**0.215**
Coeff. of Var. $[\%]_{norm}$		**4.719**	**2.708**
Min. $Value_{norm}$	**0.0080**	**75.940**	**7.667**
Max. $Value_{norm}$	**0.0087**	**85.691**	**8.317**
$Number_{norm}$		**6**	**6**


Laminate Tension -- (CTD)
Normalized Strength
NB-321/3K70P Carbon Fabric
Pooled Average = 80.925 [ksi]
Pooled Standard Deviation = 3.819 [ksi]
Pooled Coeff. of Variation = 4.719 [%]
Batch #
1
0
0
20
40
60
80
100
120
140
Laminate Tension Strength [ksi]


Laminate Tension -- (CTD)
Normalized Modulus
NB-321/3K70P Carbon Fabric
Pooled Average = 7.923 [Msi]
Pooled Standard Deviation = 0.215 [Msi]
Pooled Coeff. of Variation = 2.708 [%]
Batch #
1
0
0
2
4
6
8
10
12
14
LaminateTension Modulus [Msi]

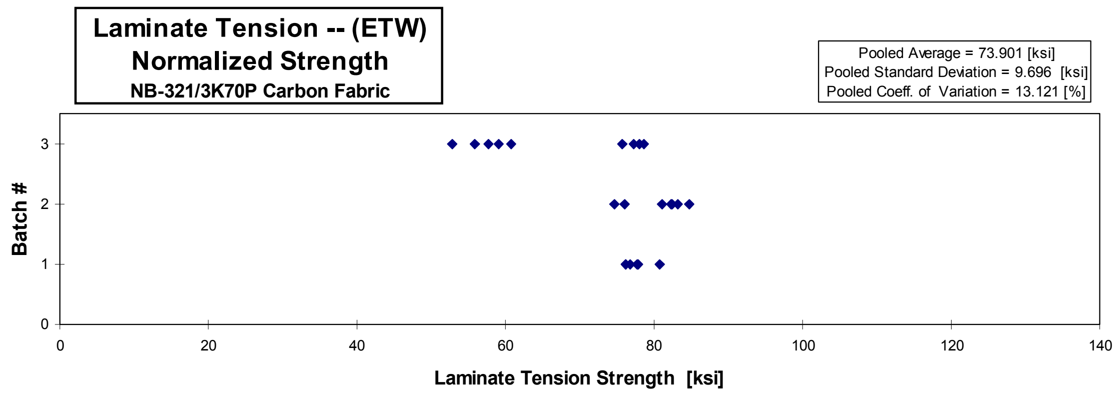
Laminate Tension -- (ETW)
Strength & Modulus
NB-321/3K70P Carbon Fabric

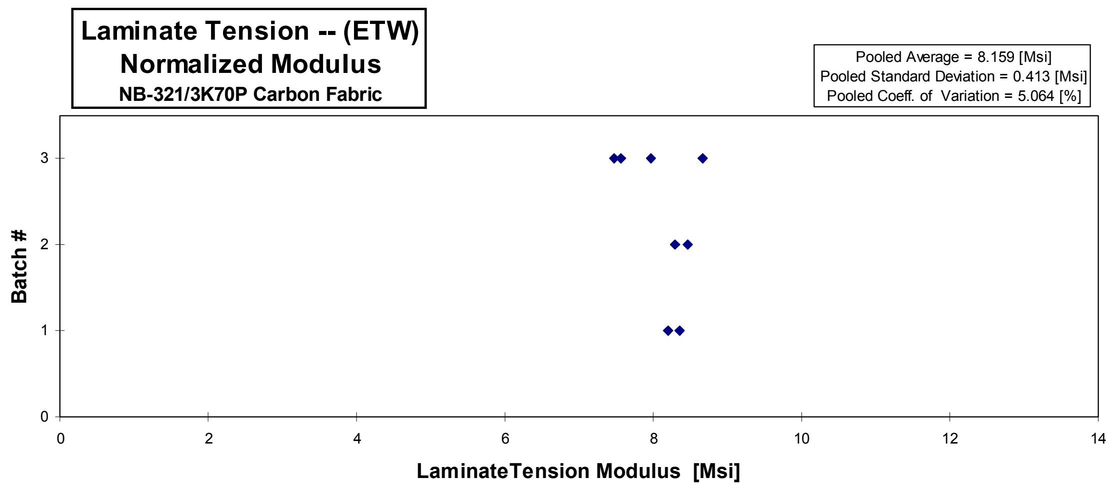
normalizing t_{ply} [in]: 0.0085

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]
MCJ1111C	85.345		1	0.072	9	0.0080	80.808	
MCJ1112C	77.861		1	0.075	9	0.0083	76.181	
MCJ1113C	81.233	8.579	1	0.073	9	0.0081	77.675	8.203
MCJ1114C	80.529	8.648	1	0.074	9	0.0082	77.810	8.356
MCJ1115C	81.521		1	0.072	9	0.0080	76.744	
MCJ1116C	80.704		1	0.072	9	0.0080	76.185	
MCJ2111C	85.565		2	0.074	9	0.0082	82.265	
MCJ2112C	83.855		2	0.074	9	0.0082	81.005	
MCJ2113C	78.638	8.576	2	0.074	9	0.0082	76.051	8.294
MCJ2114C	89.899	8.972	2	0.072	9	0.0080	84.767	8.460
MCJ2115C	75.232	8.520	2	0.076	9	0.0084	74.707	8.461
MCJ2116C	86.571		2	0.073	9	0.0081	82.459	
MCJ2117C	87.158		2	0.073	9	0.0081	83.208	
MCJ3211C	79.424		3	0.075	9	0.0084	78.040	
MCJ3212C	80.130		3	0.075	9	0.0083	78.611	
MCJ3213C	53.539		3	0.075	9	0.0084	52.816	
MCJ3214C	61.308	7.528	3	0.076	9	0.0084	60.800	7.466
MCJ3215C	59.219	7.990	3	0.076	9	0.0085	59.012	7.962
MCJ3111C	76.959		3	0.075	9	0.0084	75.719	
MCJ3112C	59.350	7.772	3	0.074	9	0.0083	57.772	7.566
MCJ3113C	57.740	8.943	3	0.074	9	0.0082	55.928	8.663
MCJ3114C	79.164		3	0.075	9	0.0083	77.267	

	Strength [ksi]	Modulus [Msi]
Average	**76.406**	**8.392**
Standard Dev.	**10.757**	**0.510**
Coeff. of Var. [%]	**14.079**	**6.081**
Min. Value	**53.539**	**7.528**
Max. Value	**89.899**	**8.972**
Number	**22**	**9**

	Avg. t_{ply} [in]	$Strength_{norm}$ [ksi]	$Modulus_{norm}$ [Msi]
$Average_{norm}$	**0.00823**	**73.901**	**8.159**
$Standard Dev._{norm}$		**9.696**	**0.413**
$Coeff. of Var. [\%]_{norm}$		**13.121**	**5.064**
$Min. Value_{norm}$	**0.0080**	**52.816**	**7.466**
$Max. Value_{norm}$	**0.0085**	**84.767**	**8.663**
$Number_{norm}$		**22**	**9**


Laminate Tension -- (ETW)
Normalized Strength
NB-321/3K70P Carbon Fabric
Pooled Average = 73.901 [ksi]
Pooled Standard Deviation = 9.696 [ksi]
Pooled Coeff. of Variation = 13.121 [%]
Batch #
Laminate Tension Strength [ksi]
0
20
40
60
80
100
120
140
0
1
2
3


Laminate Tension -- (ETW)
Normalized Modulus
NB-321/3K70P Carbon Fabric
Pooled Average = 8.159 [Msi]
Pooled Standard Deviation = 0.413 [Msi]
Pooled Coeff. of Variation = 5.064 [%]
Batch #
LaminateTension Modulus [Msi]
0
2
4
6
8
10
12
14
0
1
2
3

Laminate Compression -- (CTD) Strength & Modulus

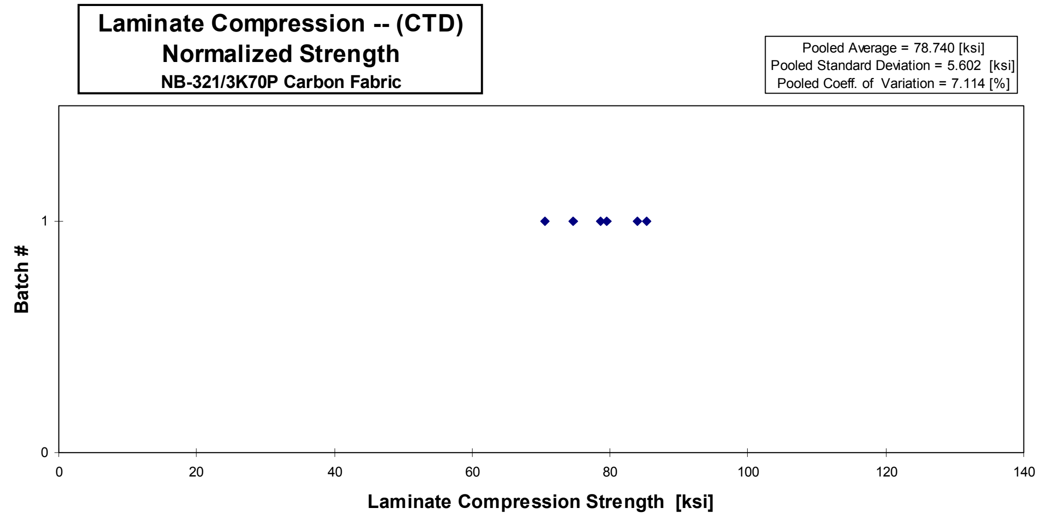
NB-321/3K70P Carbon Fabric

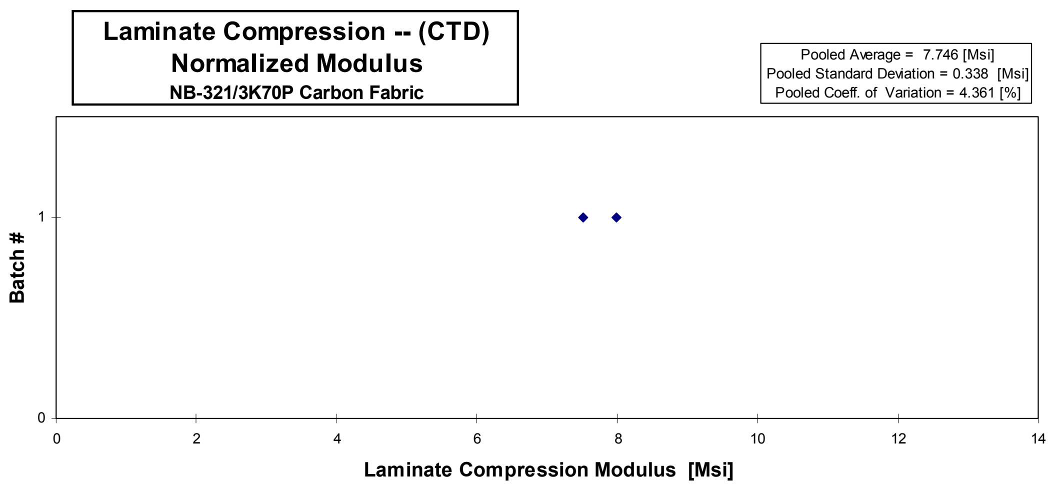
normalizing t_{ply} [in]: 0.0085

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]
MCK12A1B	74.521		1	0.108	12	0.0090	78.539	
MCK12A2B	76.159		1	0.107	12	0.0089	79.519	
MCK12A3B	69.337		1	0.110	12	0.0091	74.606	
MCK12A4B	78.436		1	0.109	12	0.0091	84.011	
MCK12A5B	68.456		1	0.105	12	0.0088	70.469	
MCK12A6B	81.119		1	0.107	12	0.0089	85.294	
MCK15A4B		7.594	1	0.107	12	0.0089		7.985
MCK15A5B		7.058	1	0.109	12	0.0090		7.507

	Strength	Modulus
Average	**74.671**	**7.326**
Standard Dev.	**5.001**	**0.379**
Coeff. of Var. [%]	**6.698**	**5.179**
Min. Value	**68.456**	**7.058**
Max. Value	**81.119**	**7.594**
Number	**6**	**2**

	Avg. t_{ply}	$Strength_{norm}$	$Modulus_{norm}$
$Average_{norm}$	**0.00897**	**78.740**	**7.746**
Standard $Dev._{norm}$		**5.602**	**0.338**
Coeff. of Var. $[\%]_{norm}$		**7.114**	**4.361**
Min. $Value_{norm}$	**0.0088**	**70.469**	**7.507**
Max. $Value_{norm}$	**0.0091**	**85.294**	**7.985**
$Number_{norm}$		**6**	**2**


Laminate Compression -- (CTD)
Normalized Strength
NB-321/3K70P Carbon Fabric
Pooled Average = 78.740 [ksi]
Pooled Standard Deviation = 5.602 [ksi]
Pooled Coeff. of Variation = 7.114 [%]
Batch #
Laminate Compression Strength [ksi]


Laminate Compression -- (CTD)
Normalized Modulus
NB-321/3K70P Carbon Fabric
Pooled Average = 7.746 [Msi]
Pooled Standard Deviation = 0.338 [Msi]
Pooled Coeff. of Variation = 4.361 [%]
Batch #
Laminate Compression Modulus [Msi]

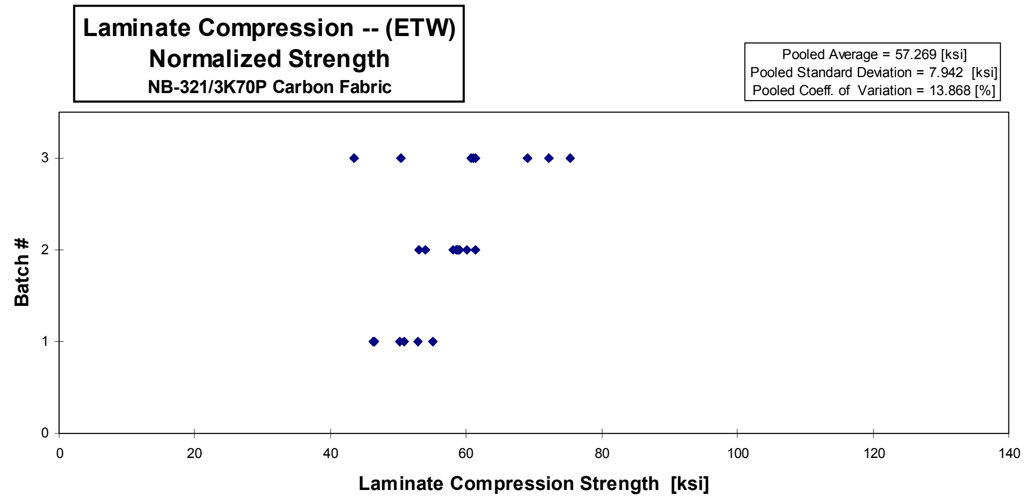
Laminate Compression -- (ETW)
Strength & Modulus
NB-321/3K70P Carbon Fabric

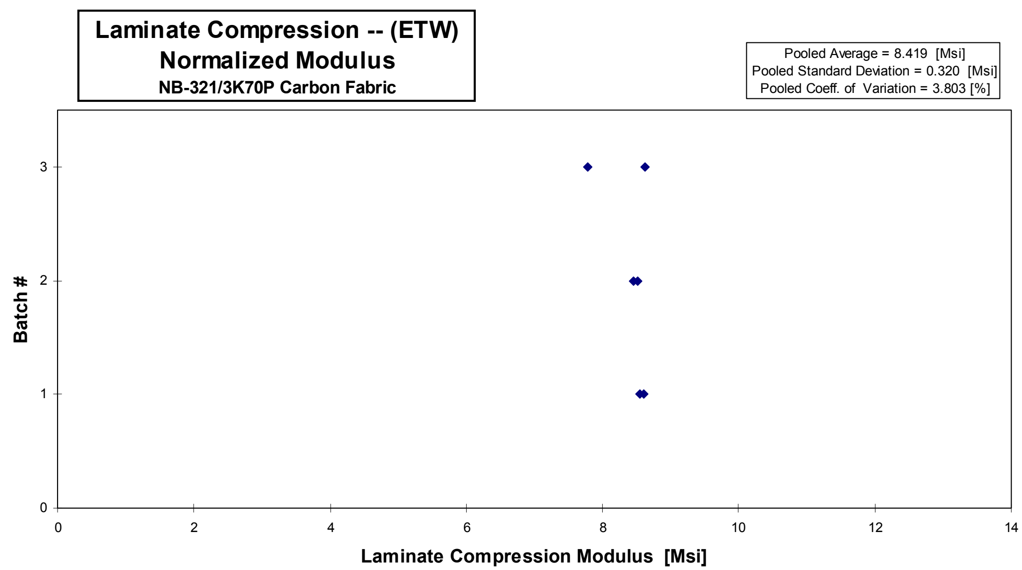
normalizing t_{ply} [in]: 0.0085

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]
MCK11A1C	44.302		1	0.107	12	0.0089	46.474	
MCK11A2C	49.556		1	0.103	12	0.0086	50.163	
MCK11A3C	47.402		1	0.100	12	0.0083	46.240	
MCK11A4C	50.888		1	0.102	12	0.0085	50.888	
MCK11A5C	56.347		1	0.100	12	0.0083	55.104	
MCK11A6C	52.946		1	0.102	12	0.0085	52.946	
MCK15A8C		8.238	1	0.107	12	0.0089		8.602
MCK15A9C		8.048	1	0.108	12	0.0090		8.542
MCK2711C	59.960		2	0.105	12	0.0087	61.430	
MCK2712C	57.027		2	0.105	12	0.0087	58.564	
MCK2713C	52.883		2	0.104	12	0.0087	54.050	
MCK2714C	56.504		2	0.106	12	0.0088	58.720	
MCK2715C	57.538		2	0.105	12	0.0087	58.948	
MCK2716C	51.672		2	0.105	12	0.0087	53.065	
MCK2717C	55.546		2	0.107	12	0.0089	57.997	
MCK2718C	58.475		2	0.105	12	0.0087	60.052	
MCK2719C	58.014		2	0.104	12	0.0086	58.867	
MCK26A1C		8.293	2	0.105	12	0.0087		8.516
MCK26A2C		8.292	2	0.104	12	0.0087		8.454
MCK32A1C	71.220		3	0.108	12	0.0090	75.410	
MCK32A2C	69.668		3	0.106	12	0.0088	72.229	
MCK32A3C	58.346		3	0.107	12	0.0089	61.063	
MCK32A4C	58.501		3	0.107	12	0.0089	61.369	
MCK32A5C	42.064		3	0.106	12	0.0088	43.507	
MCK32A6C	49.243		3	0.104	12	0.0087	50.329	
MCK32A7C	60.127		3	0.103	12	0.0086	60.716	
MCK32A8C	64.612		3	0.109	12	0.0091	69.046	
MCK35A2C		7.574	3	0.105	12	0.0087		7.778
MCK35A3C		8.379	3	0.105	12	0.0088		8.625

	Strength [ksi]	Modulus [Msi]
Average	**55.776**	**8.137**
Standard Dev.	**7.091**	**0.297**
Coeff. of Var. [%]	**12.713**	**3.653**
Min. Value	**42.064**	**7.574**
Max. Value	**71.220**	**8.379**
Number	**23**	**6**

	Avg. t_{ply} [in]	$Strength_{norm}$ [ksi]	$Modulus_{norm}$ [Msi]
$Average_{norm}$	**0.00873**	**57.269**	**8.419**
Standard $Dev._{norm}$		**7.942**	**0.320**
Coeff. of Var. $[\%]_{norm}$		**13.868**	**3.803**
Min. $Value_{norm}$	**0.0083**	**43.507**	**7.778**
Max. $Value_{norm}$	**0.0091**	**75.410**	**8.625**
$Number_{norm}$		**23**	**6**


Laminate Compression -- (ETW)
Normalized Strength
NB-321/3K70P Carbon Fabric
Pooled Average = 57.269 [ksi]
Pooled Standard Deviation = 7.942 [ksi]
Pooled Coeff. of Variation = 13.868 [%]
Batch #
Laminate Compression Strength [ksi]


Laminate Compression -- (ETW)
Normalized Modulus
NB-321/3K70P Carbon Fabric
Pooled Average = 8.419 [Msi]
Pooled Standard Deviation = 0.320 [Msi]
Pooled Coeff. of Variation = 3.803 [%]
Batch #
Laminate Compression Modulus [Msi]

