Solvay (Formerly Cytec) 5320-1 T650 3k-PW fabric with 36% RC Equivalency Material Property Data Report for Laminate Repair Prepreg Batch

NCAMP Project Number: NPN 031801

NCAMP Test Report Number: CAM-RP-2019-045 Rev N/C

Report Date: December 19, 2019

Testing Facility:
National Institute for Aviation Research
Wichita State University
1845 N. Fairmount
Wichita, KS 67260-0093

Test Panel Fabrication Facility:
National Institute for Aviation Research - NCAT
Wichita State University
4004 North Webb Road
Wichita, KS 67226

3UHSDUHG E\

(YHO\Q /LDQ

5HYLHZHG E\

TABLE OF CONTENTS

List of Tables

1. Introduction

1.1 Scope

The test methods and results described in this document are intended to provide basic composite properties essential to most methods of analysis and are consistent with CMH-17-1G—Composite Materials Handbook for Polymer Matrix Composites. This report contains material property data of common usefulness to wide range of projects. The lamina and laminate material property data have been generated with NCAMP oversight in accordance with NSP 100 NCAMP Standard Operating Procedures; the test panels and test specimens have been inspected by NCAMP Authorized Inspection Representatives (AIR) and the testing has been witnessed by NCAMP Authorized Engineering Representatives (AER). However, the data may not fulfill all the needs of any specific company's program; specific properties, environments, laminate architecture, and loading situations may require additional testing.

The use of NCAMP material and process specifications does not guarantee material or structural performance. Material users should be actively involved in evaluating material performance and quality including, but not limited to, performing regular purchaser quality control tests, performing periodic equivalency/additional testing, participating in material change management activities, conducting statistical process control, and conducting regular supplier audits.

The applicability of NCAMP material property data, material allowables, and specifications must be evaluated on a case-by-case basis by aircraft companies and certifying agencies. NCAMP assumes no liability whatsoever, expressed or implied, related to the use of the material property data, material allowables and specifications.

This report contains material property data only. Equivalency statistical analysis data is given in NCP-RP-2018-017 Rev N/C and engineering basis values generated from material qualification testing can be obtained from NCP-RP-2012-023 Rev N/C or later revisions. The equivalency material was procured to NCAMP Material Specification NMS 532/6 Rev A Release dated September 19, 2016. The equivalency test panels were cured in accordance with NCAMP Process Specification NPS 85321 Revision C dated May 31, 2018 Baseline “C” Cure Cycle. The NCAMP Test Plan NTP 5325QR1 was used for this equivalency program.

Part fabricators that wish to utilize the material property data, allowables and specifications may be able to do so by demonstrating the capability to reproduce the original material properties; a process known as equivalency. More information about this equivalency process including the test statistics and its limitations can be found in Section 6 of DOT/FAA/AR-03/19 and Section 8.4.1 of CMH-17-1G. The applicability of equivalency process must be evaluated on program-by-program basis by the applicant and certifying agency. The applicant and certifying agency must agree that the equivalency test plan, along with the equivalency process described in Section 6 of DOT/FAA/AR-03/19 and Section 8.4.1 of CMH-17-1G, are adequate for the given program.

Aircraft companies should not use the data published in this report without specifying NCAMP Material Specification NMS 532/6. NMS 532/6 have additional requirements that are listed in its prepreg process control document (PCD), fiber specification, fiber PCD and other raw material specifications and PCDs which impose essential quality controls on the raw materials and raw material manufacturing equipment and processes. Aircraft companies and certifying agencies should assume that the material property data published in this report is not applicable when the material is not procured to NMS 532/6. NMS 532/6 is a free, publicly available, non-proprietary aerospace industry material specification.

The data in this report is intended for general distribution to the public, either freely or at a price that does not exceed the cost of reproduction (e.g. printing) and distribution (e.g. postage).

1.2 Symbols

Q_{12}^{t}	major Poisson's ratio, tension
P H	micro-strain
E_1^{c}	compressive modulus, longitu