Laminate Compression -- (ETD) Strength

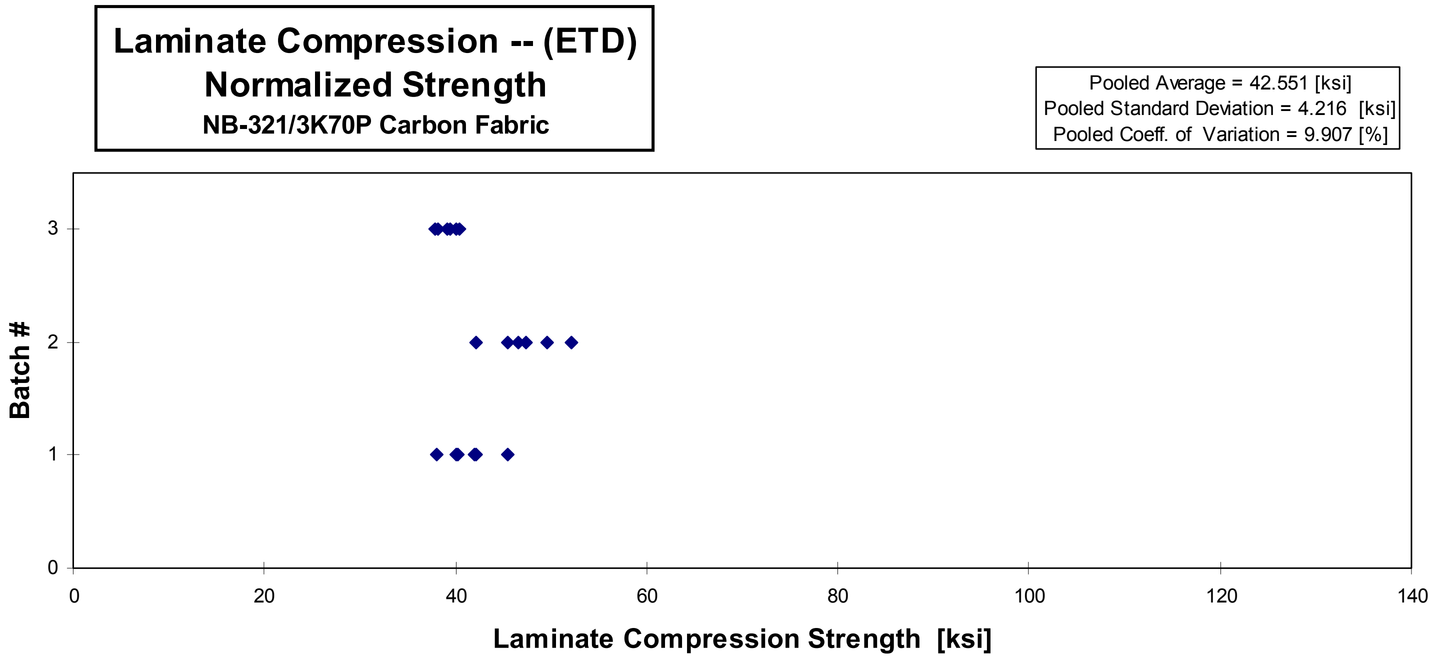
NB-321/3K70P Carbon Fabric

normalizing t_{ply} [in]: 0.0085

Specimen Number	Strength [ksi]	Batch Number	Avg. Specimen Thickn. [in]	# Plies in Laminate	Avg. t_{ply} [in]	$Strength_{norm}$ [ksi]
MCK11A1E	41.850	1	0.102	12	0.0085	41.953
MCK11A2E	45.631	1	0.102	12	0.0085	45.407
MCK11A3E	42.780	1	0.101	12	0.0084	42.151
MCK11A4E	40.052	1	0.103	12	0.0085	40.249
MCK11A5E	36.290	1	0.107	12	0.0089	37.980
MCK11A6E	37.628	1	0.109	12	0.0091	40.118
MCK2721E	45.714	2	0.104	12	0.0087	46.611
MCK2722E	44.121	2	0.105	12	0.0088	45.418
MCK2723E	48.065	2	0.105	12	0.0088	49.596
MCK2724E	46.007	2	0.105	12	0.0088	47.360
MCK2725E	50.299	2	0.106	12	0.0088	52.025
MCK2726E	40.574	2	0.106	12	0.0088	42.066
MCK32A1E	39.485	3	0.104	12	0.0087	40.356
MCK32A2E	37.924	3	0.102	12	0.0085	37.924
MCK32A3E	38.732	3	0.103	12	0.0086	39.111
MCK32A4E	39.810	3	0.103	12	0.0086	40.103
MCK32A5E	39.464	3	0.102	12	0.0085	39.367
MCK32A6E	37.565	3	0.104	12	0.0086	38.117

Average	**41.777**
Standard Dev.	**4.022**
Coeff. of Var. [%]	**9.627**
Min. Value	**36.290**
Max. Value	**50.299**
Number	**18**

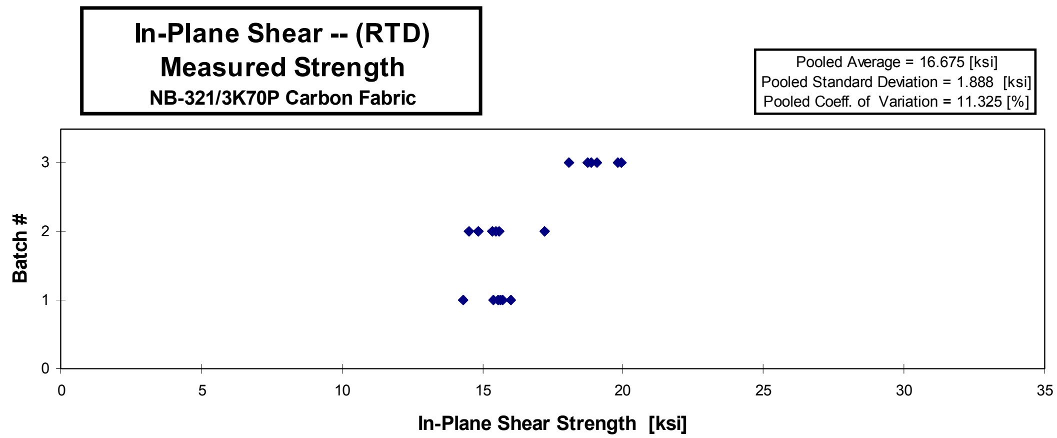
$Average_{norm}$	**0.00866**	**42.551**
$Standard\ Dev._{norm}$		**4.216**
$Coeff.\ of\ Var.\ [\%]_{norm}$		**9.907**
$Min.\ Value_{norm}$	**0.0084**	**37.924**
$Max.\ Value_{norm}$	**0.0091**	**52.025**
$Number_{norm}$		**18**

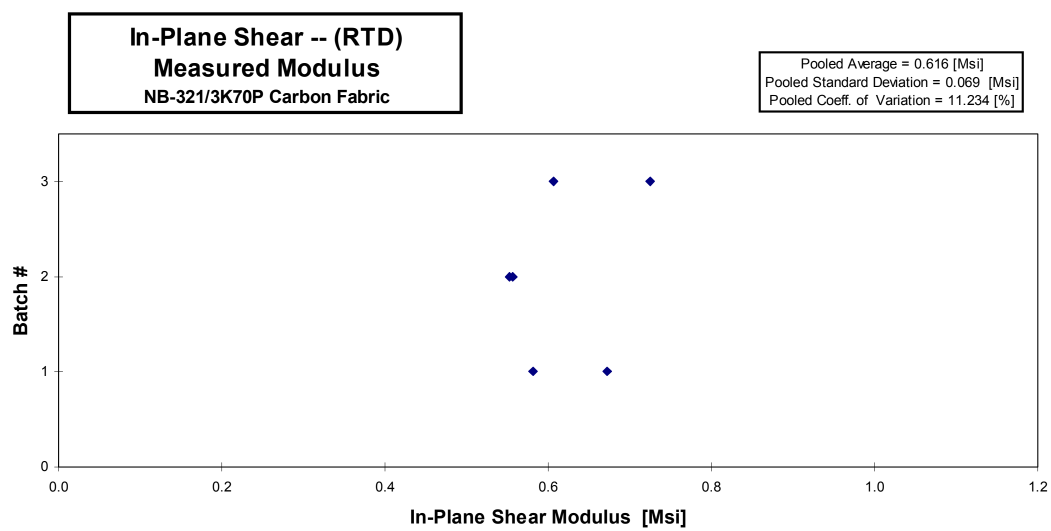

Laminate Compression -- (ETD)
Normalized Strength
NB-321/3K70P Carbon Fabric
Pooled Average = 42.551 [ksi]
Pooled Standard Deviation = 4.216 [ksi]
Pooled Coeff. of Variation = 9.907 [%]
Batch #
0
1
2
3
0
20
40
60
80
100
120
140
Laminate Compression Strength [ksi]

In-Plane Shear -- (RTD)
Strength & Modulus
NB-321/3K70P Carbon Fabric

Specimen Number	Strength [ksi]	Modulus [Msi]	Batch Number	Avg. Specimen Thickn. [in]	# Plies in Laminate	Avg. t_{ply} [in]
MCN12A1A	15.404		1	0.084	10	0.0084
MCN12A2A	15.538		1	0.084	10	0.0084
MCN12A3A	15.729		1	0.082	10	0.0082
MCN12A4A	16.020	0.672	1	0.083	10	0.0083
MCN12A5A	15.628		1	0.085	10	0.0085
MCN12A6A	14.325	0.582	1	0.085	10	0.0085
MCN21A1A	17.227		2	0.086	10	0.0086
MCN21A2A	14.864		2	0.082	10	0.0082
MCN21A3A	15.356		2	0.086	10	0.0086
MCN21A4A	15.588		2	0.086	10	0.0086
MCN21A5A	15.476	0.552	2	0.083	10	0.0083
MCN21A6A	14.511	0.557	2	0.085	10	0.0085
MCN34A1A	18.741		3	0.087	10	0.0087
MCN24A2A	18.077		3	0.088	10	0.0088
MCN34A3A	18.847		3	0.088	10	0.0088
MCN34A4A	19.083	0.725	3	0.088	10	0.0088
MCN34A5A	19.937		3	0.090	10	0.0090
MCN34A6A	19.797	0.607	3	0.087	10	0.0087

	Strength	Modulus				
Average	**16.675**	**0.616**				
Standard Dev.	**1.888**	**0.069**				
Coeff. of Var. [%]	**11.325**	**11.234**				
Min.	**14.325**	**0.552**			**Min.**	**0.0082**
Max.	**19.937**	**0.725**			**Max.**	**0.0090**
Number of Spec.	**18**	**6**				

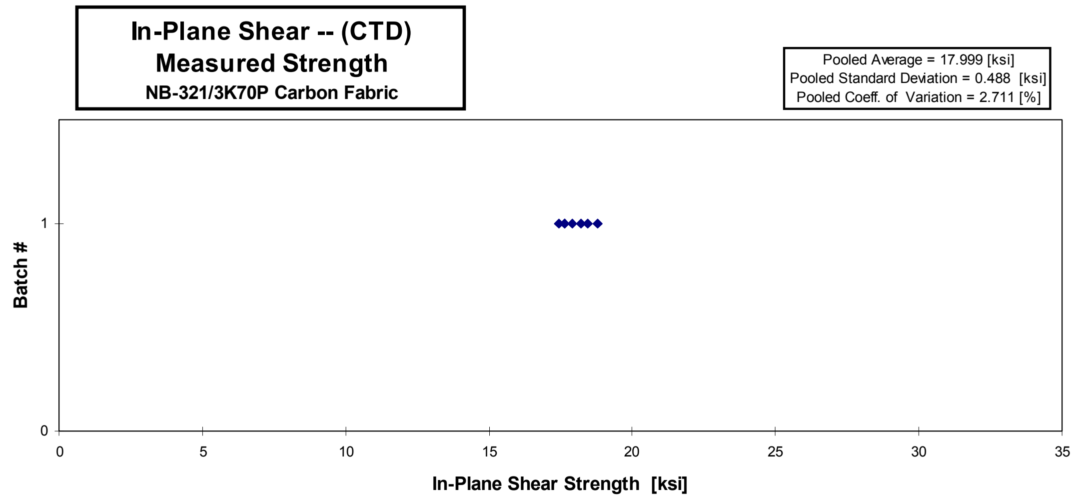

In-Plane Shear -- (RTD)
Measured Strength
NB-321/3K70P Carbon Fabric
Pooled Average = 16.675 [ksi]
Pooled Standard Deviation = 1.888 [ksi]
Pooled Coeff. of Variation = 11.325 [%]
Batch #
0
1
2
3
0
5
10
15
20
25
30
35
In-Plane Shear Strength [ksi]

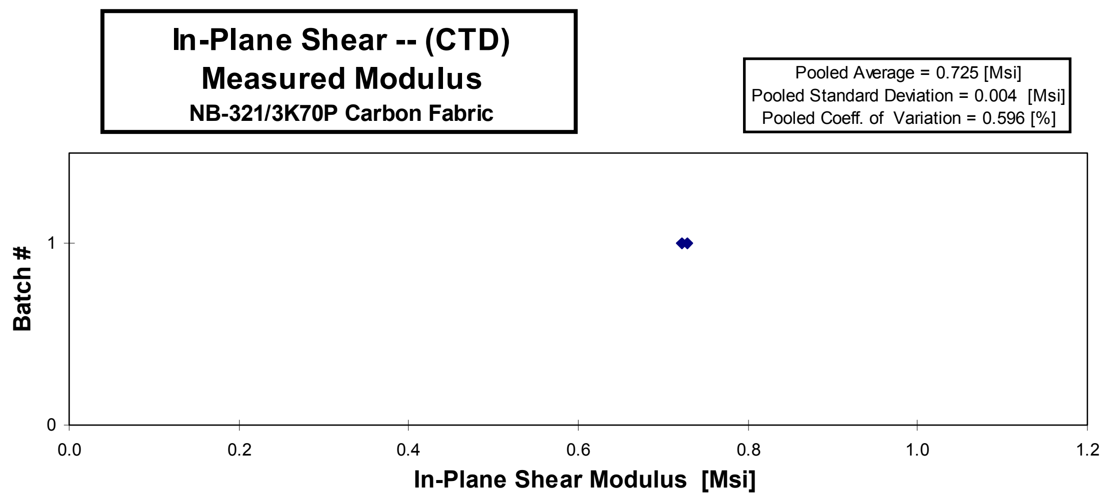

In-Plane Shear -- (RTD)
Measured Modulus
NB-321/3K70P Carbon Fabric
Pooled Average = 0.616 [Msi]
Pooled Standard Deviation = 0.069 [Msi]
Pooled Coeff. of Variation = 11.234 [%]
Batch #
0
1
2
3
0.0
0.2
0.4
0.6
0.8
1.0
1.2
In-Plane Shear Modulus [Msi]

In-Plane Shear -- (CTD)
Strength & Modulus
NB-321/3K70P Carbon Fabric

Specimen Number	Strength [ksi]	Modulus [Msi]	Batch Number	Avg. Specimen Thickn. [in]	# Plies in Laminate	Avg. t_{ply} [in]
MCN14A1B	17.441		1	0.085	10	0.0085
MCN14A2B	18.205		1	0.084	10	0.0084
MCN14A3B	18.773		1	0.084	10	0.0084
MCN14A4B	18.431		1	0.083	10	0.0083
MCN14A5B	17.617		1	0.083	10	0.0083
MCN14A6B	17.895	0.728	1	0.085	10	0.0085
MCN14A8B	17.634	0.722	1	0.084	10	0.0084

	Strength	Modulus		
Average	**17.999**	**0.725**		
Standard Dev.	**0.488**	**0.004**		
Coeff. of Var. [%]	**2.711**	**0.596**		
Min.	**17.441**	**0.722**	**Min.**	**0.0083**
Max.	**18.773**	**0.728**	**Max.**	**0.0085**
Number of Spec.	**7**	**2**		

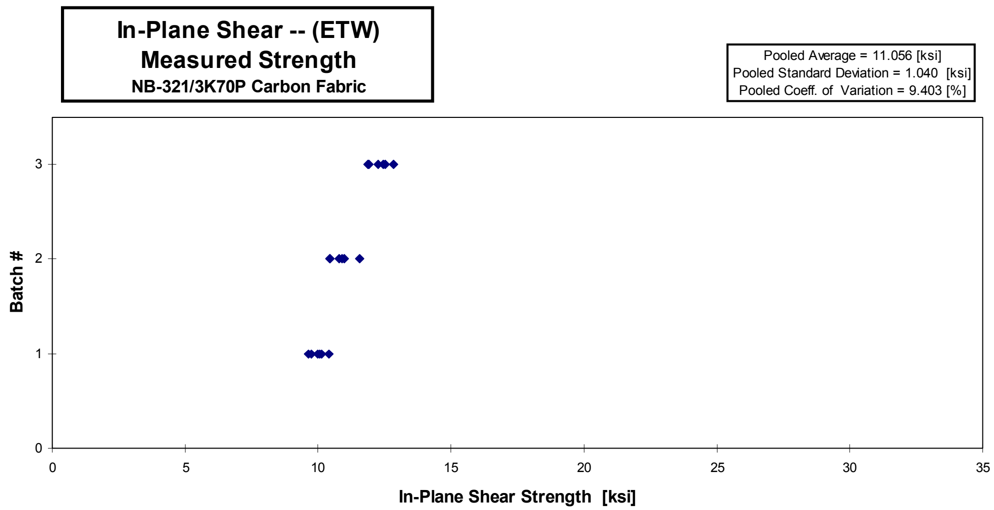

In-Plane Shear -- (CTD)
Measured Strength
NB-321/3K70P Carbon Fabric
Pooled Average = 17.999 [ksi]
Pooled Standard Deviation = 0.488 [ksi]
Pooled Coeff. of Variation = 2.711 [%]
Batch #
0
1
0
5
10
15
20
25
30
35
In-Plane Shear Strength [ksi]

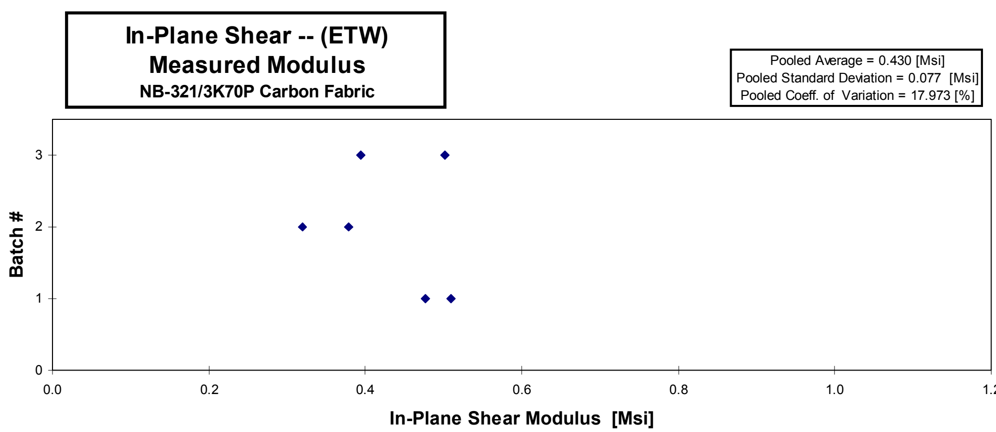

In-Plane Shear -- (CTD)
Measured Modulus
NB-321/3K70P Carbon Fabric
Pooled Average = 0.725 [Msi]
Pooled Standard Deviation = 0.004 [Msi]
Pooled Coeff. of Variation = 0.596 [%]
Batch #
0
1
0.0
0.2
0.4
0.6
0.8
1.0
1.2
In-Plane Shear Modulus [Msi]

In-Plane Shear -- (ETW)
Strength & Modulus
NB-321/3K70P Carbon Fabric

Specimen Number	Strength [ksi]	Modulus [Msi]	Batch Number	Avg. Specimen Thickn. [in]	# Plies in Laminate	Avg. t_{ply} [in]
MCN11A1C	9.630		1	0.089	10	0.0089
MCN11A2C	10.415		1	0.085	10	0.0085
MCN11A3C	10.062		1	0.086	10	0.0086
MCN11A4C	9.740		1	0.087	10	0.0087
MCN11A5C	9.979	0.477	1	0.086	10	0.0086
MCN11A6C	10.128	0.509	1	0.087	10	0.0087
MCN23A1C	10.458		2	0.084	10	0.0084
MCN23A2C	10.924	0.379	2	0.083	10	0.0083
MCN23A3C	10.461	0.319	2	0.084	10	0.0084
MCN21A4C	10.984		2	0.087	10	0.0087
MCN21A5C	11.570		2	0.083	10	0.0083
MCN23A6C	10.787		2	0.084	10	0.0084
MCN32A1C	12.519	0.394	3	0.084	10	0.0084
MCN32A2C	12.434	0.502	3	0.086	10	0.0086
MCN32A3C	12.840		3	0.085	10	0.0085
MCN32A4C	12.259		3	0.086	10	0.0086
MCN32A5C	11.891		3	0.085	10	0.0085
MCN32A6C	11.922		3	0.084	10	0.0084

	Strength	Modulus				
Average	**11.056**	**0.430**				
Standard Dev.	**1.040**	**0.077**				
Coeff. of Var. [%]	**9.403**	**17.973**				
Min.	**9.630**	**0.319**			**Min.**	**0.0083**
Max.	**12.840**	**0.509**			**Max.**	**0.0089**
Number of Spec.	**18**	**6**				

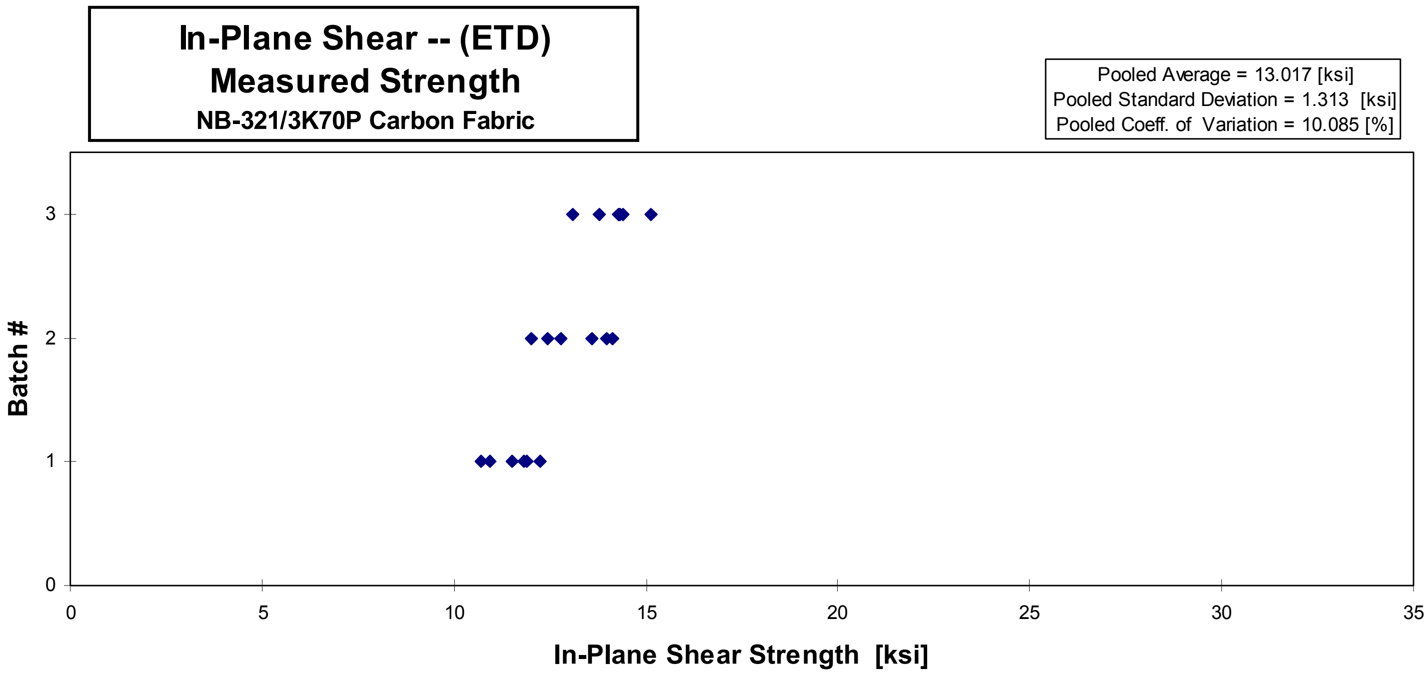

In-Plane Shear -- (ETW)
Measured Strength
NB-321/3K70P Carbon Fabric
Pooled Average = 11.056 [ksi]
Pooled Standard Deviation = 1.040 [ksi]
Pooled Coeff. of Variation = 9.403 [%]
Batch #
In-Plane Shear Strength [ksi]


In-Plane Shear -- (ETW)
Measured Modulus
NB-321/3K70P Carbon Fabric
Pooled Average = 0.430 [Msi]
Pooled Standard Deviation = 0.077 [Msi]
Pooled Coeff. of Variation = 17.973 [%]
Batch #
In-Plane Shear Modulus [Msi]

In-Plane Shear -- (ETD)
Strength
NB-321/3K70P Carbon Fabric

Specimen Number	Strength [ksi]	Batch Number	Avg. Specimen Thickn. [in]	# Plies in Laminate	Avg. t_{ply} [in]
MCN11A1E	12.229	1	0.084	10	0.0084
MCN11A2E	11.913	1	0.085	10	0.0085
MCN11A3E	11.827	1	0.083	10	0.0083
MCN12A4E	11.496	1	0.085	10	0.0085
MCN12A5E	10.720	1	0.085	10	0.0085
MCN12A6E	10.932	1	0.080	10	0.0080
MCN21A1E	14.130	2	0.083	10	0.0083
MCN23A2E	12.776	2	0.086	10	0.0086
MCN23A3E	13.970	2	0.085	10	0.0085
MCN23A4E	13.608	2	0.088	10	0.0088
MCN23A5E	12.428	2	0.087	10	0.0087
MCN23A6E	12.003	2	0.085	10	0.0085
MCN32A1E	14.325	3	0.085	10	0.0085
MCN32A2E	14.275	3	0.084	10	0.0084
MCN32A3E	13.773	3	0.085	10	0.0085
MCN32A4E	14.391	3	0.086	10	0.0086
MCN32A5E	13.078	3	0.086	10	0.0086
MCN32A6E	15.125	3	0.086	10	0.0086
MCN32A7E	14.321	3	0.084	10	0.0084

Average	**13.017**		
Standard Dev.	**1.313**		
Coeff. of Var. [%]	**10.085**		
Min.	**10.720**	**Min.**	**0.0080**
Max.	**15.125**	**Max.**	**0.0088**
Number	**19**		

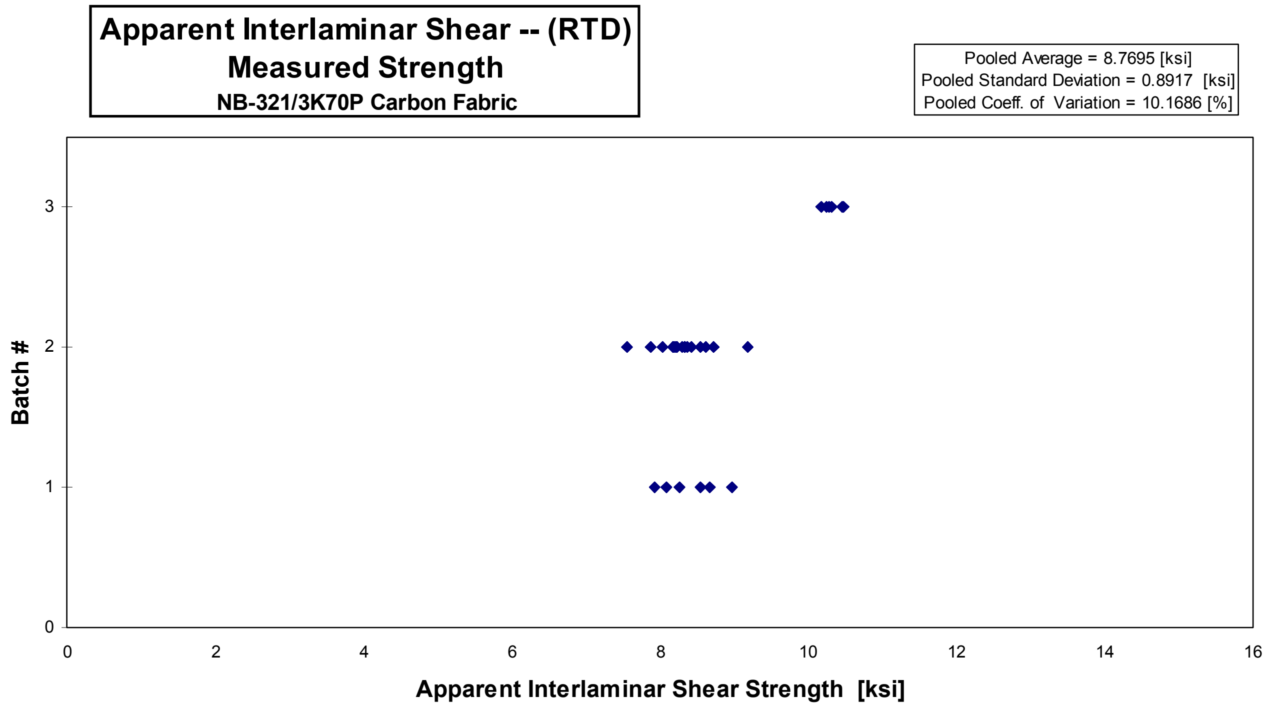

In-Plane Shear -- (ETD)
Measured Strength
NB-321/3K70P Carbon Fabric
Pooled Average = 13.017 [ksi]
Pooled Standard Deviation = 1.313 [ksi]
Pooled Coeff. of Variation = 10.085 [%]
Batch #
In-Plane Shear Strength [ksi]
0
1
2
3
0
5
10
15
20
25
30
35

Apparent Interlaminar Shear -- (RTD) Strength

NB-321/3K70P Carbon Fabric

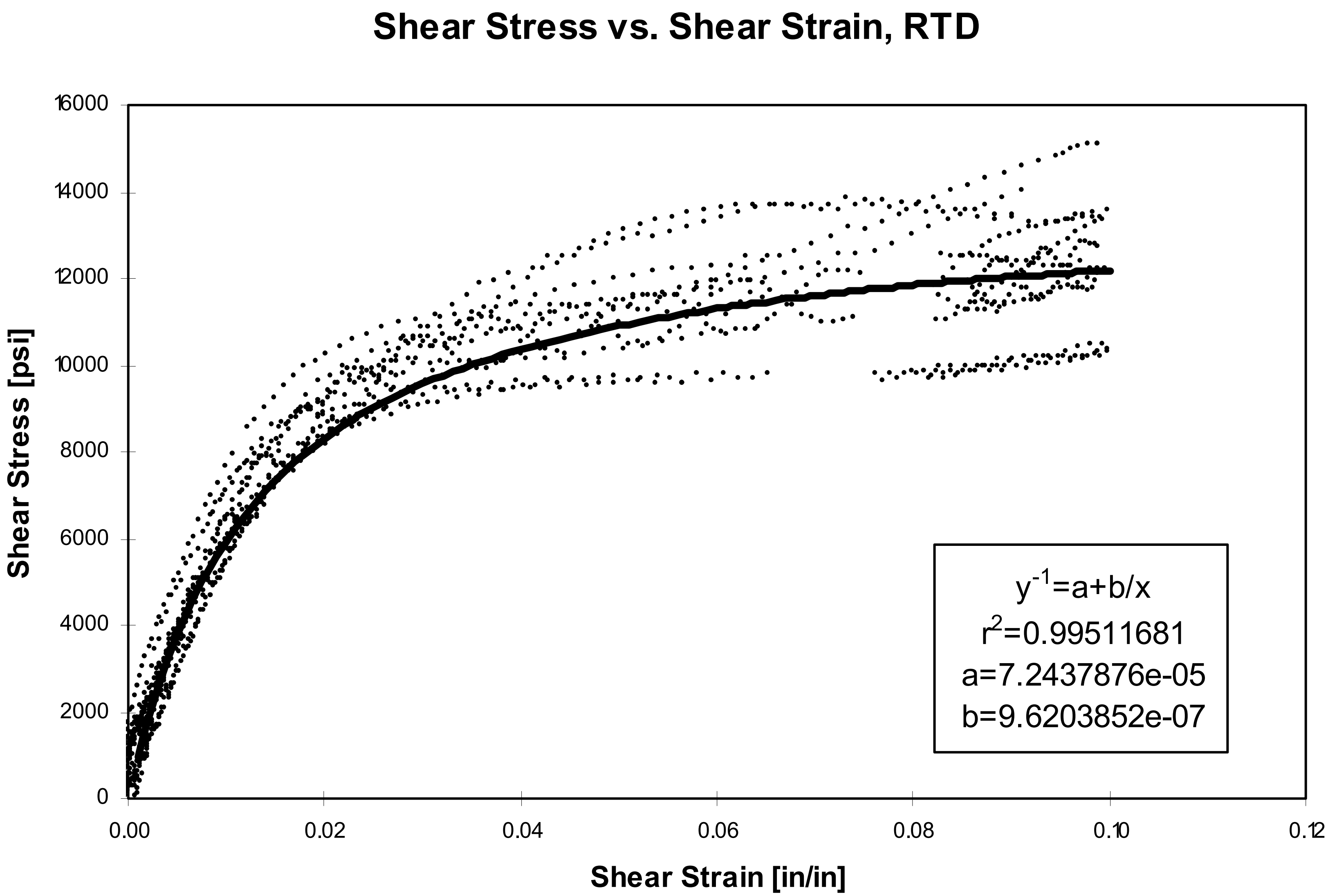
Specimen Number	Strength [ksi]	Batch Number	Avg. Specimen Thickn. [in]	# Plies in Laminate	Avg. t_{ply} [in]
MCQ11A1A	8.6718	1	0.075	9	0.0084
MCQ11A2A	7.9250	1	0.074	9	0.0082
MCQ11A3A	8.9699	1	0.072	9	0.0080
MCQ11A4A	8.0827	1	0.076	9	0.0084
MCQ11A5A	8.2574	1	0.075	9	0.0083
MCQ11A6A	8.5415	1	0.074	9	0.0082
MCQ21A1A	8.3285	2	0.072	9	0.0080
MCQ21A2A	8.7270	2	0.074	9	0.0082
MCQ21A3A	9.1801	2	0.076	9	0.0085
MCQ21A4A	8.2921	2	0.077	9	0.0085
MCQ21A5A	8.5436	2	0.076	9	0.0085
MCQ21A6A	8.6127	2	0.073	9	0.0082
MCQ22A1A	8.2076	2	0.077	9	0.0085
MCQ22A2A	8.4197	2	0.075	9	0.0083
MCQ22A3A	8.1683	2	0.079	9	0.0088
MCQ22A4A	8.3426	2	0.078	9	0.0086
MCQ22A5A	8.0442	2	0.078	9	0.0087
MCQ22A6A	8.3767	2	0.076	9	0.0085
MCQ22A7A	7.8824	2	0.075	9	0.0083
MCQ22A8A	8.1974	2	0.074	9	0.0082
MCQ22A9A	7.5522	2	0.077	9	0.0086
MCQ22AAA	8.2344	2	0.076	9	0.0084
MCQ31A1A	10.1817	3	0.079	9	0.0088
MCQ31A2A	10.3199	3	0.079	9	0.0088
MCQ31A3A	10.4656	3	0.077	9	0.0086
MCQ31A4A	10.2523	3	0.078	9	0.0087
MCQ31A5A	10.2889	3	0.079	9	0.0088
MCQ31A6A	10.4803	3	0.077	9	0.0086

Average	**8.770**		
Standard Dev.	**0.892**		
Coeff. of Var. [%]	**10.169**		
Min.	**7.552**	**Min.**	**0.0080**
Max.	**10.480**	**Max.**	**0.0088**
Number	**28**		


Apparent Interlaminar Shear -- (RTD)
Measured Strength
NB-321/3K70P Carbon Fabric
Pooled Average = 8.7695 [ksi]
Pooled Standard Deviation = 0.8917 [ksi]
Pooled Coeff. of Variation = 10.1686 [%]
Batch #
Apparent Interlaminar Shear Strength [ksi]
0
1
2
3
0
2
4
6
8
10
12
14
16

3.2.2 Representative Stress-Strain Curve

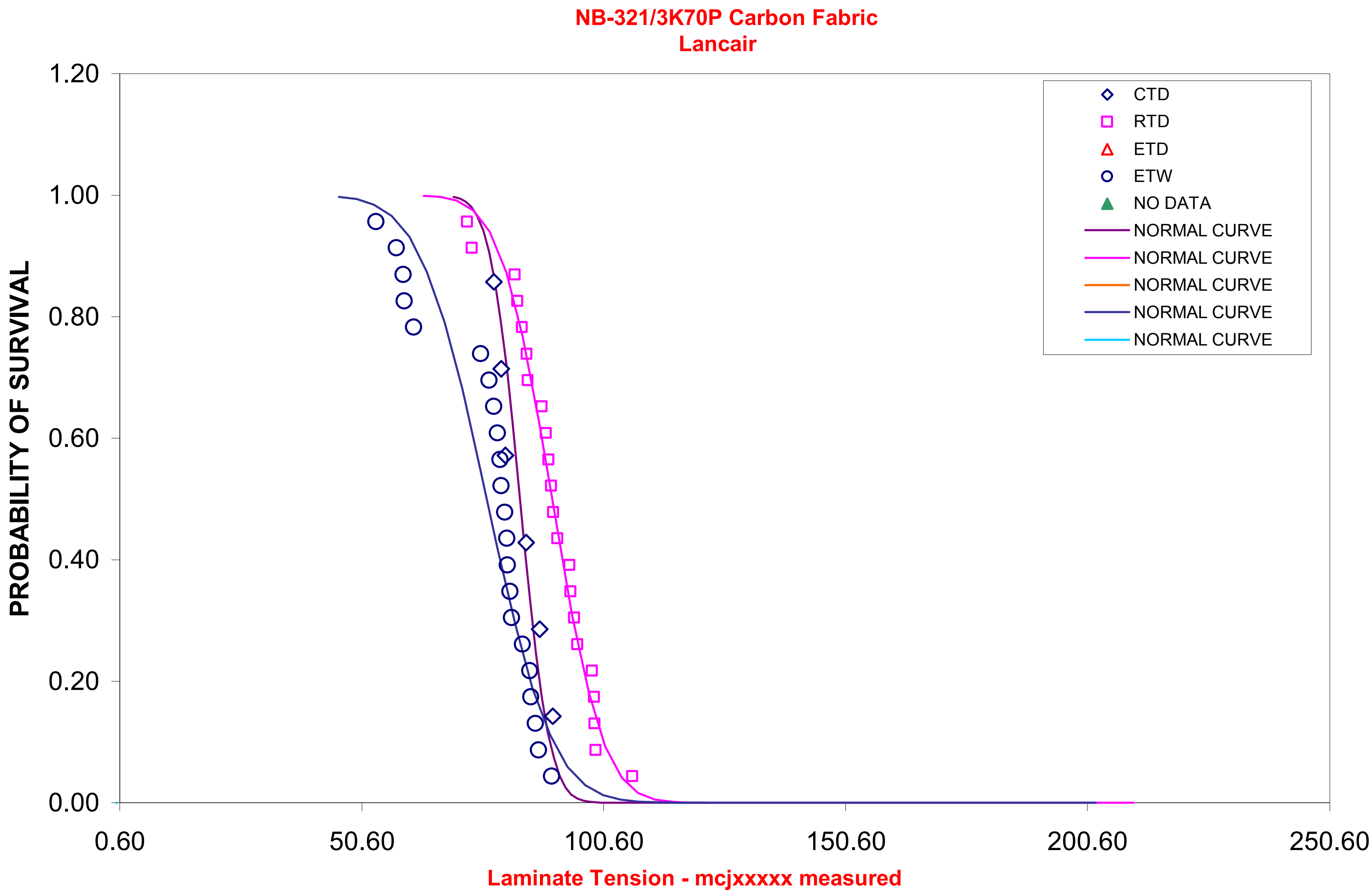
The following stress-strain curve is representative of the 3K70P / NB 321 prepreg system. The tension and compression stress-strain curves are not presented in graphical form. If strain design allowables from these tests are required, simple one-dimensional linear stress-strain relationships may be used 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.

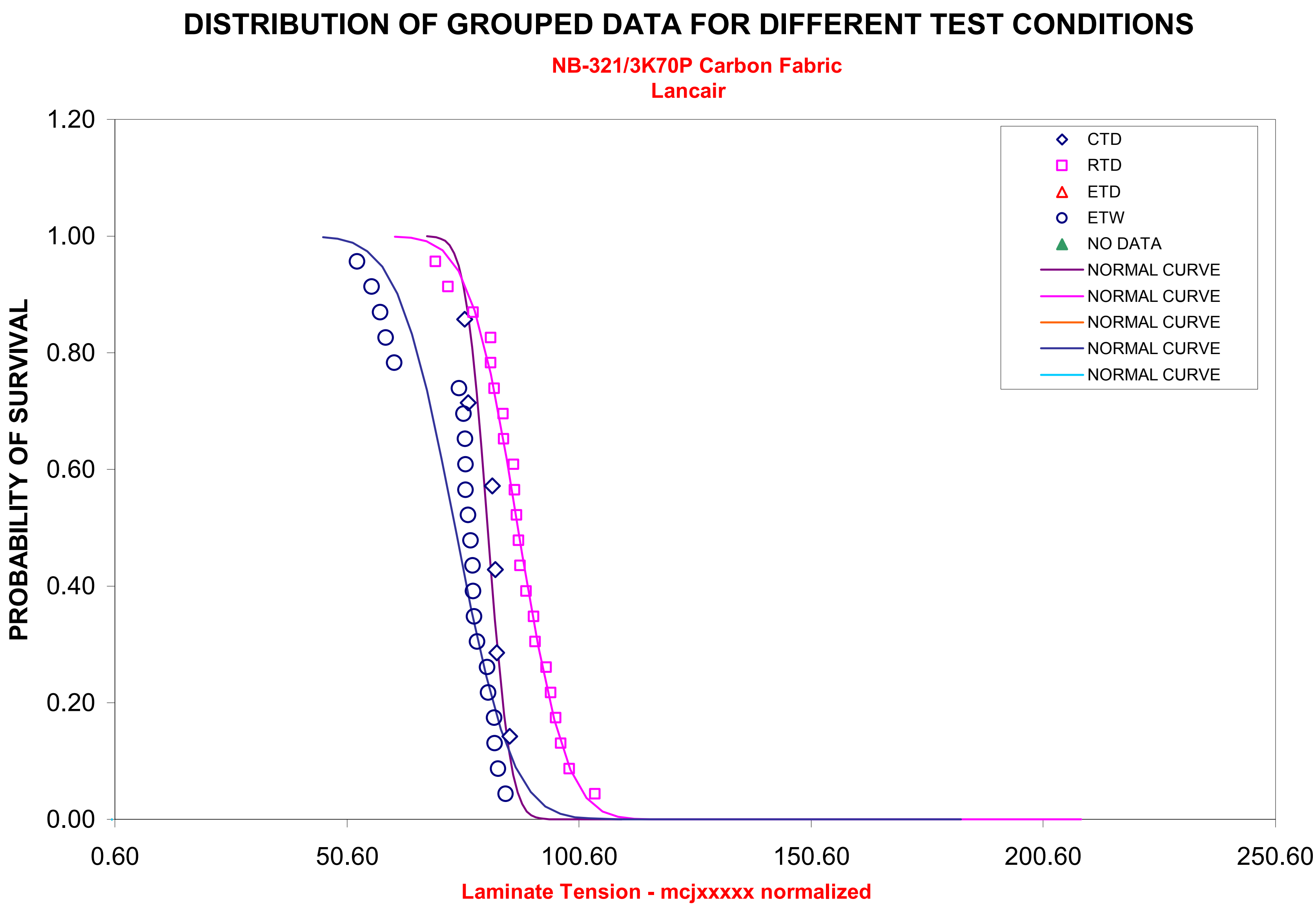

Shear Stress vs. Shear Strain, RTD
Shear Stress [psi]
0
2000
4000
6000
8000
10000
12000
14000
16000
Shear Strain [in/in]
0.00
0.02
0.04
0.06
0.08
0.10
0.12
y^-1=a+b/x
r^2=0.99511681
a=7.2437876e-05
b=9.6203852e-07