1.3 NIARï Specimen Naming Format

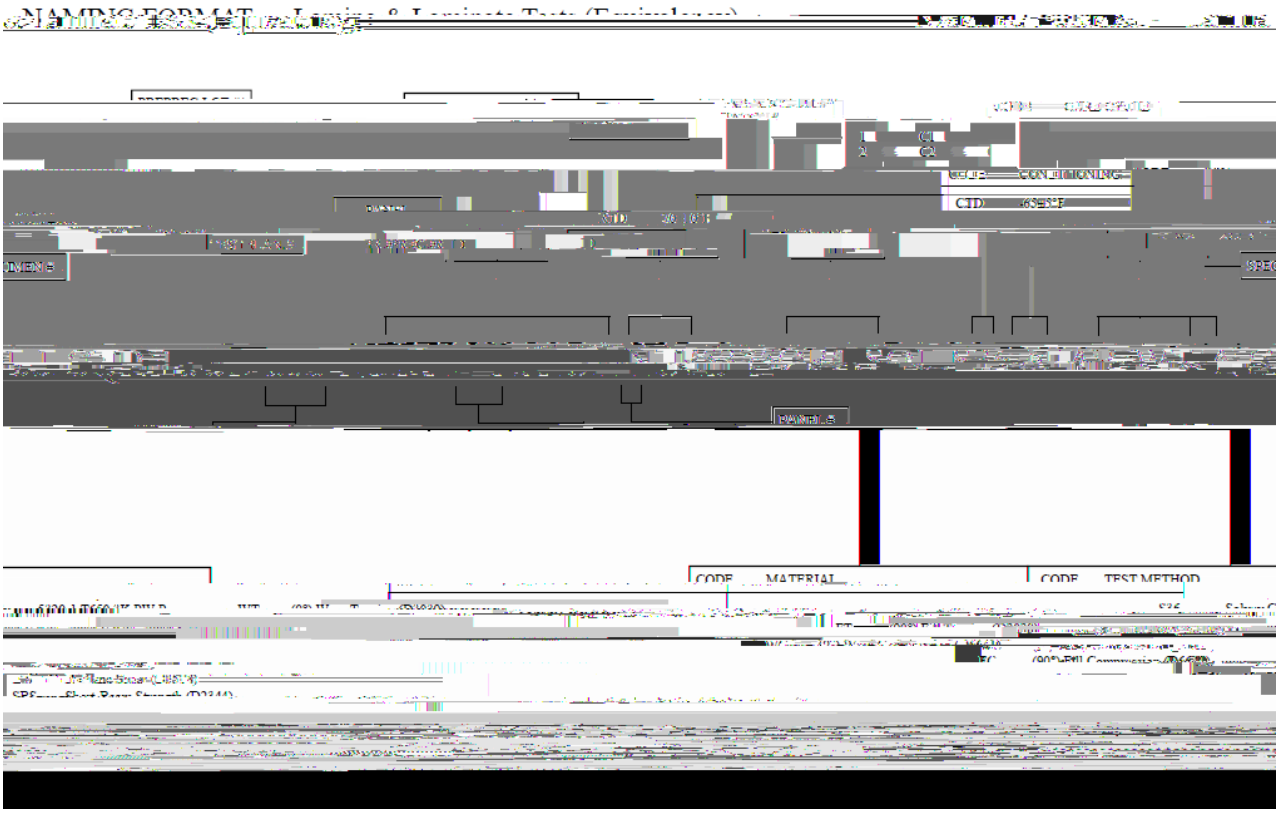


Figure 1-1: Material Naming Format

1.4 References

ASTM Standards

All testing was in accordance

1.5 Methodology

1.5.1 Process Definition

A single batch of prepreg was used to demonstrate equivalency. These single batch tests are designed to demonstrate equivalency with the original three batches qualification data for purposes described in CMH-17-1G Section 8.4.1 and DOT/FAA/AR-03/19 Section 6.

For each combination of test, batch and condition, the specimens were selected from a minimum of two separate panels cured separately as shown in Figure 1-2 unless

Figure 1-3: Specimen Traceability Line

1.5.2 Specimen & Testing Details

1.5.2.1 Tabbing

Tabs were not used for this program.

1.5.2.2

1.5.3 Test Matrix

The table below shows lay-ups and test matrices used for lamina and laminate level testing on the single batch equivalency of the Solvay 5320-1 T650 3k PW prepreg material.