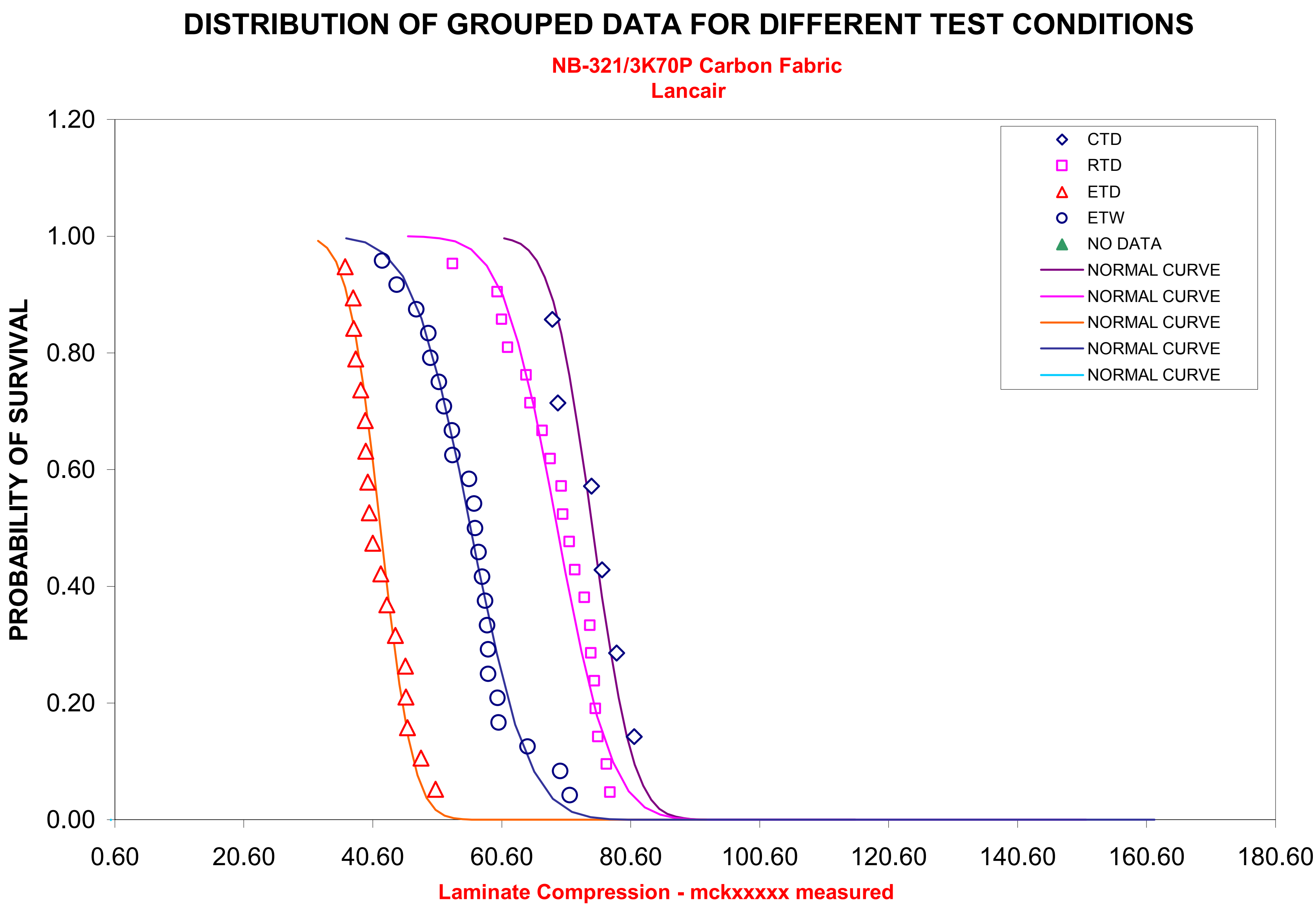
3.3 Statistical Results

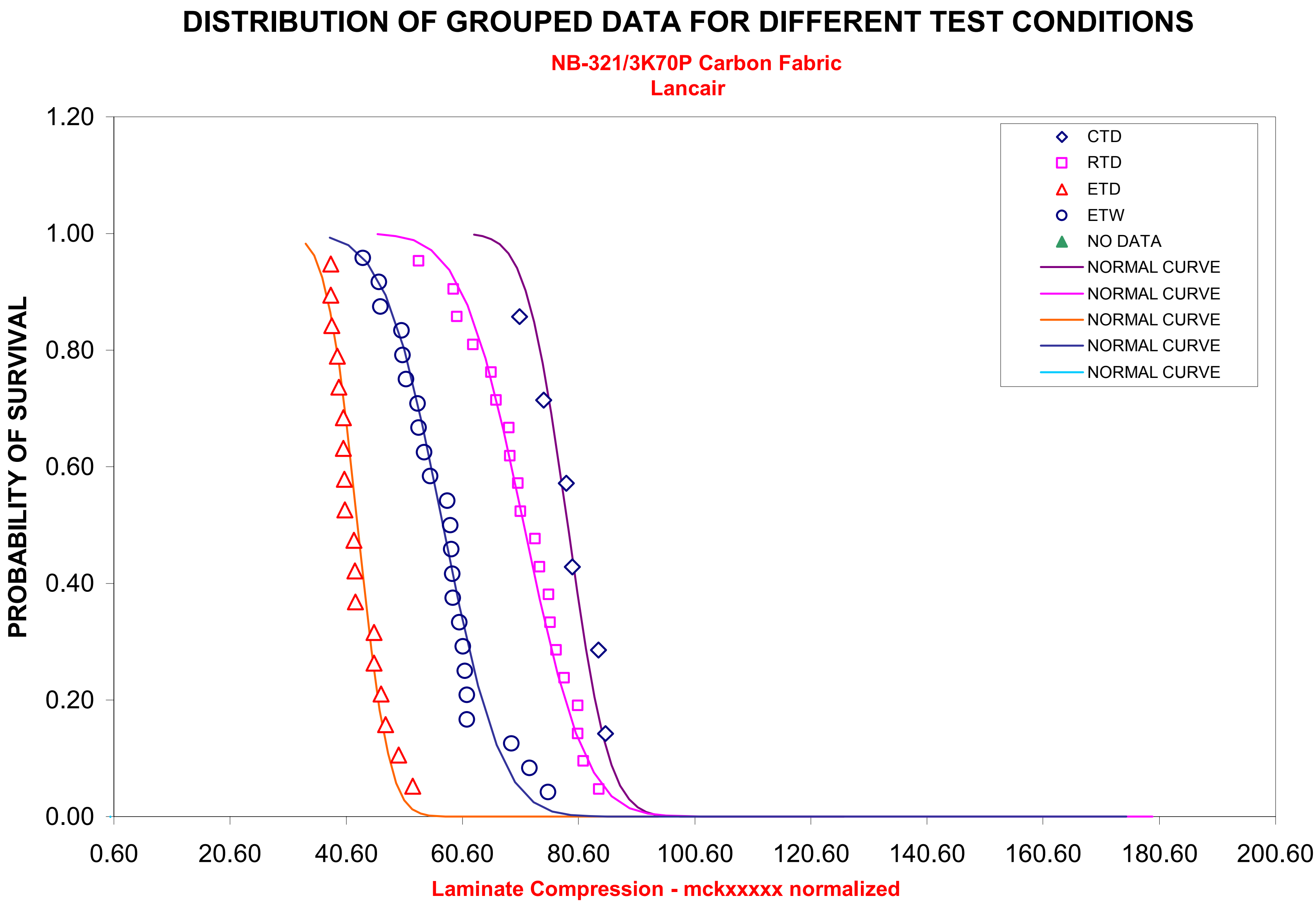
3.3.1 Plot by Condition

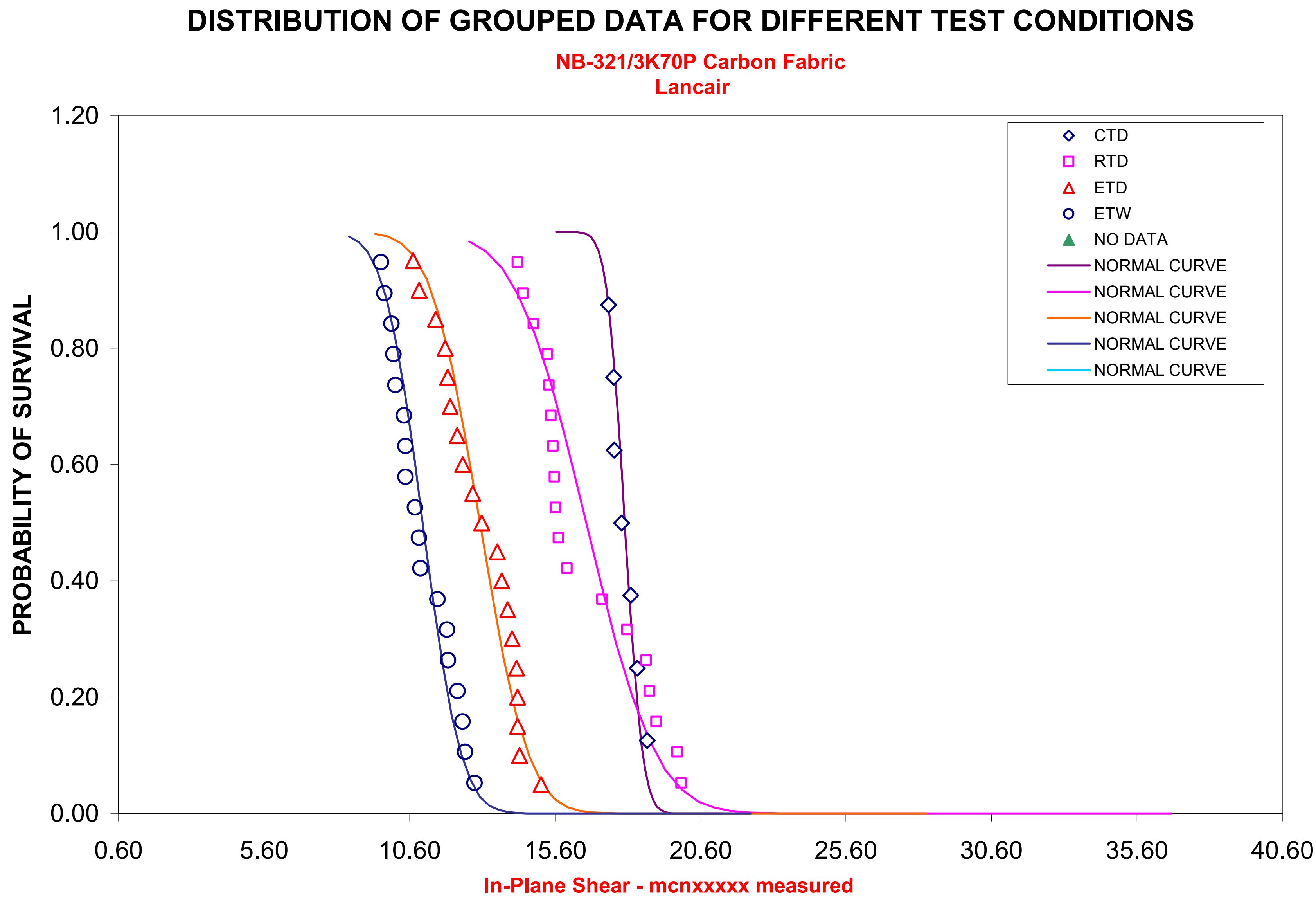
DISTRIBUTION OF GROUPED DATA FOR DIFFERENT TEST CONDITIONS

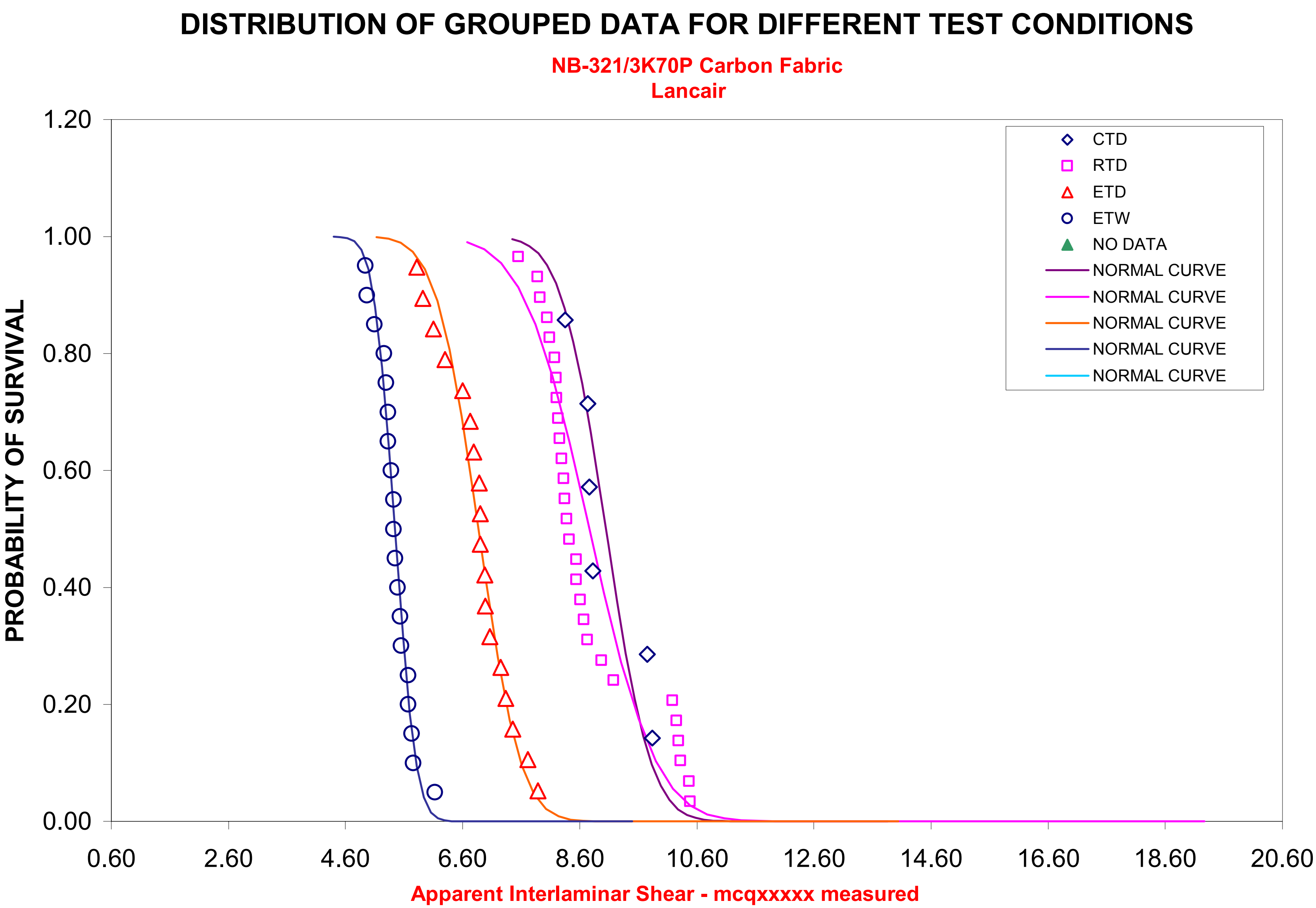



DISTRIBUTION OF GROUPED DATA FOR DIFFERENT TEST CONDITIONS
NB-321/3K70P Carbon Fabric
Lancair
PROBABILITY OF SURVIVAL
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0.60
50.60
100.60
150.60
200.60
250.60
Laminate Tension - mcjxxxxx normalized
CTD
RTD
ETD
ETW
NO DATA
NORMAL CURVE
NORMAL CURVE
NORMAL CURVE
NORMAL CURVE
NORMAL CURVE

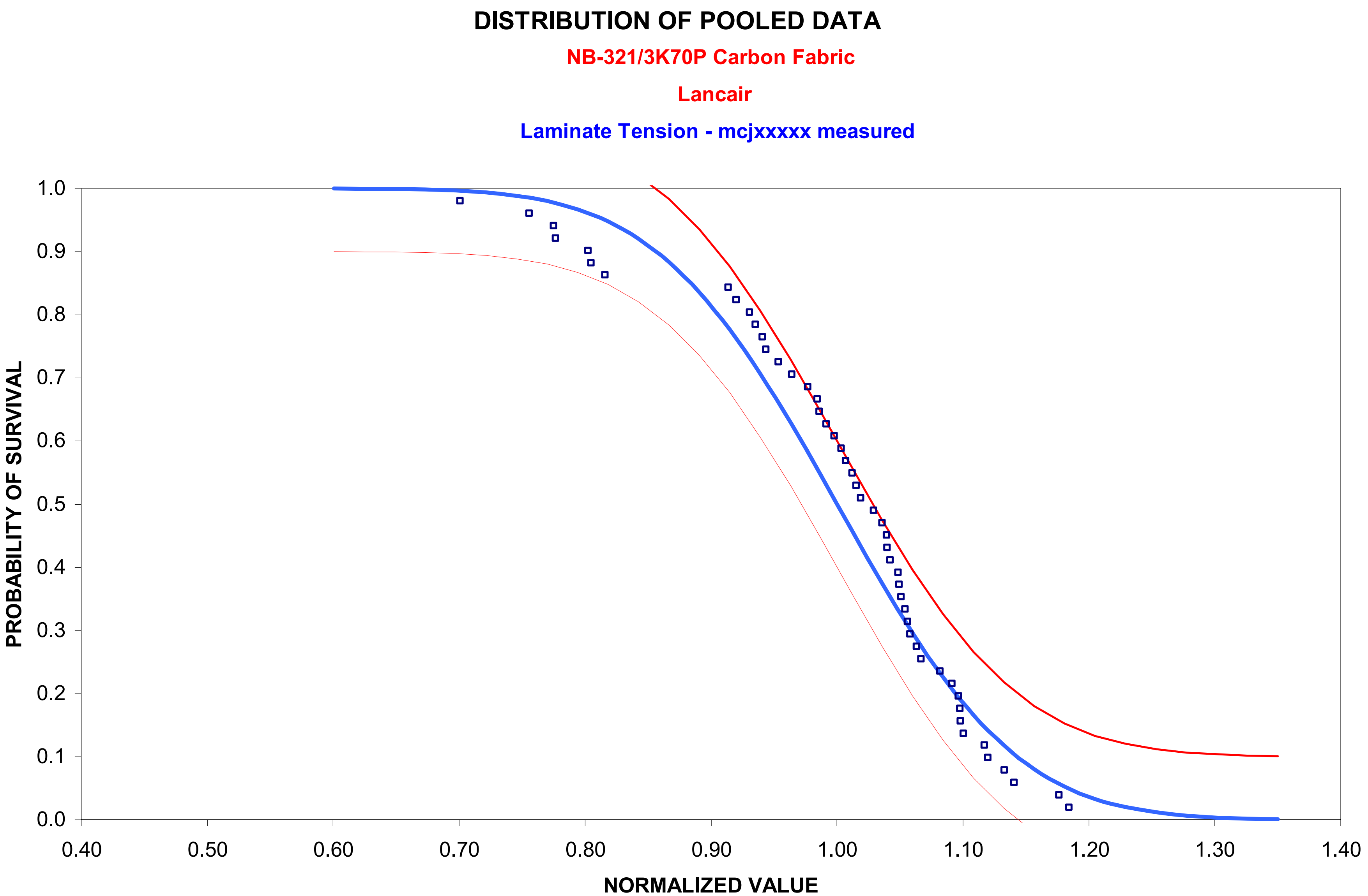

DISTRIBUTION OF GROUPED DATA FOR DIFFERENT TEST CONDITIONS
NB-321/3K70P Carbon Fabric
Lancair
PROBABILITY OF SURVIVAL
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0.60
20.60
40.60
60.60
80.60
100.60
120.60
140.60
160.60
180.60
Laminate Compression - mckxxxxx measured
CTD
RTD
ETD
ETW
NO DATA
NORMAL CURVE
NORMAL CURVE
NORMAL CURVE
NORMAL CURVE
NORMAL CURVE

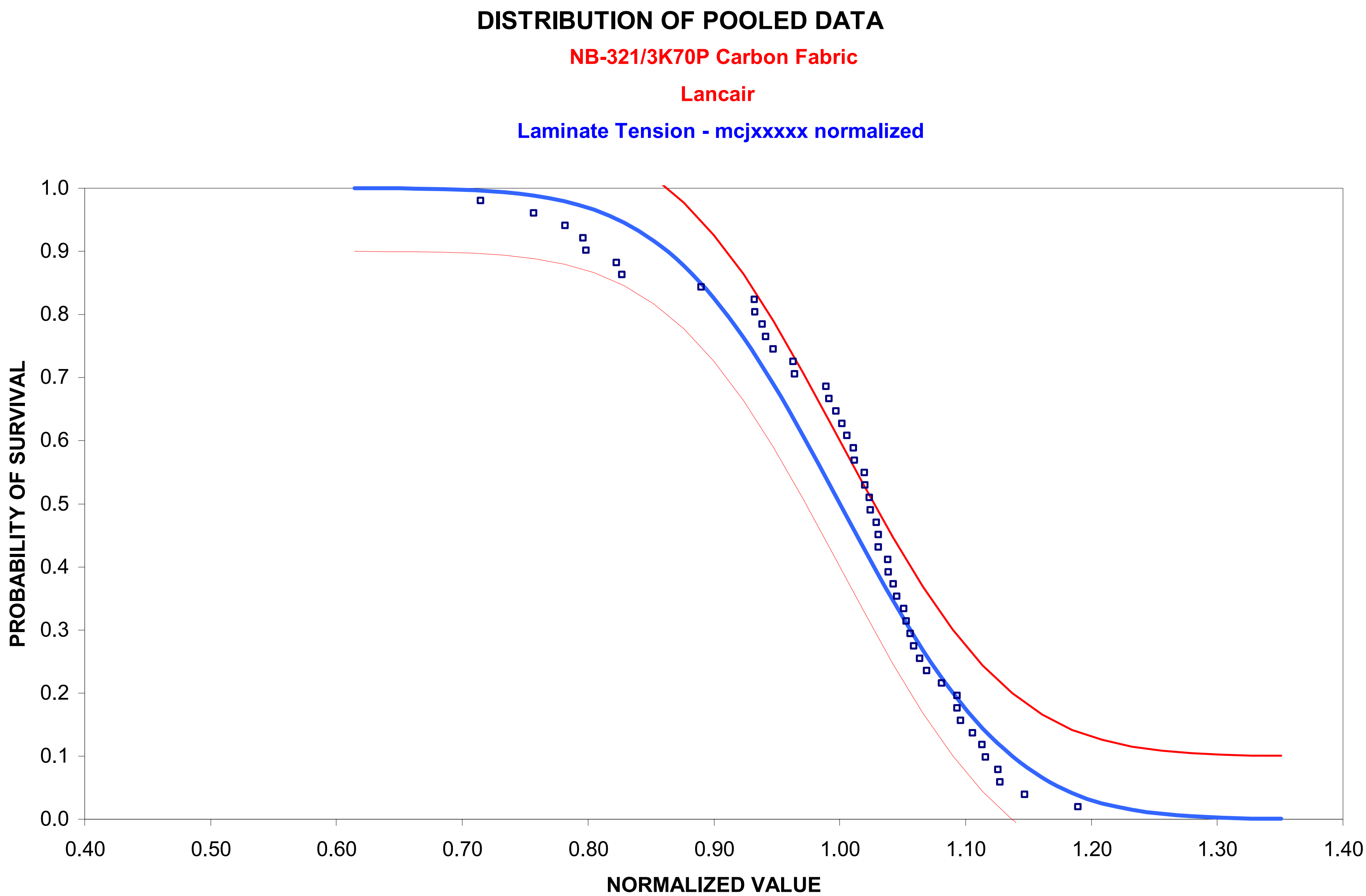

DISTRIBUTION OF GROUPED DATA FOR DIFFERENT TEST CONDITIONS
NB-321/3K70P Carbon Fabric
Lancair
PROBABILITY OF SURVIVAL
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0.60
20.60
40.60
60.60
80.60
100.60
120.60
140.60
160.60
180.60
200.60
Laminate Compression - mckxxxxx normalized
CTD
RTD
ETD
ETW
NO DATA
NORMAL CURVE
NORMAL CURVE
NORMAL CURVE
NORMAL CURVE
NORMAL CURVE

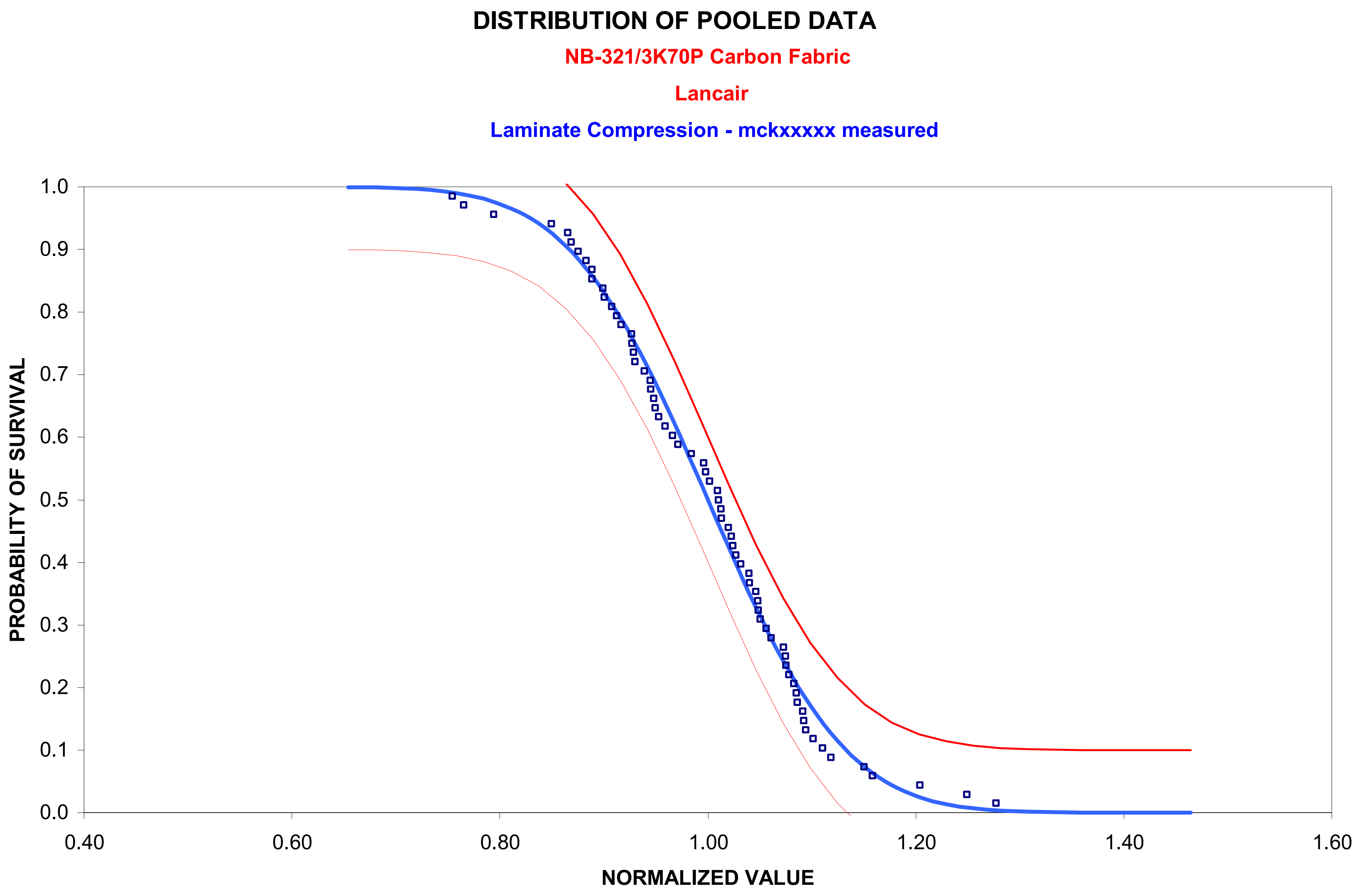

DISTRIBUTION OF GROUPED DATA FOR DIFFERENT TEST CONDITIONS
NB-321/3K70P Carbon Fabric
Lancair
PROBABILITY OF SURVIVAL
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0.60
5.60
10.60
15.60
20.60
25.60
30.60
35.60
40.60
In-Plane Shear - mcnxxxxx measured
CTD
RTD
ETD
ETW
NO DATA
NORMAL CURVE
NORMAL CURVE
NORMAL CURVE
NORMAL CURVE
NORMAL CURVE

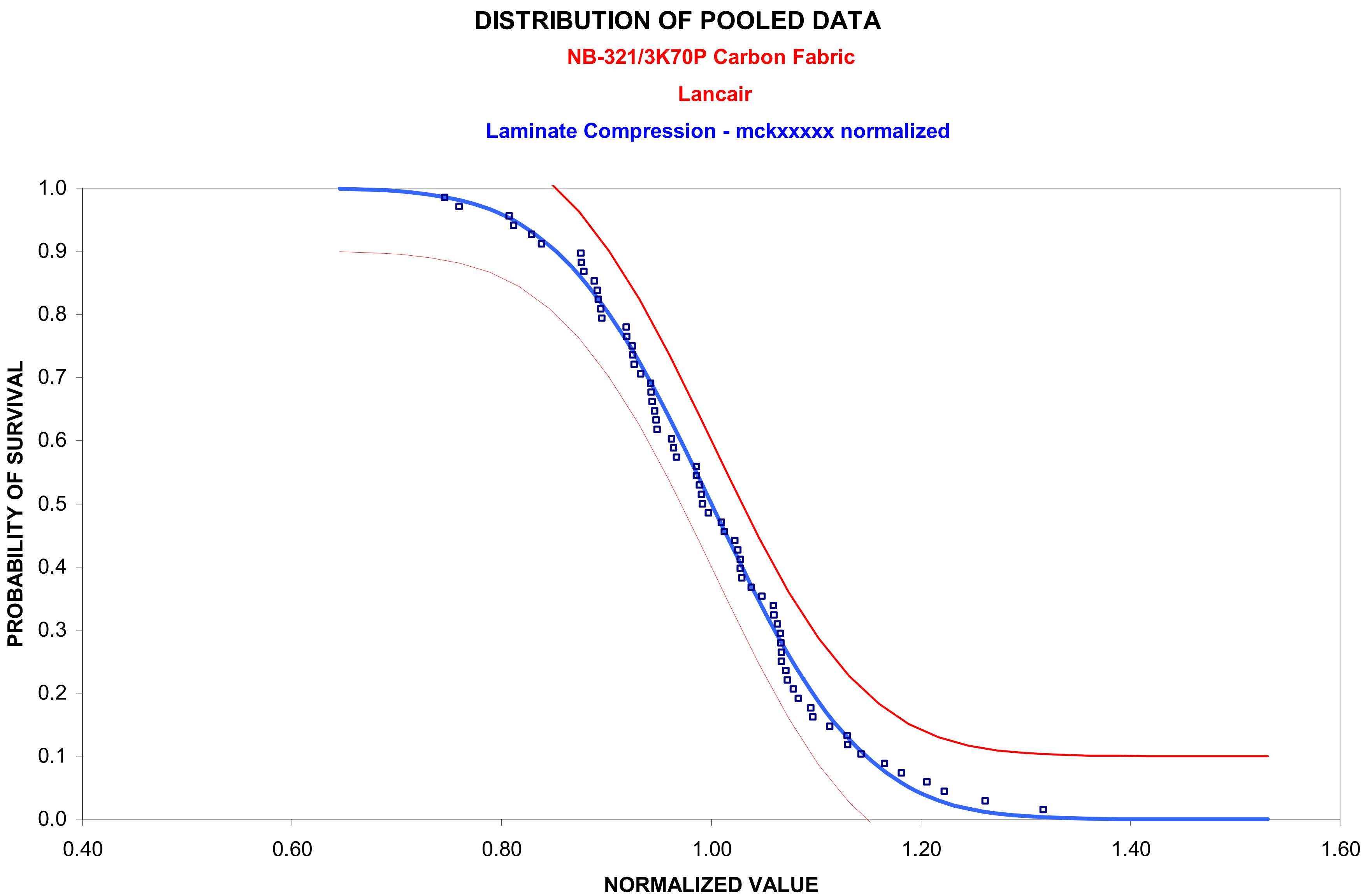

DISTRIBUTION OF GROUPED DATA FOR DIFFERENT TEST CONDITIONS
NB-321/3K70P Carbon Fabric
Lancair
PROBABILITY OF SURVIVAL
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0.60
2.60
4.60
6.60
8.60
10.60
12.60
14.60
16.60
18.60
20.60
Apparent Interlaminar Shear - mcqxxxxx measured
CTD
RTD
ETD
ETW
NO DATA
NORMAL CURVE
NORMAL CURVE
NORMAL CURVE
NORMAL CURVE
NORMAL CURVE

3.3.2 Plot of Pooled Data


DISTRIBUTION OF POOLED DATA
NB-321/3K70P Carbon Fabric
Lancair
Laminate Tension - mcjxxxxx measured
PROBABILITY OF SURVIVAL
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.40
0.50
0.60
0.70
0.80
0.90
1.00
1.10
1.20
1.30
1.40
NORMALIZED VALUE


DISTRIBUTION OF POOLED DATA
NB-321/3K70P Carbon Fabric
Lancair
Laminate Tension - mcjxxxxx normalized
PROBABILITY OF SURVIVAL
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.40
0.50
0.60
0.70
0.80
0.90
1.00
1.10
1.20
1.30
1.40
NORMALIZED VALUE


DISTRIBUTION OF POOLED DATA
NB-321/3K70P Carbon Fabric
Lancair
Laminate Compression - mckxxxxx measured
PROBABILITY OF SURVIVAL
NORMALIZED VALUE
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.40
0.60
0.80
1.00
1.20
1.40
1.60

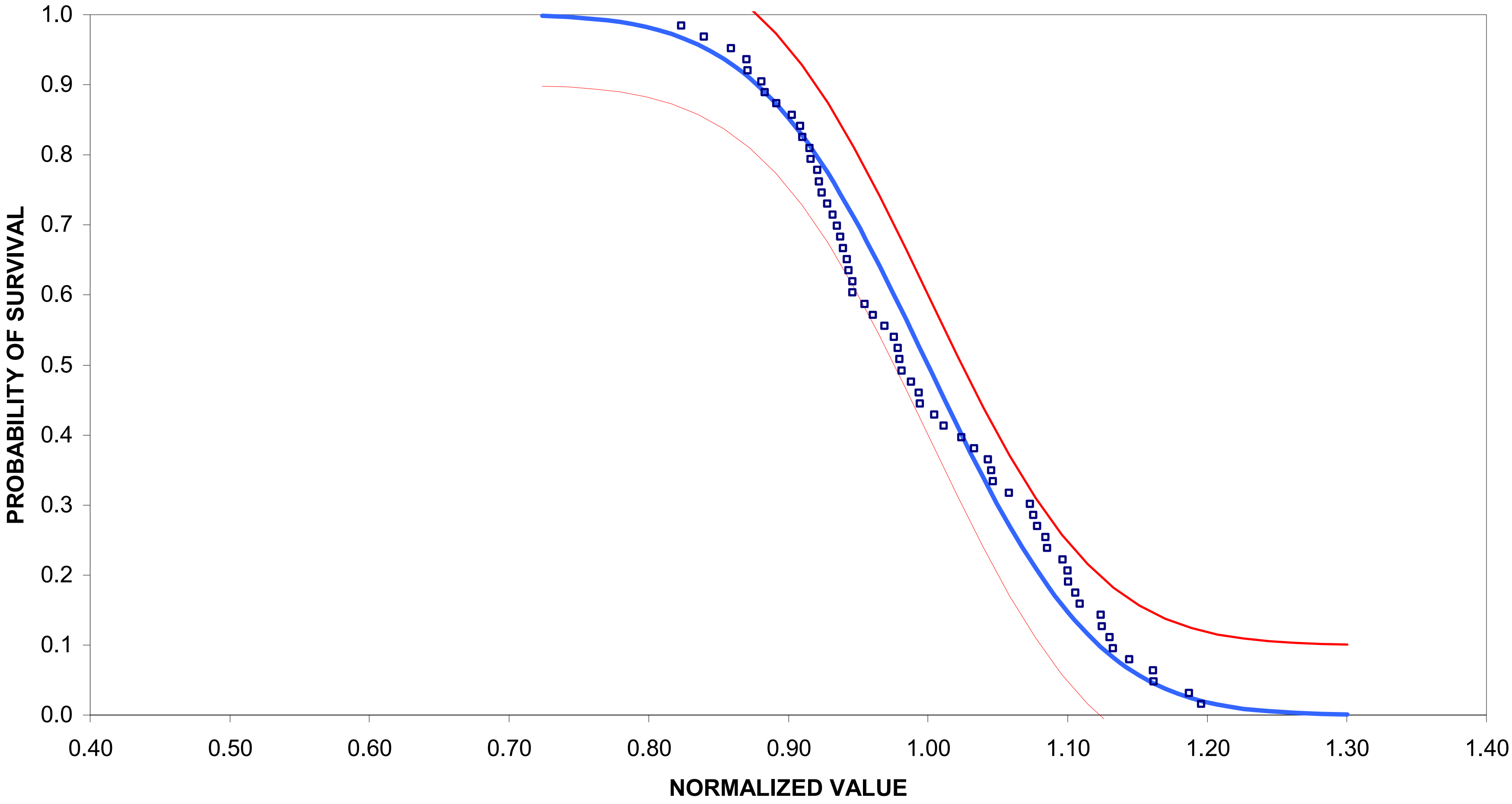

DISTRIBUTION OF POOLED DATA
NB-321/3K70P Carbon Fabric
Lancair
Laminate Compression - mckxxxxx normalized
PROBABILITY OF SURVIVAL
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.40
0.60
0.80
1.00
1.20
1.40
1.60
NORMALIZED VALUE

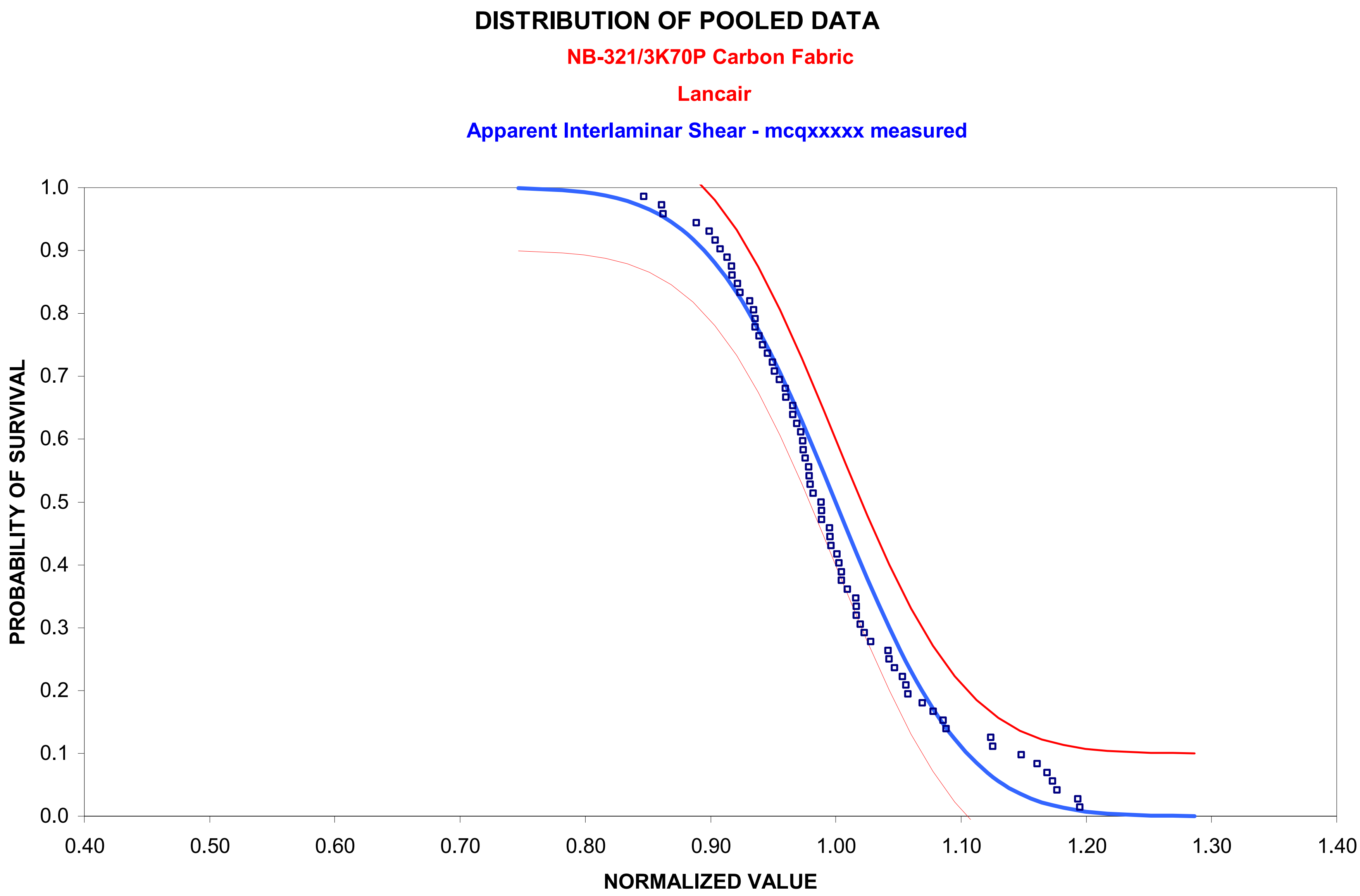
DISTRIBUTION OF POOLED DATA

NB-321/3K70P Carbon Fabric

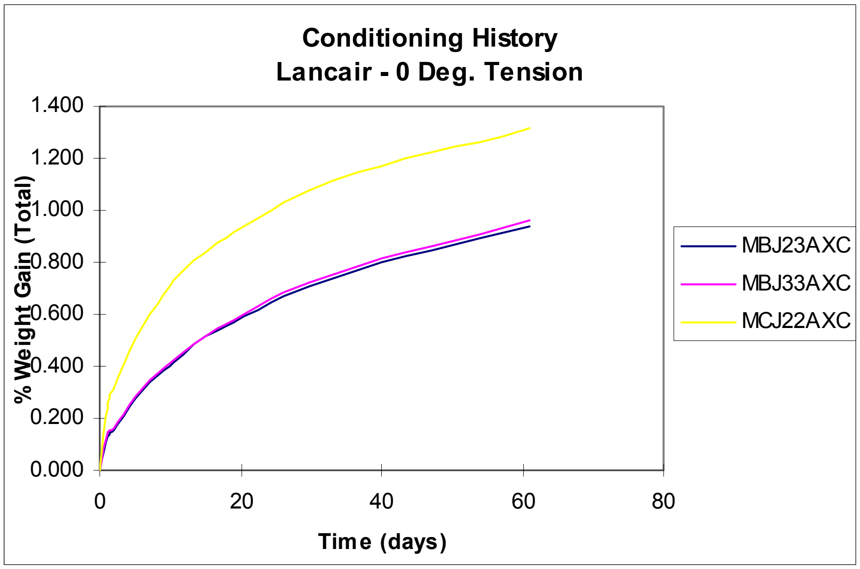
Lancair

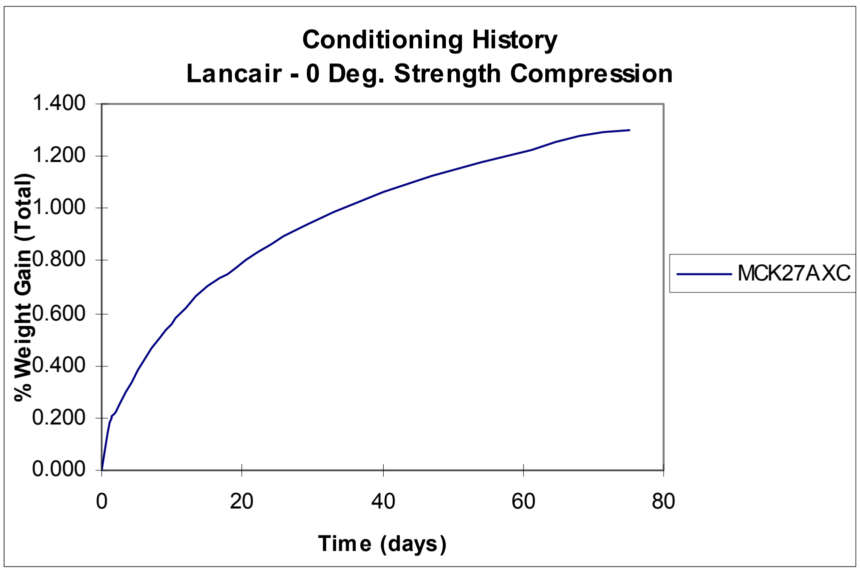
In-Plane Shear - mcnxxxxx measured

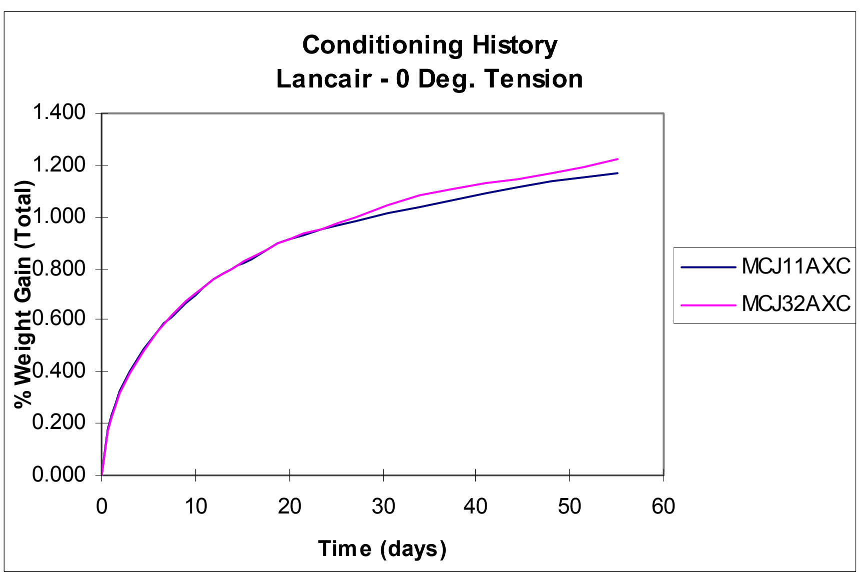


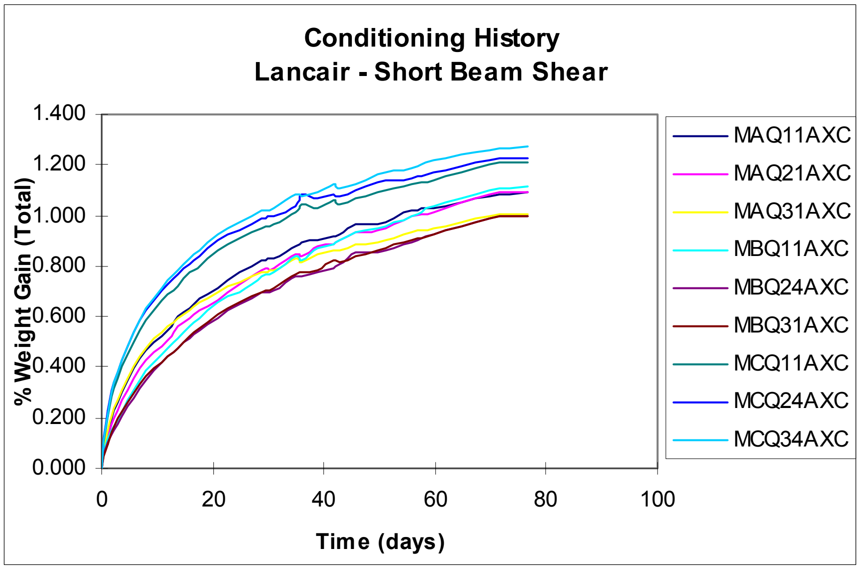

DISTRIBUTION OF POOLED DATA
NB-321/3K70P Carbon Fabric
Lancair
Apparent Interlaminar Shear - mcqxxxxx measured
PROBABILITY OF SURVIVAL
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.40
0.50
0.60
0.70
0.80
0.90
1.00
1.10
1.20
1.30
1.40
NORMALIZED VALUE