Layup	Test Type and Direction	Property	Number of Batches x Number of Panels x Number of Specimens Test Temperature/ Moisture Condition		
			CTD	RTD	ETW2
$[0]_{15}$	ASTM D3039 Warp Tension	Strength, Modulus and Poisson's Ratio	1x2x4	1x2x4 (4)	1x2x4
$[0]_{15}$	ASTM D6641 Warp Compression	Strength, Modulus and Poisson's Ratio	1x2x4	1x2x4 (1)(4)	1x2x4 (3)
$[90]_{15}$	ASTM D3039 Fill Tension	Strength and Modulus	1x2x4	1x2x4 (4)	1x2x4
$[90]_{15}$	ASTM D6641 Fill Compression	Strength and Modulus	1x2x4	1x2x4 (1)(4)	1x2x4 (3)
$[45/-45]_{3S}$	ASTM D3518 In-Plane Shear (2)	Strength and Modulus	1x2x4	1x2x4 (4)	1x2x4
$[0]_{32}$	ASTM D2344 Short Beam	Strength	1x2x4	1x2x4	1x2x4
(25/50/25 - QI) [45/0/-45/90]2S	ASTM D5766 Open-Hole Tension	Strength		1x2x4	1x2x4
(25/50/25 - QI) [45/0/-45/90/45/0/-45/90/-45/90]S	ASTM D6484 Open-Hole Compression (5)	Strength		1x2x4 (1)	1x2x4
(25/50/25 - QI) [45/0/-45/90]3S	ASTM D7136 & D7137 Compression After Impact (1500 in/lb/in)	Strength		1x2x4	

Table 1-1: Equivalency Test Matrix

Note 1: Back-to-back strain gages are needed on the first two specimens. If no buckling is observed, the remaining modulus specimens will require a strain gage on one side of the specimens only. An appropriate extensometer may be used in place of the strain gage.

Note 2: Gripped (tab) length is 1.5±0.5" on each end of the 10" long specimen. Once the samples have reached the 5% strain level, the actuator/crosshead displacement rate can be increased by four times the initial rate. Continue testing at the higher strain rate until ultimate failure is observed.

Note 3: If strain gage is used for modulus measurement, a separate un-gaged specimen must be used for strength measurement; because the strain gage and its protective coating may prevent moisture absorption in the gage area.

Note 4: At least two specimens must be gaged to obtain full stress-strain curve to failure. An appropriate extensometer may be used in place of the strain gage for the remaining specimens.

Note 5: Open-hole configuration: 0.25" hole diameter, 1.5" width.

Table 1-1 shows the single batch of the Solvay 5320-1 T650 3k PW prepreg test matrix. The layup angles 0º, 45º, -45º and 90º refer to the orientation of the warp direction. The laminate stacking sequences in this program are not specific to any design. Therefore, careful consideration should be given to the validity of properties derived from this program based on the design specific laminates in a structure to be certified.

1.5.4 Cured Laminate Physical Testing

The properties in Table 1-2 were determined for each panel used for test coupons with the exception of Tg by DMA which were conducted on one laminate per batch from each oven cure conducted where that batch is present. The tests were performed by the National Institute for Aviation Research (NIAR) Composites Laboratory under the supervision of NCAMP.

Property	Condition/Method

1.5.5 Environmental Conditioning

The following tests were performed by the NIAR Composites Laboratory under the supervision of NCAMP.

Test environments are defined as:

CTD = -65±5°F, dry
RTD = 70±10°F, dry
ETW2 = 250±5°F, wet

Within each test method and test environment, the failure mode was evaluated immediately after each test by an NCAMP staff engineer or NCAMP AER. All tested

1.5.6 Non-ambient Testing

The chamber was of adequate size so that all test fixtures and load frame grips were contained within the chamber.

For elevated temperature testing, the temperature chamber, test fixture, and grips were preheated to the specified temperature. Each specimen was heated to the required test temperature as verified by a thermocouple in direct contact with and taped to the specimen gage section. The heat-up time of the specimen did not exceed 5 minutes, unless otherwise specified in individual test summary sheets. The test was started $5\ ^{1}_{0}$ minutes after the specimen reached the test temperature. During the test, the temperature, as measured on the specimen, was within r5°F of the required test temperature.

For subzero temperature testing, each specimen was cooled to the required test temperature as verified by a thermocouple in direct contact with and taped to the specimen gage section. The test started $5\ ^{1}_{0}$ minutes after the specimen reached the test temperature. During the test, the temperature, as measured on the specimen, was within r5°F of the required test temperature.

For wet specimens, the moisture loss was determined by subjecting representative specimens to the same amount of time required to heat-up and fail the specimens. For filled-hole or bearing specimens, fasteners were removed prior

1.5.7 Normalization Procedures

Most lamina level tension and compression strength and modulus properties, and all laminate level properties were normalized according to nominal cured ply thickness. Lamina level properties that were not normalized include 90º tensile strength and modulus (unidirectional only), 90º compressive strength and modulus (unidirectional only), in-plane shear strength and modulus, Poisson's ratio, SBS, and ILT. After normalizing, data scatter reduced or remained the same. If data scatter increased significantly after normalizing, the reason was investigated. Wherever properties are normalized, both measured and normalized data were reported.