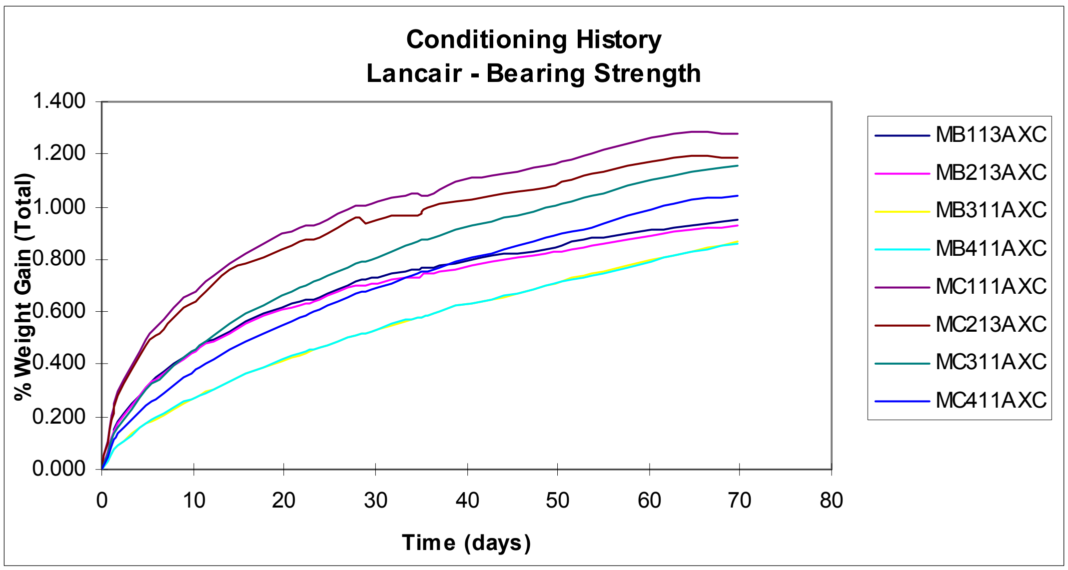
3.4 Moisture Conditioning History Charts

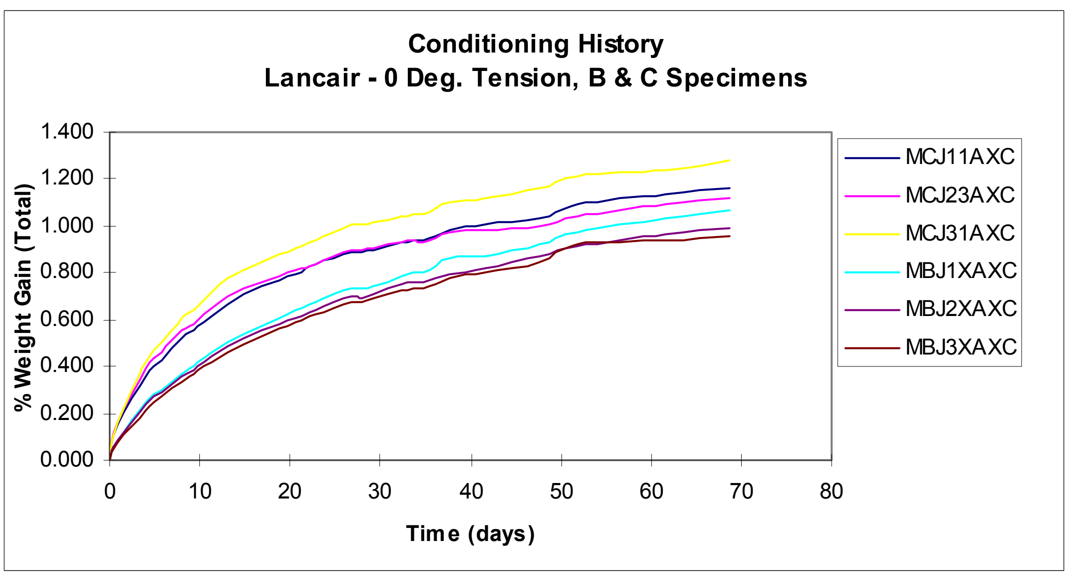

Conditioning History
Lancair - 0 Deg. Tension
% Weight Gain (Total)
1.400
1.200
1.000
0.800
0.600
0.400
0.200
0.000
0
20
40
60
80
Time (days)
MBJ23AXC
MBJ33AXC
MCJ22AXC

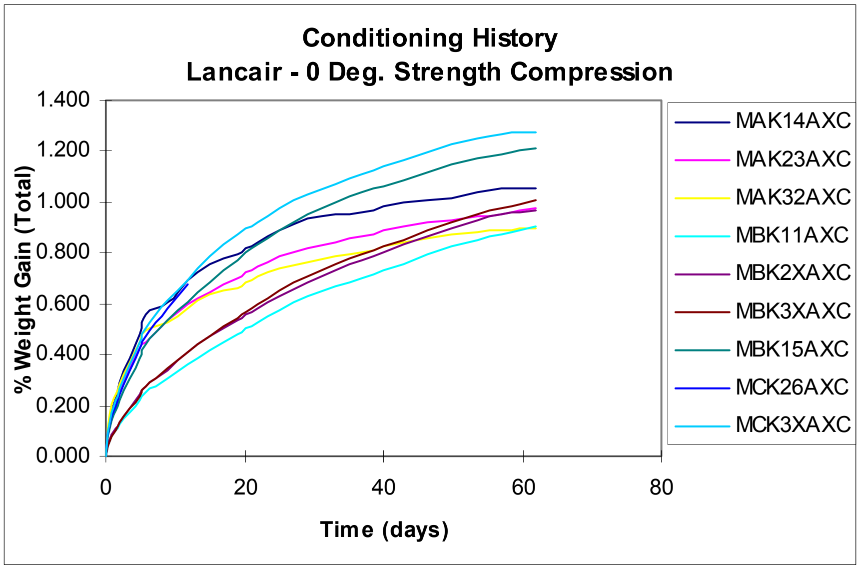

Conditioning History
Lancair - 0 Deg. Strength Compression
% Weight Gain (Total)
1.400
1.200
1.000
0.800
0.600
0.400
0.200
0.000
0
20
40
60
80
Time (days)
MCK27AXC


Conditioning History
Lancair - 0 Deg. Tension
% Weight Gain (Total)
1.400
1.200
1.000
0.800
0.600
0.400
0.200
0.000
0
10
20
30
40
50
60
Time (days)
MCJ11AXC
MCJ32AXC


Conditioning History
Lancair - Short Beam Shear
% Weight Gain (Total)
1.400
1.200
1.000
0.800
0.600
0.400
0.200
0.000
0
20
40
60
80
100
Time (days)
MAQ11AXC
MAQ21AXC
MAQ31AXC
MBQ11AXC
MBQ24AXC
MBQ31AXC
MCQ11AXC
MCQ24AXC
MCQ34AXC


Conditioning History
Lancair - Bearing Strength
% Weight Gain (Total)
1.400
1.200
1.000
0.800
0.600
0.400
0.200
0.000
0
10
20
30
40
50
60
70
80
Time (days)
MB113AXC
MB213AXC
MB311AXC
MB411AXC
MC111AXC
MC213AXC
MC311AXC
MC411AXC


Conditioning History
Lancair - 0 Deg. Tension, B & C Specimens
% Weight Gain (Total)
1.400
1.200
1.000
0.800
0.600
0.400
0.200
0.000
0
10
20
30
40
50
60
70
80
Time (days)
MCJ11AXC
MCJ23AXC
MCJ31AXC
MBJ1XAXC
MBJ2XAXC
MBJ3XAXC


Conditioning History
Lancair - 0 Deg. Strength Compression
% Weight Gain (Total)
1.400
1.200
1.000
0.800
0.600
0.400
0.200
0.000
0
20
40
60
80
Time (days)
MAK14AXC
MAK23AXC
MAK32AXC
MBK11AXC
MBK2XAXC
MBK3XAXC
MBK15AXC
MCK26AXC
MCK3XAXC

3.5 DMA Results

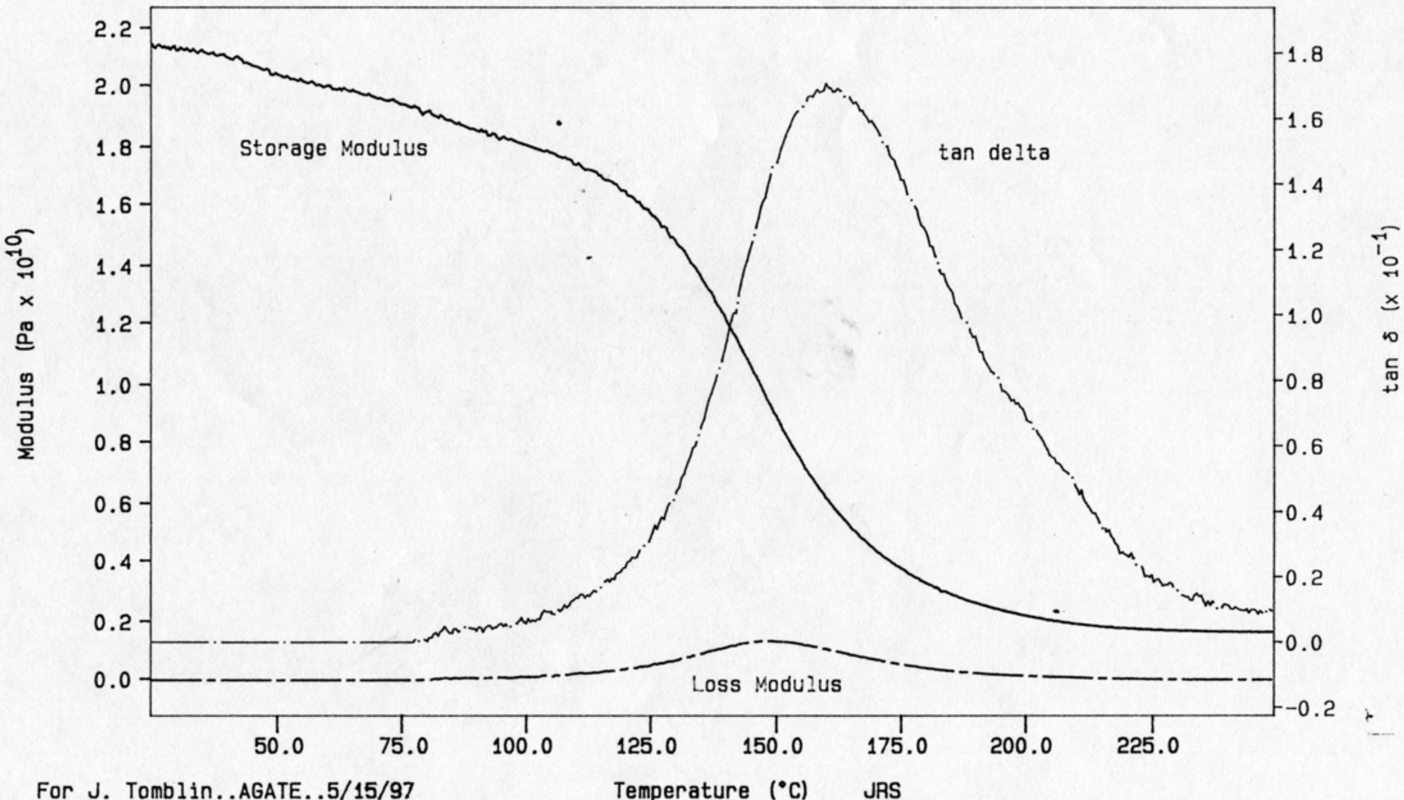
DMA Results

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*

Curve 1: DMA Temp/Time Scan in 3 Point Bending
File info: MAD1_2AxA Thu May 15 16:02:38 1997
Frequency: 1.00 Hz Strain: 0.008%
MAD1_2AxA Tension: 120.000%