The average cured ply thickness of 0.0077 inches has been used as the nominal cured ply thickness (CPT) for normalization purpose. This value was used in the normalization of data in the qualification program. The following normalization formula was used:

Normalized Value = Measured Value x Measured CPT / Nominal CPT.

1.5.8 Inspection Verification

The 1-batch equivalency panels have been fabricated according to the requirements of the test plan and conformed by an NCAMP AIR. The test specimens and test setup have also been conformed by an NCAMP AIR.

Testing was witnessed by NCAMP. Test setup and witnessing was delegated to an NCAMP AER. Mechanical testing was carried out at the National Institute for Aviation Research, Wichita State University.

1.5.9 Material Pedigree Information

The PMC Data Collection Template includes the material pedigree information required, such as material and batch information, as well as panel fabrication record, environmental conditioning, test equipment, and test procedures.

2. Test Results

2.1 Lamina Level Test Summary

2.3 Individual Test Summaries

2.3.1 Warp Tension Properties (WT)

Material:	Solvay 5320-1 T650 3k-PW fabric with 36% RC							**Tension, 1-axis** Solvay 5320-1 T650 3k-PW fabric with 36% RC [0]15	
Resin content:	37.53 %wt	**Comp. density:** 1.553 g/cc							
Fiber volume:	54.83 %vol								
Ply count:	15								
Test method:	ASTM D3039-17	**Modulus calculation:** 1000-3000 microstrain							
Normalized by:	0.0077 in. CPT								
		CTD		**RTD**		**ETW2**			
Test Temperature [ÅF]		-65		70		250			
Moisture Conditioning		Dry		Dry		Equilibrium			
Equilibrium at T, RH						160 F,85%			
Source code prefixed by: NTP-5325QRI-SOL-S36-NIAR-		WT-X-CX-1-CTD-X		WT-X-CX-1-RTD-X		WT-X-CX-1-ETW2-X			
		Normalized	**Measured**	**Normalized**	**Measured**	**Normalized**	**Measured**		
	Mean	108.021	109.315	121.316	122.606	135.410	136.203		
	Minimum	105.173	106.713	118.808	119.498	129.038	130.257		
	Maximum	111.779	113.515	124.669	126.754	140.538	142.805		
F_1^{tu} **[ksi]**	**C.V.(%)**	2.222	2.238	1.662	1.929	2.473	2.774		
	No. Specimens	8		9		16			
	No. Prepreg Lots	1		1		1			
	Mean	9.806	9.923	9.755	9.858	9.751	9.809		
	Minimum	9.728	9.838	9.663	9.775	9.487	9.456		
	Maximum	9.908	10.062	9.902	10.068	9.971	10.140		
E_1^t **[Msi]**	**C.V.(%)**	0.637	0.717	0.688	0.948	1.483	2.253		
	No. Specimens	8		9		16			
	No. Prepreg Lots	1		1		1			
	Mean		0.054		0.049		0.046		
	Minimum		0.049		0.042		0.034		
	Maximum		0.060		0.055		0.051		
Q^t	**C.V.(%)**		7.419		7.228		11.600		
	No. Specimens	8		9		8			
	No. Prepreg Lots	1		1		1			

2.3.3 Warp Compression Properties (WC)

Material:

Resin content: 37.60 %wt

2.3.5 In-Plane Shear Properties (IPS)

Material:

Resin content: 37.09 %wt **Comp. density:** 1.551 g/cc
Fiber volume: 55.12 %vol
Ply count: 12

Test method: ASTM D3518-18 **Modulus calculation:** 2000-6000 microstrain

Normalized by: NA

	Normalized	Measured	Normalized	Measured	Normalized	Measured
Mean		11.536		8.322		3.523
Minimum		11.169		8.230		3.434
Maximum		11.788		8.415		3.633
C.V.(%)		1.703		0.630		1.870
No. Specimens						
No. Prepreg Lots						
Mean		18.308		14.455		6.712
Minimum		17.843		14.289		6.549
Maximum		18.761		14.700		6.968
C.V.(%)		2.137		0.835		2.182
No. Specimens						
No. Prepreg Lots						
Mean		0.847		0.726		0.365
Minimum						

December 19, 2019

2.3.7 ñ25/50/25ò Open-Hole Tension 1 Properties (OHT1)

Material: Solvay 5320-1 T650 3k-PW fabric with 36% RC

Resin content: 37.65 % wt **Comp. density:** 1.544 g/cc
Fiber volume: 54.40 % vol
Ply count: 16

Test method: ASTM D5766-11

Normalized by: 0.0077 in. CPT

Open-Hole Tension 1
Solvay 5320-1 T650 3k-PW fabric with 36% RC
[45/0/-45/90]2S

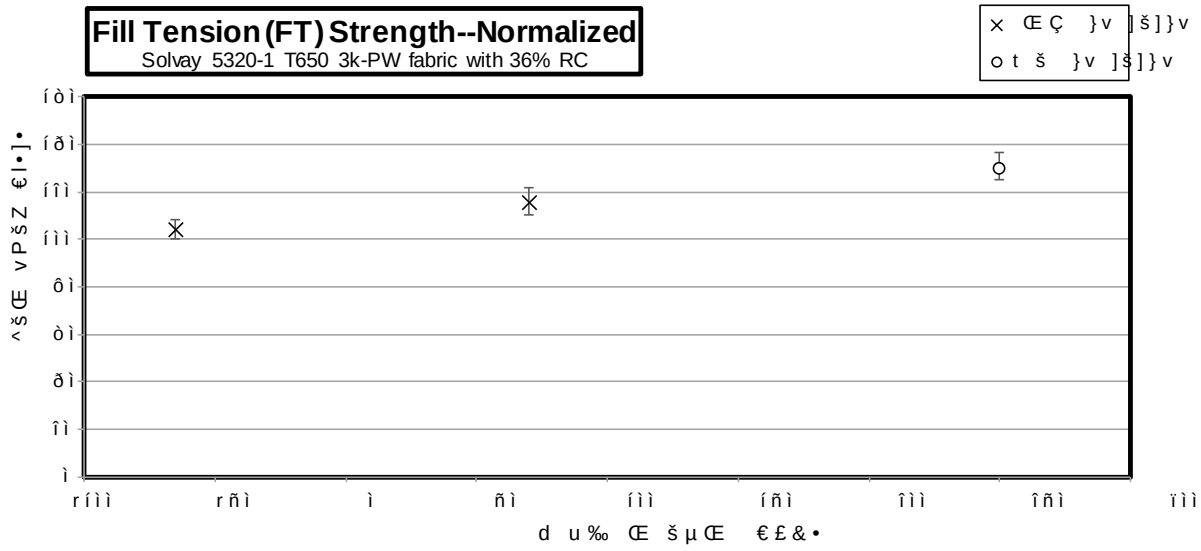
		RTD		ETW2					
Test Temperature [ÅF]		70		250					
Moisture Conditioning		Dry		Equilibrium					
Equilibrium at T, RH				160 F,85%					
Source code prefixed by: NTP-5325QRI-SOL-S36-NIAR-		OHT1-X-CX-1-RTD-X		OHT1-X-CX-1-ETW2-X					
		Normalized	**Measured**	**Normalized**	**Measured**				
	Mean	43.951	43.910	48.089	48.046				
	Minimum	40.550	40.534	46.157	46.151				
	Maximum	46.590	46.634	49.744	49.663				
OHT1 Strength [ksi]	**C.V.(%)**	4.420	4.457	2.929	2.874				
	No. Specimens	8		8					
	No. Prepreg Lots	1		1					

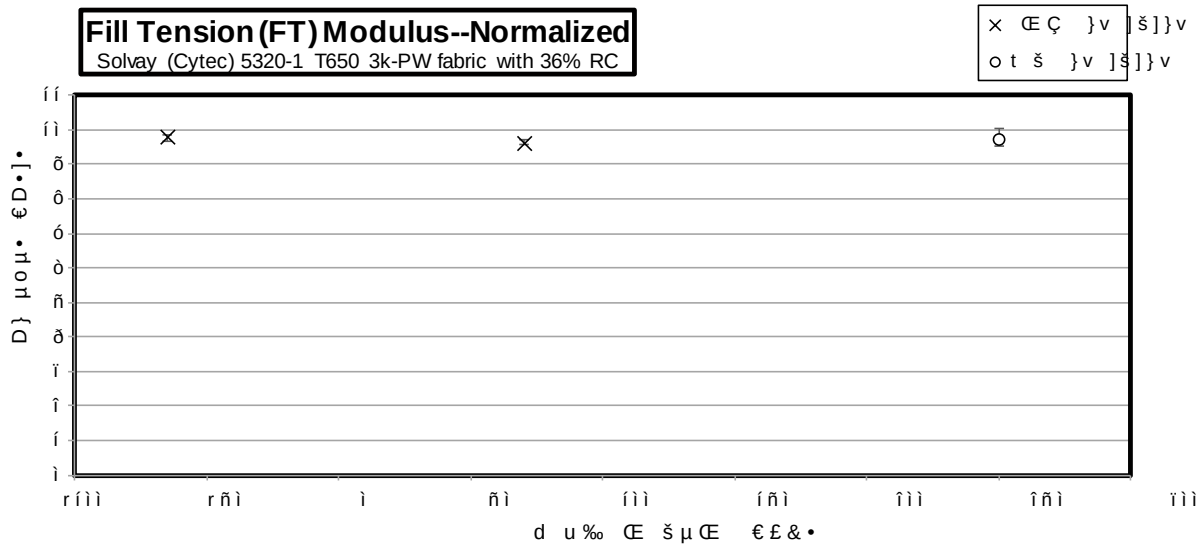
2.3.8 ñ25/50/25ò Open-Hole Compression 1 Properties (OHC1)