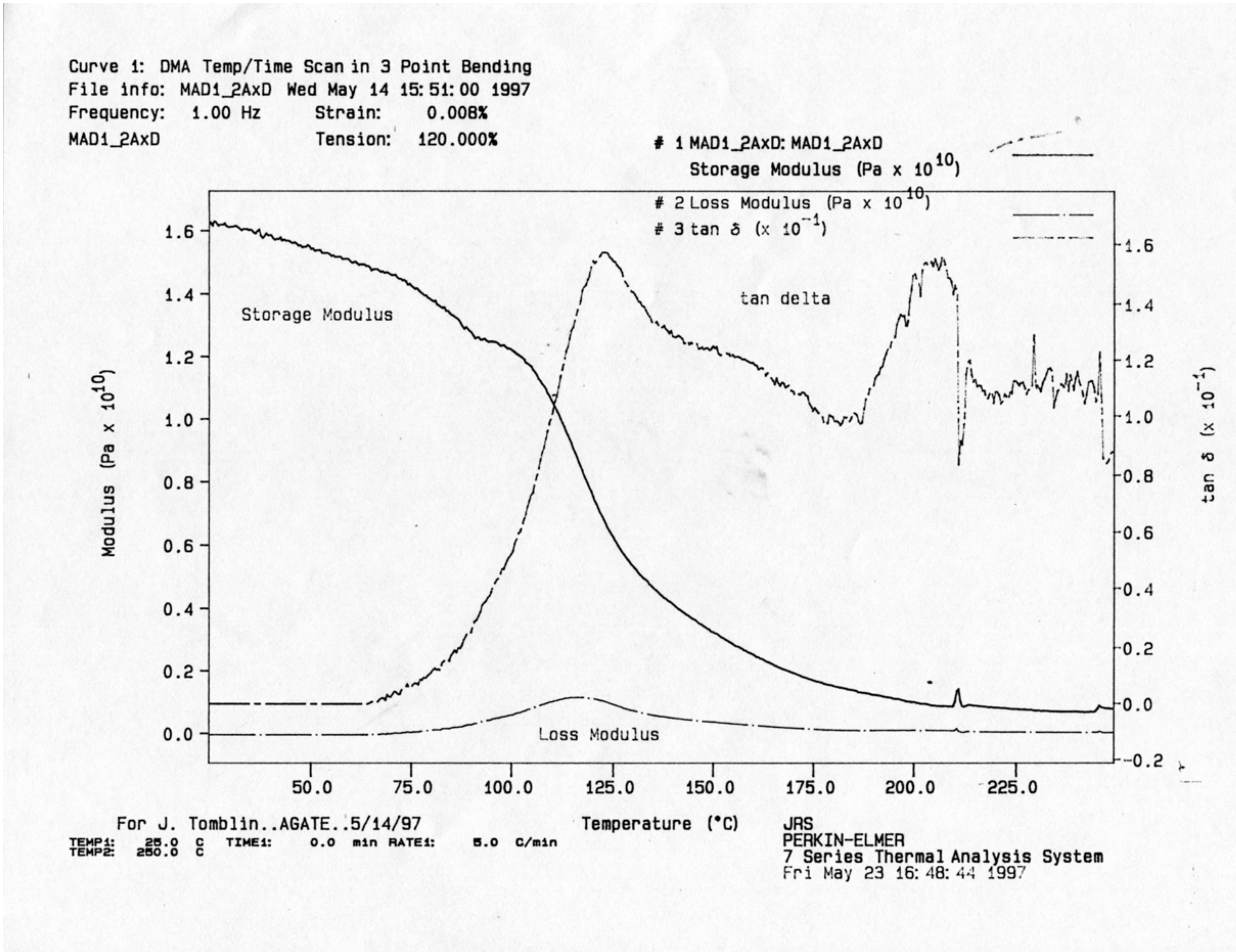
MAD1_2AxA

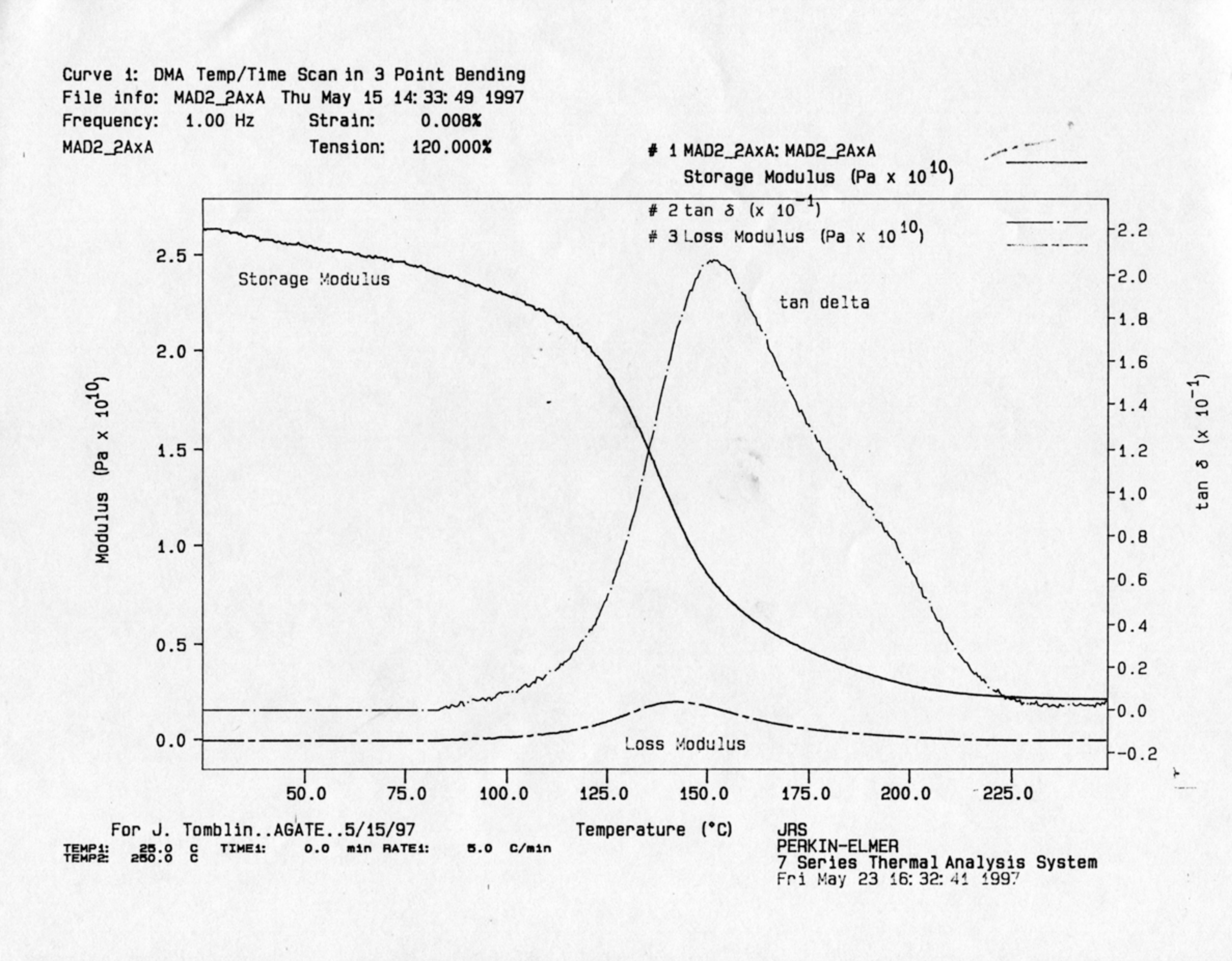


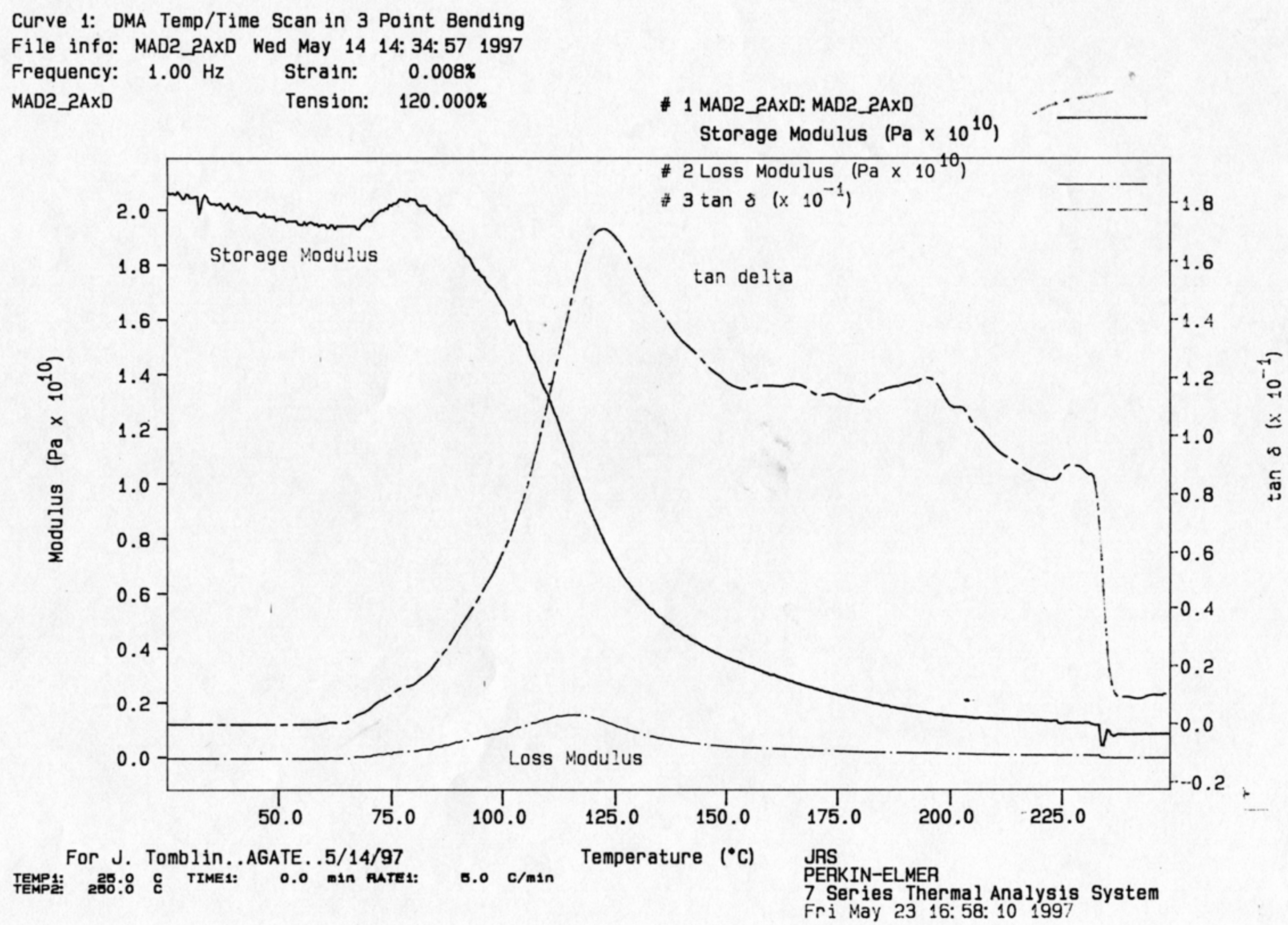
For J. Tomblin..AGATE..5/15/97

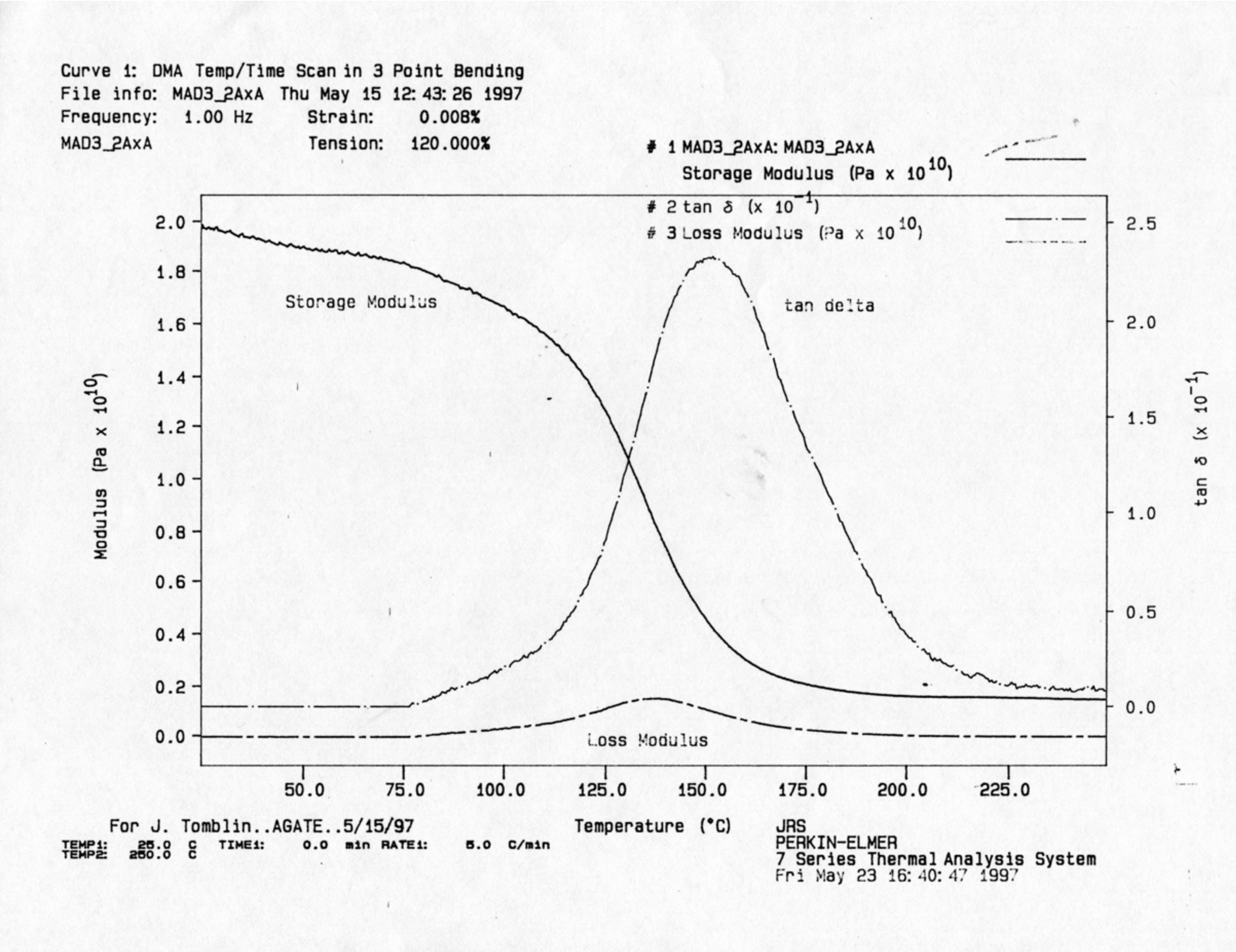
TEMP1: 25.0 C TIME1: 0.0 min RATE1: 5.0 C/min
TEMP2: 250.0 C

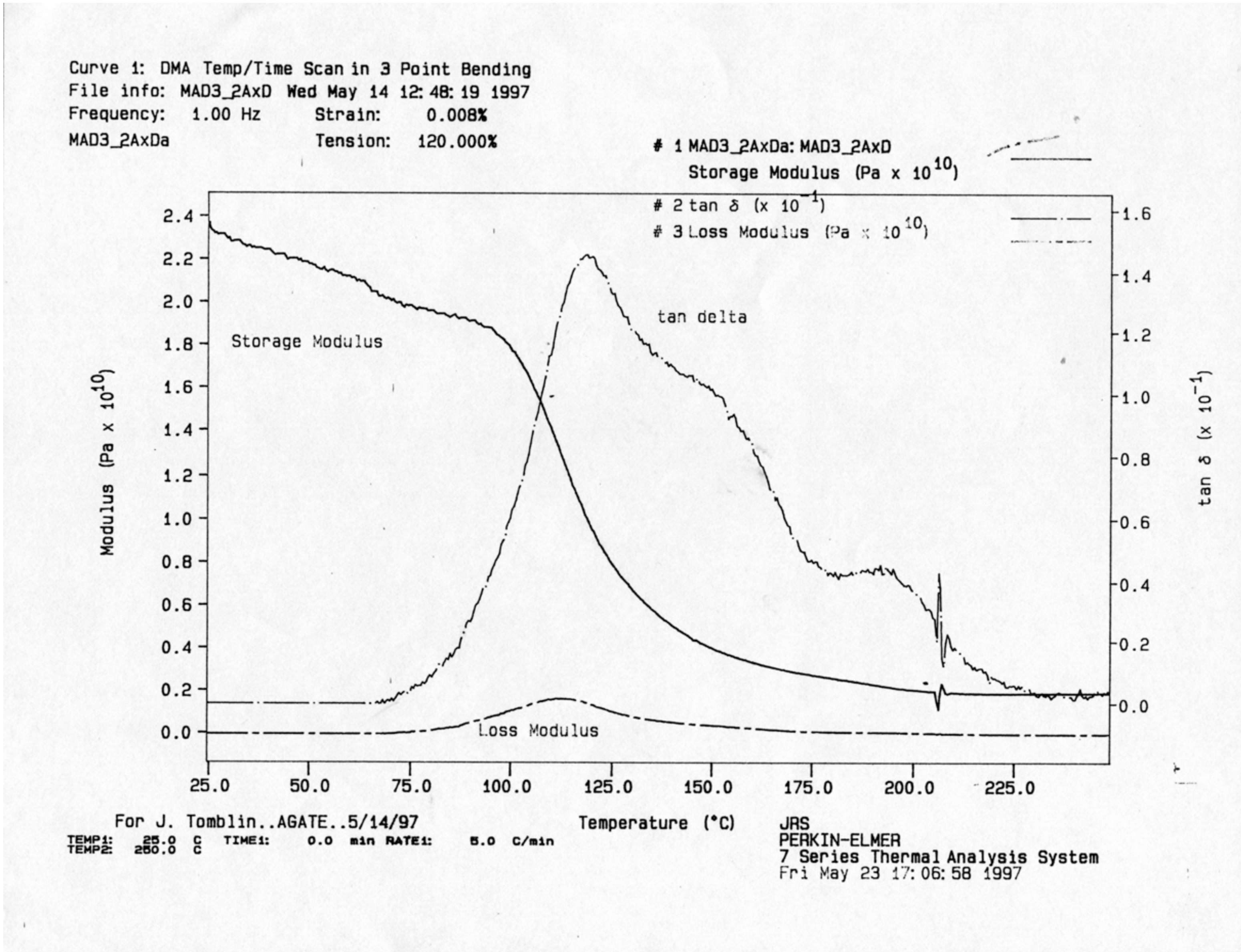
JRS
PERKIN-ELMER
7 Series Thermal Analysis System
Fri May 23 16:23:30 1997

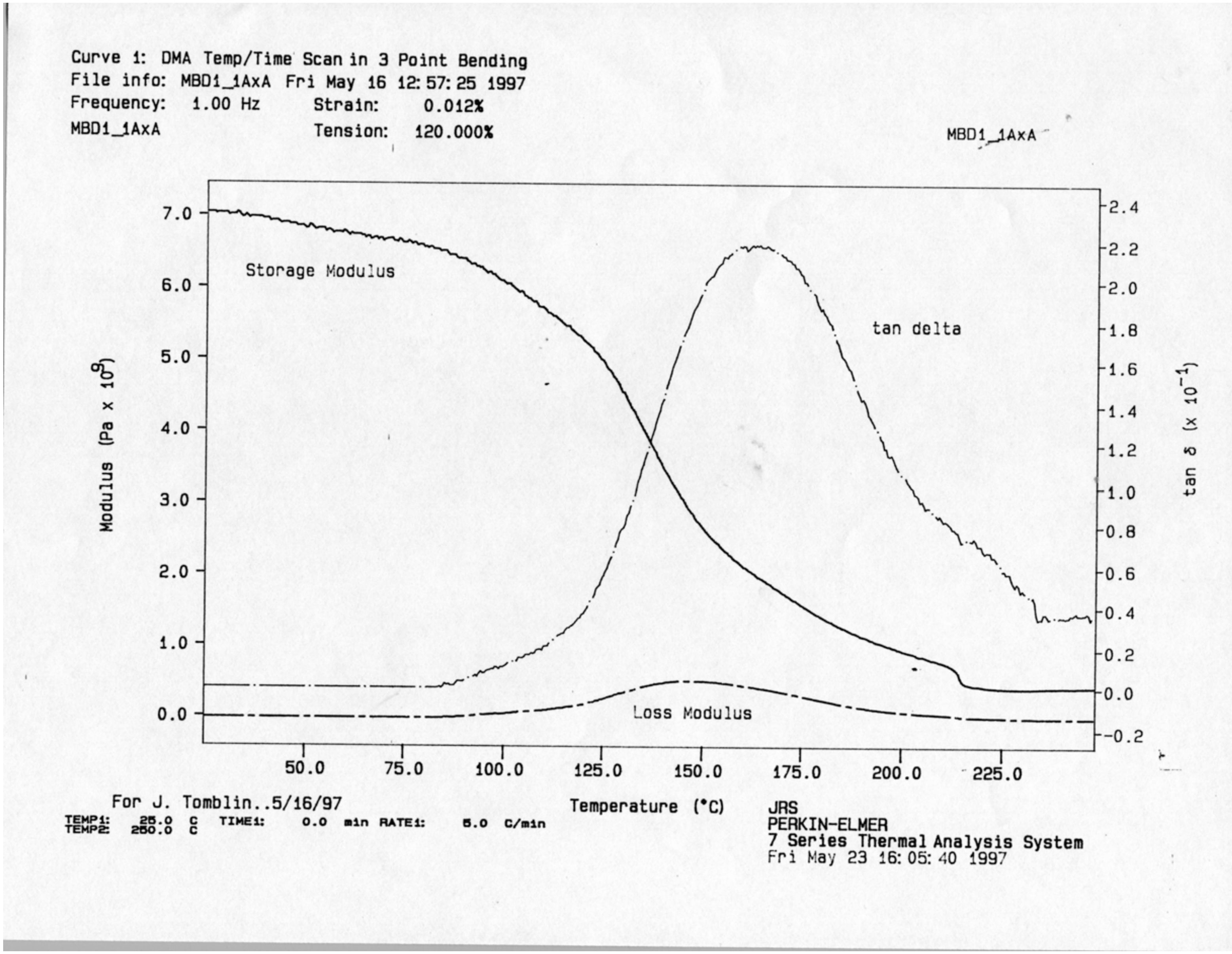

Curve 1: DMA Temp/Time Scan in 3 Point Bending
File info: MAD1_2AxD Wed May 14 15:51:00 1997
Frequency: 1.00 Hz
Strain: 0.008%
MAD1_2AxD
Tension: 120.000%
1 MAD1_2AxD: MAD1_2AxD
Storage Modulus (Pa x 10^10)
2 Loss Modulus (Pa x 10^10)
3 tan δ (x 10^-1)
Storage Modulus
tan delta
Loss Modulus
Modulus (Pa x 10^10)
tan δ (x 10^-1)
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
50.0
75.0
100.0
125.0
150.0
175.0
200.0
225.0
Temperature (°C)
For J. Tomblin..AGATE..5/14/97
TEMP1: 25.0 C TIME1: 0.0 min RATE1: 5.0 C/min
TEMP2: 250.0 C
JRS
PERKIN-ELMER
7 Series Thermal Analysis System
Fri May 23 16:48:44 1997

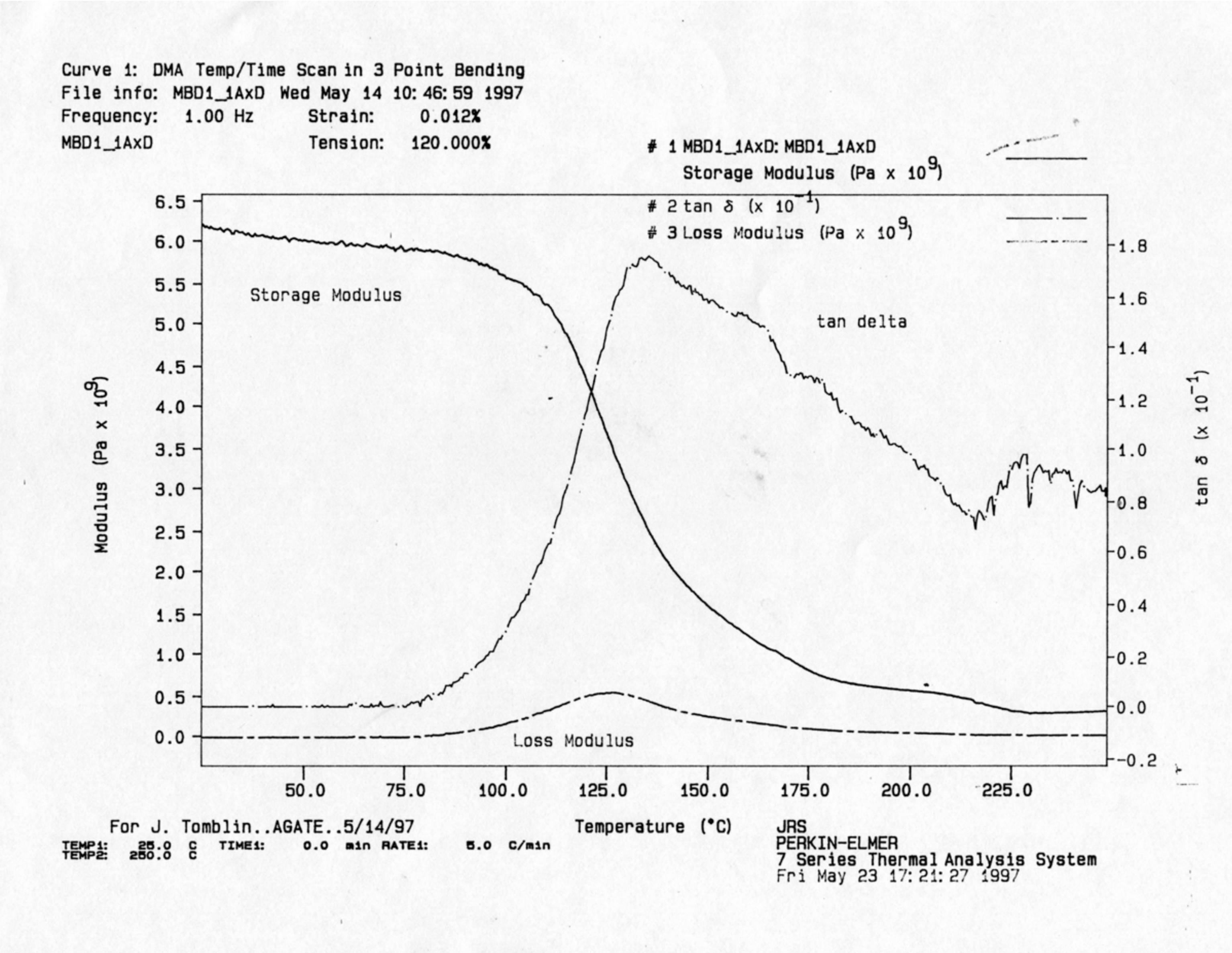

Curve 1: DMA Temp/Time Scan in 3 Point Bending
File info: MAD2_2AxA Thu May 15 14:33:49 1997
Frequency: 1.00 Hz Strain: 0.008%
MAD2_2AxA Tension: 120.000%
1 MAD2_2AxA: MAD2_2AxA
Storage Modulus (Pa x 10^10)
2 tan δ (x 10^-1)
3 Loss Modulus (Pa x 10^10)
Storage Modulus
tan delta
Loss Modulus
Modulus (Pa x 10^10)
tan δ (x 10^-1)
2.5
2.0
1.5
1.0
0.5
0.0
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
50.0
75.0
100.0
125.0
150.0
175.0
200.0
225.0
Temperature (°C)
For J. Tomblin..AGATE..5/15/97
TEMP1: 25.0 C TIME1: 0.0 min RATE1: 5.0 C/min
TEMP2: 250.0 C
JRS
PERKIN-ELMER
7 Series Thermal Analysis System
Fri May 23 16:32:41 1997