Material:	Solvay 5320-1 T650 3k-PW fabric with 36% RC					**Open-Hole Compression 1** Solvay 5320-1 T650 3k-PW fabric with 36% RC [45/0/-45/90/45/0/-45/90/-45/90]S	
Resin content:	37.47 %wt	**Comp. density:**	1.545 g/cc				
Fiber volume:	54.59 %vol						
Ply count:	20						
Test method:	ASTM D6484-14						
Normalized by:	0.0077 in. CPT						
		RTD		**ETW2**			
Test Temperature [ÁF]		70		250			
Moisture Conditioning		Dry		Equilibrium			
Equilibrium at T, RH				160 F,85%			
Source code prefixed by:	NTP-5325QRI-SOL-S36-NIAR-	OHC1-X-CX-1-RTD-X		OHC1-X-CX-1-ETW2-X			
		Normalized	**Measured**	**Normalized**	**Measured**		
	Mean	48.841	48.733	34.424	34.331		
	Minimum	47.549	47.462	32.504	32.316		
	Maximum	50.365	50.099	36.655	36.568		
OHC1 Strength [ksi]	**C.V.(%)**	1.718	1.623	3.808	3.830		
	No. Specimens	8		8			
	No. Prepreg Lots	1		1			

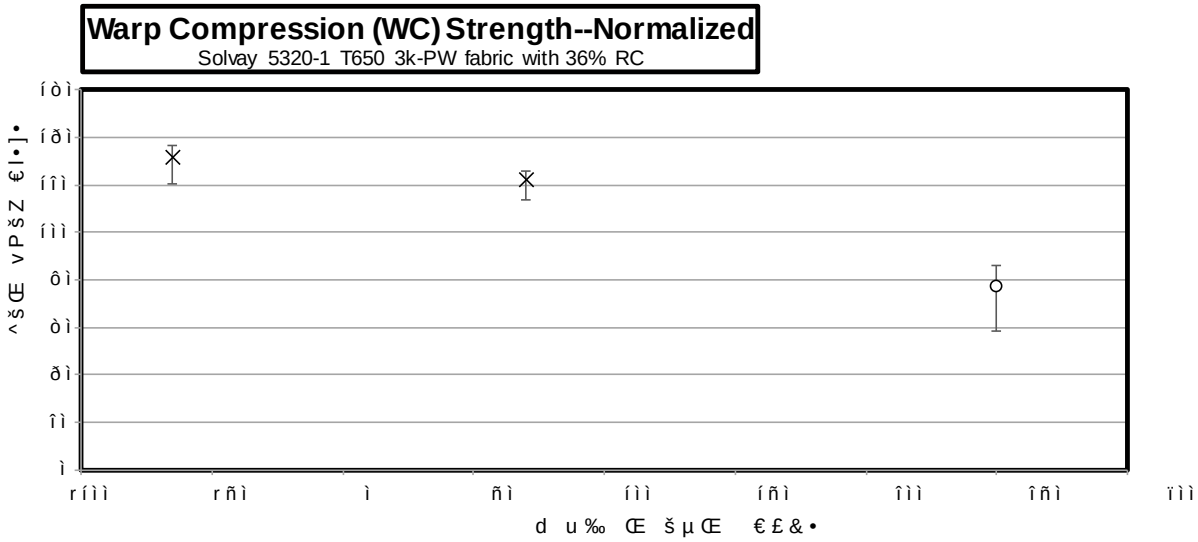
December 19, 2019

3.2 Fill Tension Properties (FT)

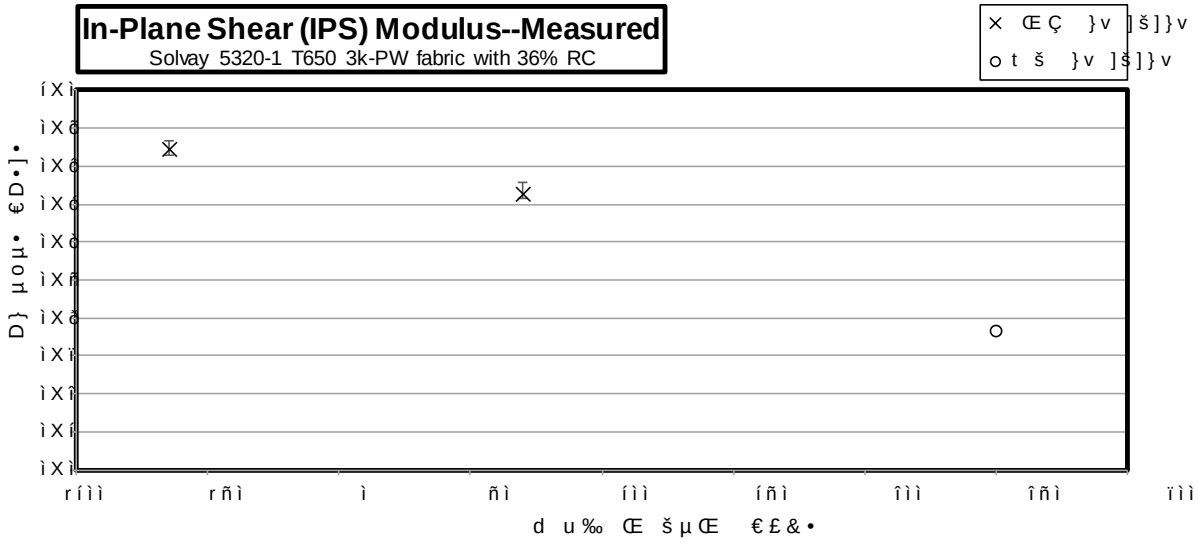




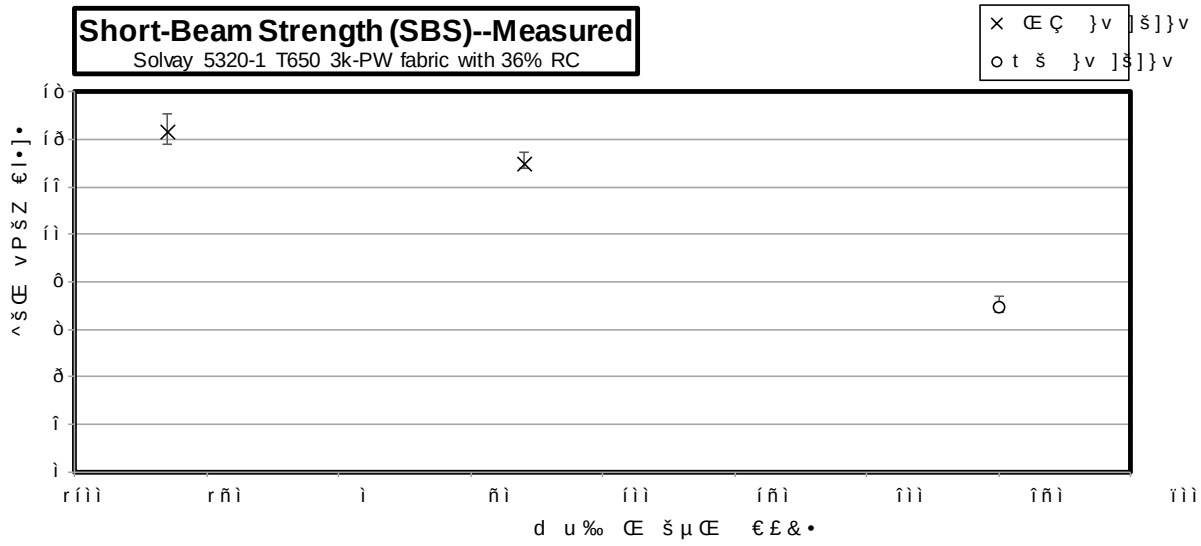
3.3 Warp Compression Properties (WC)