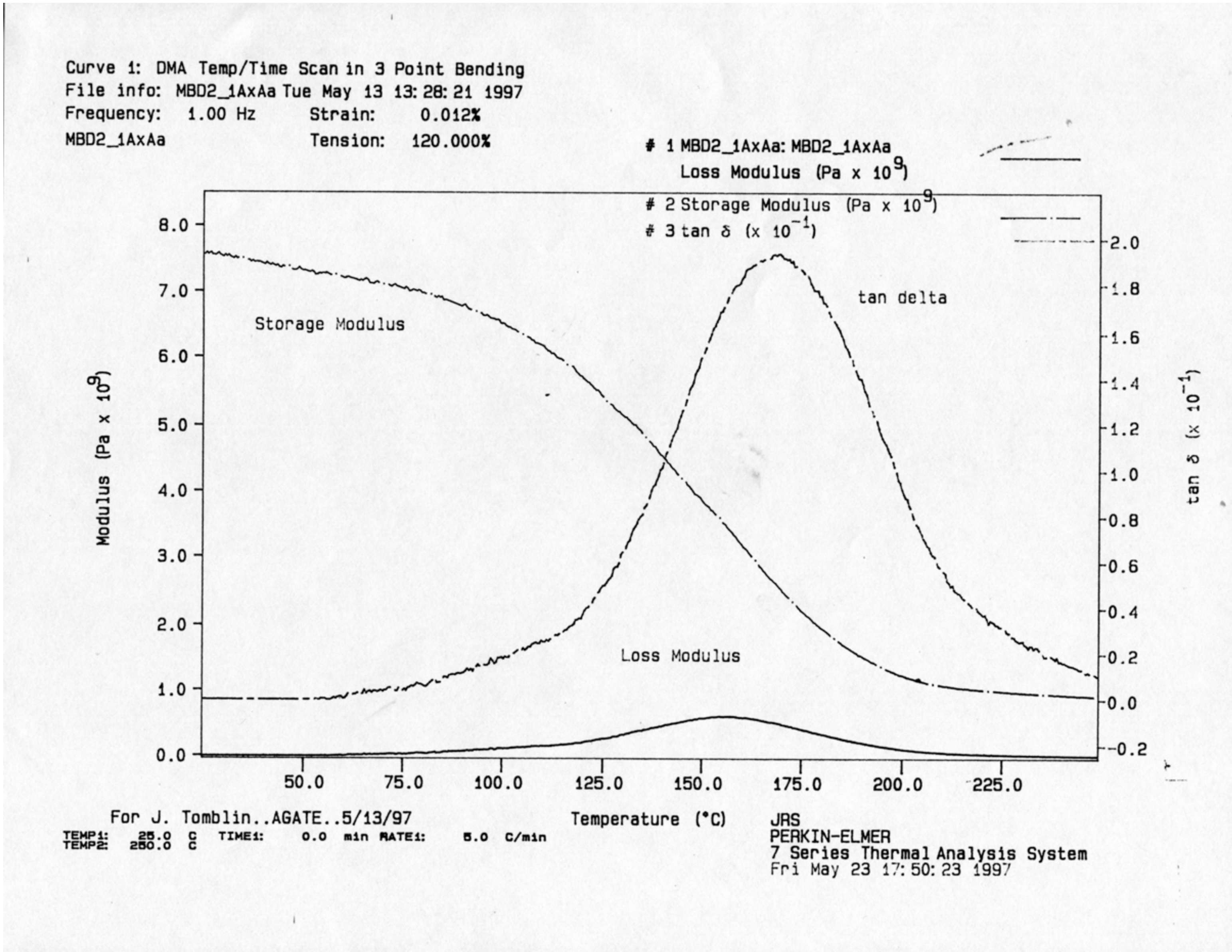

Curve 1: DMA Temp/Time Scan in 3 Point Bending
File info: MAD2_2AxD Wed May 14 14:34:57 1997
Frequency: 1.00 Hz Strain: 0.008%
MAD2_2AxD Tension: 120.000%
1 MAD2_2AxD: MAD2_2AxD
Storage Modulus (Pa x 10^10)
2 Loss Modulus (Pa x 10^10)
3 tan δ (x 10^-1)
Storage Modulus
tan delta
Loss Modulus
Modulus (Pa x 10^10)
tan δ (x 10^-1)
Temperature (°C)
50.0
75.0
100.0
125.0
150.0
175.0
200.0
225.0
For J. Tomblin..AGATE..5/14/97
TEMP1: 25.0 C TIME1: 0.0 min RATE1: 5.0 C/min
TEMP2: 250.0 C
JRS
PERKIN-ELMER
7 Series Thermal Analysis System
Fri May 23 16:58:10 1997

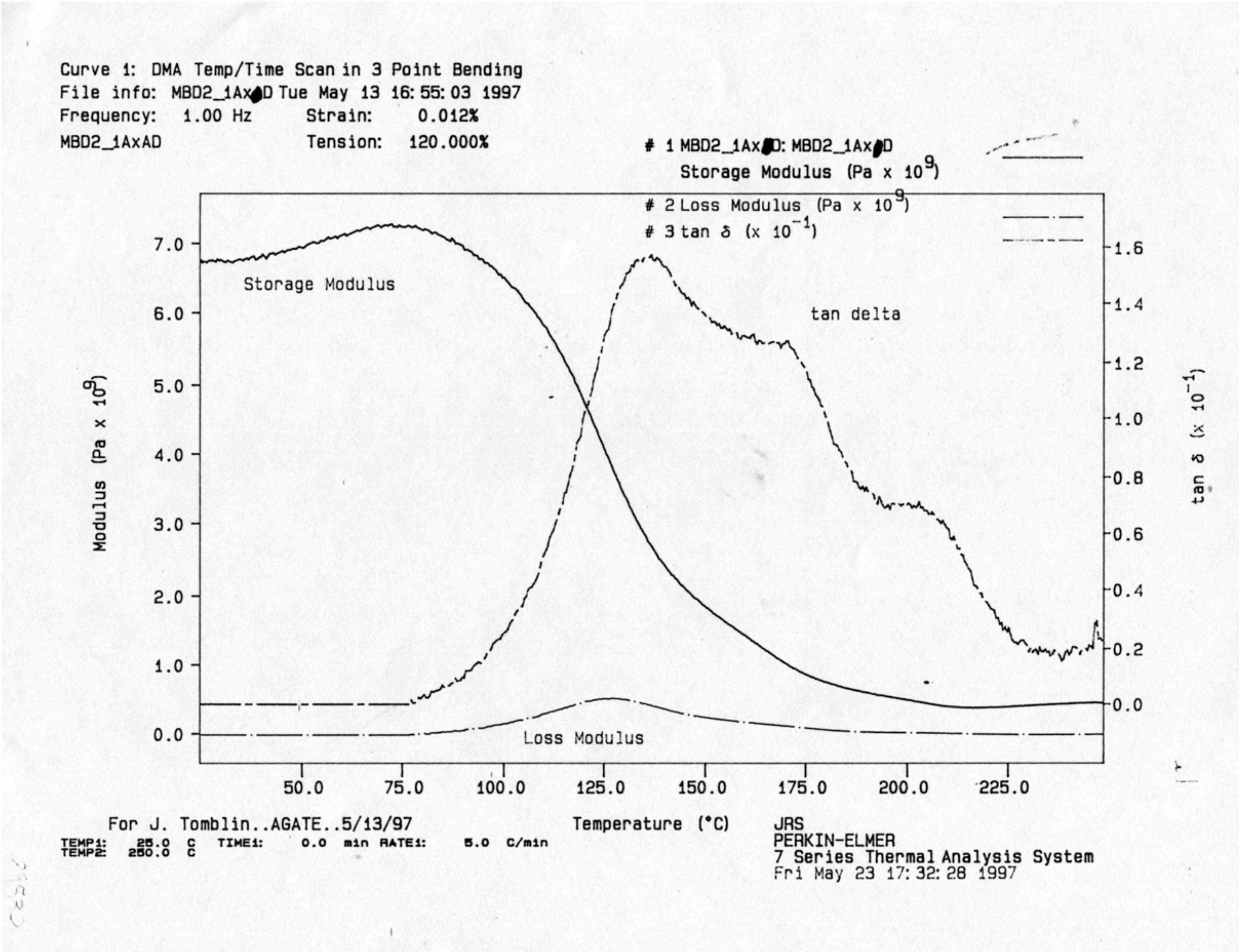

Curve 1: DMA Temp/Time Scan in 3 Point Bending
File info: MAD3_2AxA Thu May 15 12:43:26 1997
Frequency: 1.00 Hz Strain: 0.008%
MAD3_2AxA Tension: 120.000%
1 MAD3_2AxA: MAD3_2AxA
Storage Modulus (Pa x 10^10)
2 tan δ (x 10^-1)
3 Loss Modulus (Pa x 10^10)
Storage Modulus
tan delta
Loss Modulus
Modulus (Pa x 10^10)
tan δ (x 10^-1)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
2.5
2.0
1.5
1.0
0.5
0.0
50.0
75.0
100.0
125.0
150.0
175.0
200.0
225.0
Temperature (°C)
For J. Tomblin..AGATE..5/15/97
TEMP1: 25.0 C TIME1: 0.0 min RATE1: 5.0 C/min
TEMP2: 250.0 C
JRS
PERKIN-ELMER
7 Series Thermal Analysis System
Fri May 23 16:40:47 1997

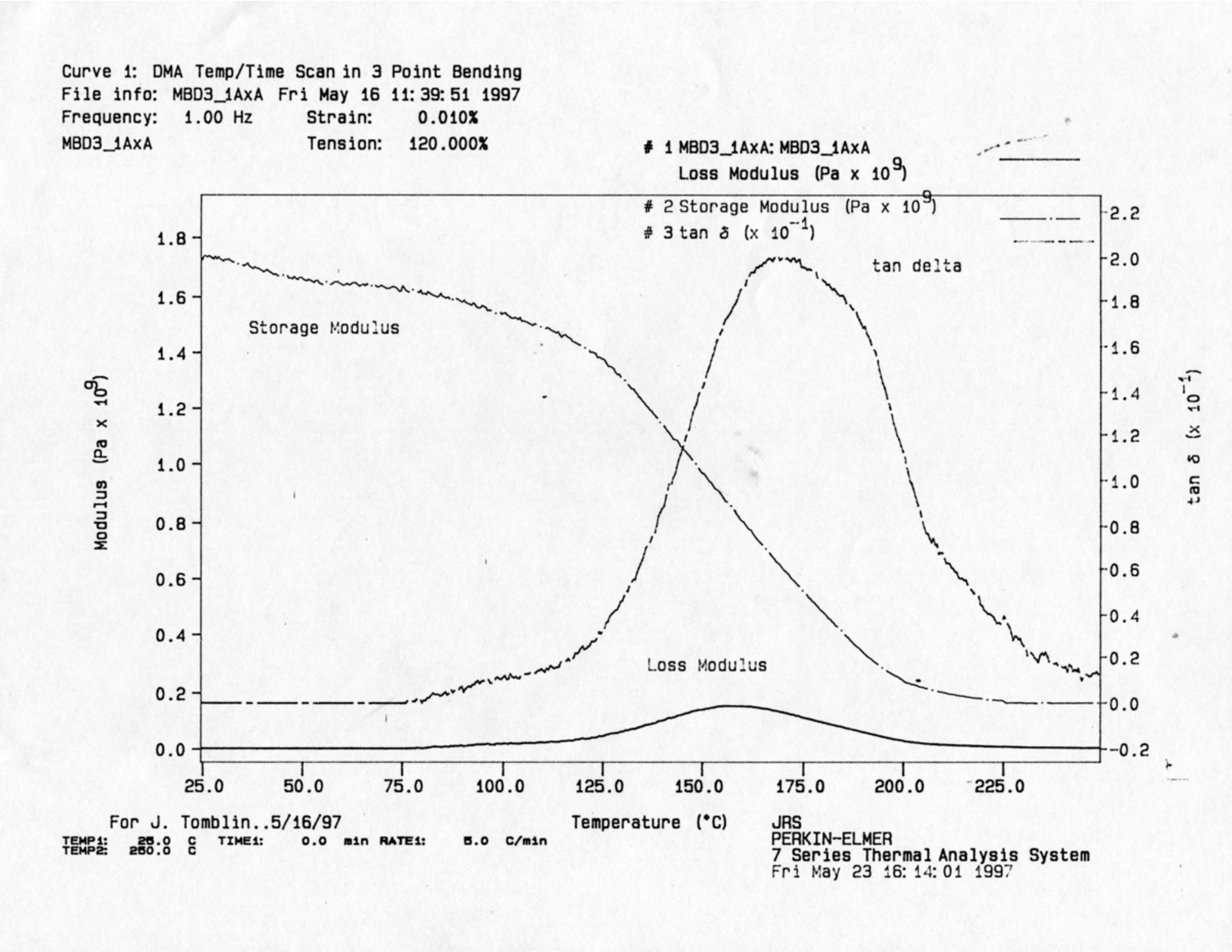

Curve 1: DMA Temp/Time Scan in 3 Point Bending
File info: MAD3_2AxD Wed May 14 12:48:19 1997
Frequency: 1.00 Hz
Strain: 0.008%
MAD3_2AxDa
Tension: 120.000%
1 MAD3_2AxDa: MAD3_2AxD
Storage Modulus (Pa x 10^10)
2 tan δ (x 10^-1)
3 Loss Modulus (Pa x 10^10)
Storage Modulus
tan delta
Loss Modulus
Modulus (Pa x 10^10)
tan δ (x 10^-1)
Temperature (°C)
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
25.0
50.0
75.0
100.0
125.0
150.0
175.0
200.0
225.0
For J. Tomblin..AGATE..5/14/97
TEMP1: 25.0 C TIME1: 0.0 min RATE1: 5.0 C/min
TEMP2: 250.0 C
JRS
PERKIN-ELMER
7 Series Thermal Analysis System
Fri May 23 17:06:58 1997

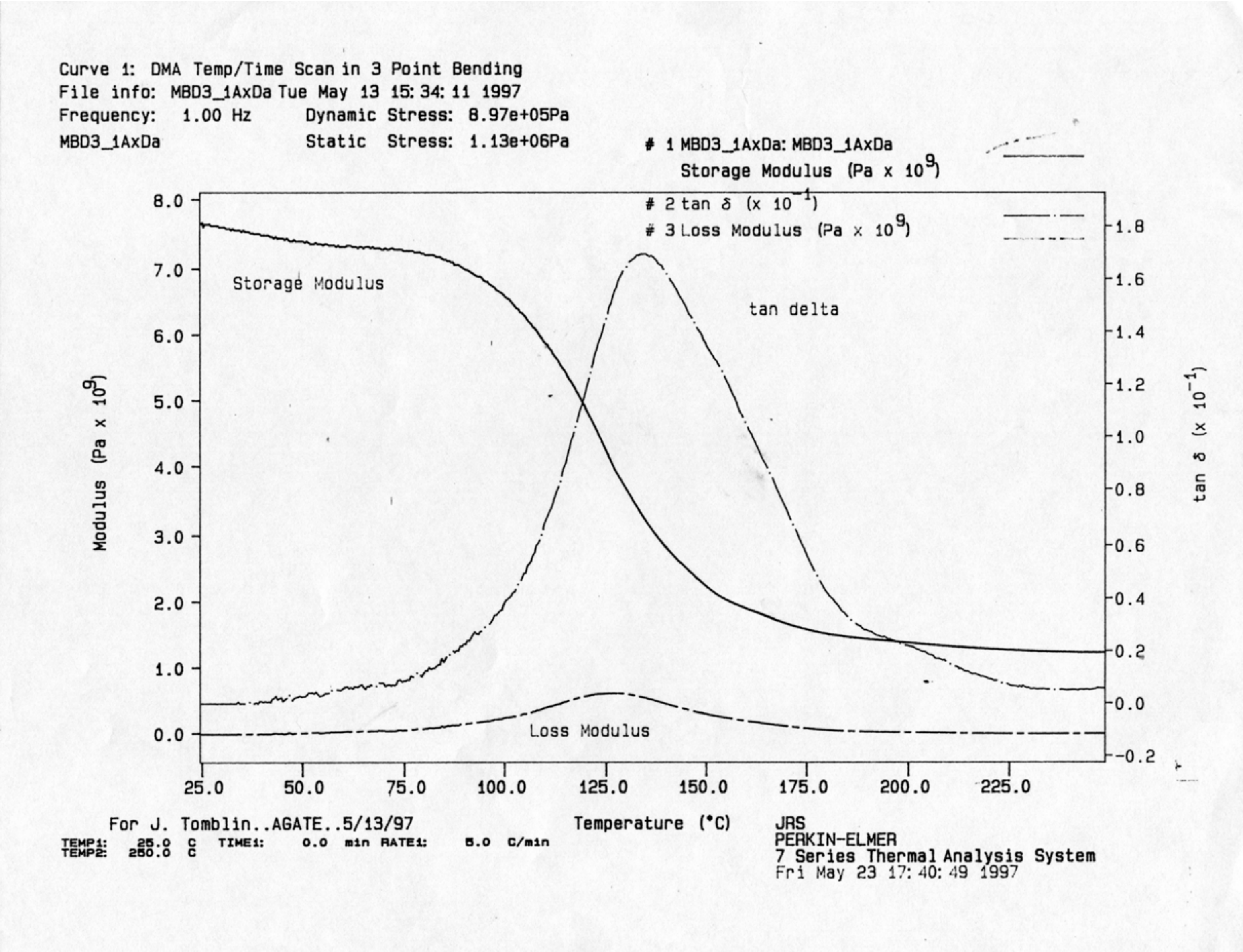

Curve 1: DMA Temp/Time Scan in 3 Point Bending
File info: MBD1_1AxA Fri May 16 12:57:25 1997
Frequency: 1.00 Hz
Strain: 0.012%
MBD1_1AxA
Tension: 120.000%
MBD1_1AxA
Storage Modulus
tan delta
Loss Modulus
Modulus (Pa x 10^9)
tan δ (x 10^-1)
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
50.0
75.0
100.0
125.0
150.0
175.0
200.0
225.0
Temperature (°C)
For J. Tomblin..5/16/97
TEMP1: 25.0 C TIME1: 0.0 min RATE1: 5.0 C/min
TEMP2: 250.0 C
JRS
PERKIN-ELMER
7 Series Thermal Analysis System
Fri May 23 16:05:40 1997


Curve 1: DMA Temp/Time Scan in 3 Point Bending
File info: MBD1_1AxD Wed May 14 10:46:59 1997
Frequency: 1.00 Hz Strain: 0.012%
MBD1_1AxD Tension: 120.000%
1 MBD1_1AxD: MBD1_1AxD
Storage Modulus (Pa x 10^9)
2 tan δ (x 10^-1)
3 Loss Modulus (Pa x 10^9)
Storage Modulus
tan delta
Loss Modulus
Modulus (Pa x 10^9)
tan δ (x 10^-1)
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
50.0
75.0
100.0
125.0
150.0
175.0
200.0
225.0
Temperature (°C)
For J. Tomblin..AGATE..5/14/97
TEMP1: 25.0 C TIME1: 0.0 min RATE1: 5.0 C/min
TEMP2: 250.0 C
JRS
PERKIN-ELMER
7 Series Thermal Analysis System
Fri May 23 17:21:27 1997


Curve 1: DMA Temp/Time Scan in 3 Point Bending
File info: MBD2_1AxAa Tue May 13 13:28:21 1997
Frequency: 1.00 Hz Strain: 0.012%
MBD2_1AxAa Tension: 120.000%
1 MBD2_1AxAa: MBD2_1AxAa
Loss Modulus (Pa x 10^9)
2 Storage Modulus (Pa x 10^9)
3 tan δ (x 10^-1)
Storage Modulus
tan delta
Loss Modulus
Modulus (Pa x 10^9)
tan δ (x 10^-1)
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
50.0
75.0
100.0
125.0
150.0
175.0
200.0
225.0
Temperature (°C)
For J. Tomblin..AGATE..5/13/97
TEMP1: 25.0 C TIME1: 0.0 min RATE1: 5.0 C/min
TEMP2: 250.0 C
JRS
PERKIN-ELMER
7 Series Thermal Analysis System
Fri May 23 17:50:23 1997


Curve 1: DMA Temp/Time Scan in 3 Point Bending
File info: MBD2_1Ax[redacted]D Tue May 13 16:55:03 1997
Frequency: 1.00 Hz
Strain: 0.012%
MBD2_1AxAD
Tension: 120.000%
1 MBD2_1Ax[redacted]D: MBD2_1Ax[redacted]D
Storage Modulus (Pa x 10^9)
2 Loss Modulus (Pa x 10^9)
3 tan δ (x 10^-1)
Storage Modulus
tan delta
Loss Modulus
Modulus (Pa x 10^9)
tan δ (x 10^-1)
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
50.0
75.0
100.0
125.0
150.0
175.0
200.0
225.0
Temperature (°C)
For J. Tomblin..AGATE..5/13/97
TEMP1: 25.0 C TIME1: 0.0 min RATE1: 5.0 C/min
TEMP2: 250.0 C
JRS
PERKIN-ELMER
7 Series Thermal Analysis System
Fri May 23 17:32:28 1997


Curve 1: DMA Temp/Time Scan in 3 Point Bending
File info: MBD3_1AxA Fri May 16 11:39:51 1997
Frequency: 1.00 Hz Strain: 0.010%
MBD3_1AxA Tension: 120.000%
1 MBD3_1AxA: MBD3_1AxA
Loss Modulus (Pa x 10^9)
2 Storage Modulus (Pa x 10^9)
3 tan δ (x 10^-1)
tan delta
Storage Modulus
Loss Modulus
Modulus (Pa x 10^9)
tan δ (x 10^-1)
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
25.0
50.0
75.0
100.0
125.0
150.0
175.0
200.0
225.0
Temperature (°C)
For J. Tomblin..5/16/97
TEMP1: 25.0 C TIME1: 0.0 min RATE1: 5.0 C/min
TEMP2: 250.0 C
JRS
PERKIN-ELMER
7 Series Thermal Analysis System
Fri May 23 16:14:01 1997


Curve 1: DMA Temp/Time Scan in 3 Point Bending
File info: MBD3_1AxDa Tue May 13 15:34:11 1997
Frequency: 1.00 Hz
Dynamic Stress: 8.97e+05Pa
MBD3_1AxDa
Static Stress: 1.13e+06Pa
1 MBD3_1AxDa: MBD3_1AxDa
Storage Modulus (Pa x 10^9)
2 tan δ (x 10^-1)
3 Loss Modulus (Pa x 10^9)
Storage Modulus
tan delta
Loss Modulus
Modulus (Pa x 10^9)
tan δ (x 10^-1)
Temperature (°C)
For J. Tomblin..AGATE..5/13/97
TEMP1: 25.0 C TIME1: 0.0 min RATE1: 5.0 C/min
TEMP2: 250.0 C
JRS
PERKIN-ELMER
7 Series Thermal Analysis System
Fri May 23 17:40:49 1997

4.0 TESTING AND REPORTING COMMENTS

Conformity data is documented and archived as part of the Lancair certification program. FAA project No. TC 1616SE-A.