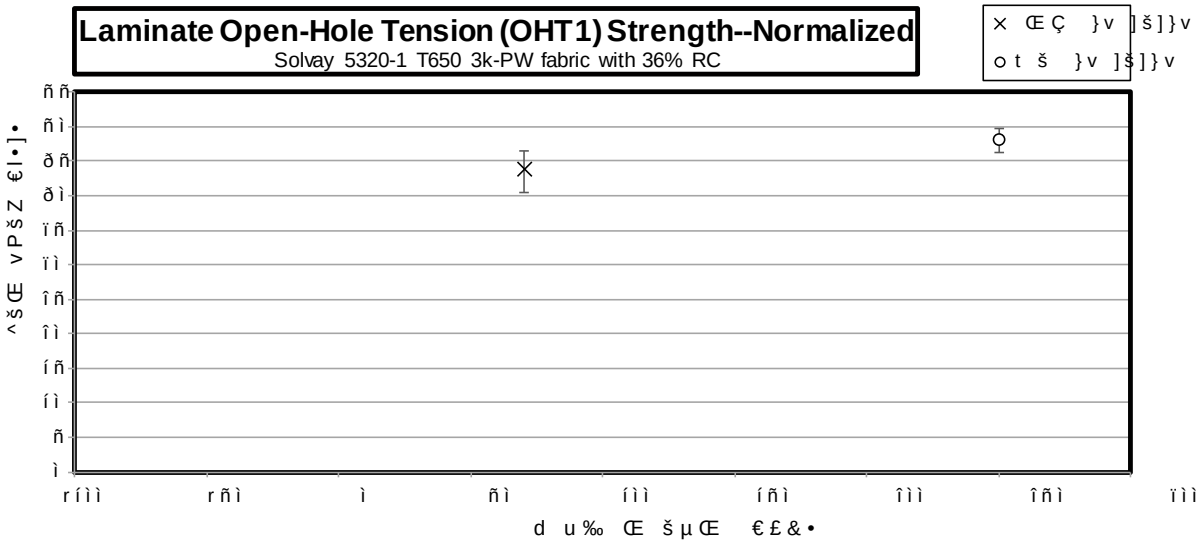
3.5 In-Plane Shear Properties (IPS)


In-Plane Shear (IPS) Modulus--Measured
Solvay 5320-1 T650 3k-PW fabric with 36% RC
× Œ Ç }v]š]}v
o t š }v]š]}v
íXì
ìXë
ìXê
ìXé
ìXè
ìXç
ìXæ
ìXå
ìXä
ìXã
ìXâ
D} µo µ• €D•]•
rí ì ì
rñ ì
ì
ñ ì
í ì ì
í ñ ì
î ì ì
î ñ ì
ï ì ì
d u ‰ Œ š µ Œ €£&•

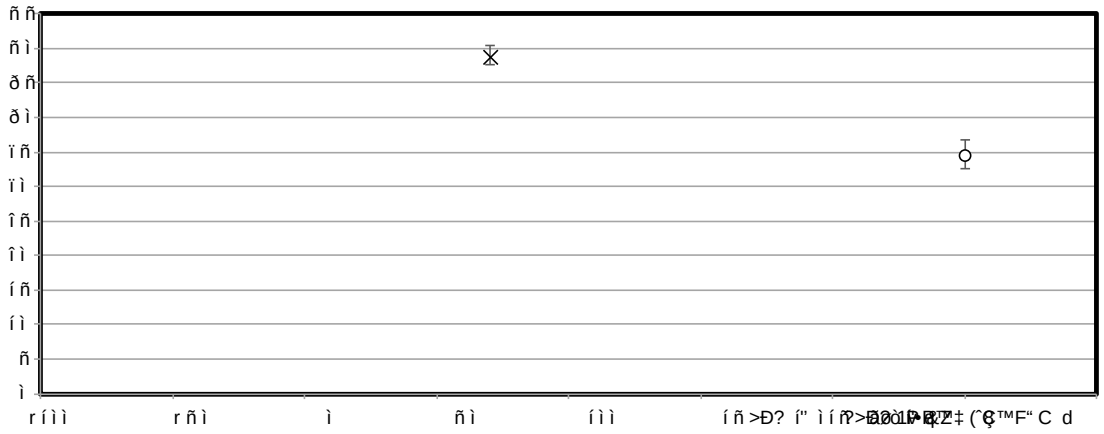
3.6 Lamina Short-Beam Strength Properties (SBS)



3.7 ñ25/50/25ò Open-Hole Tension 1 Properties (OHT1)



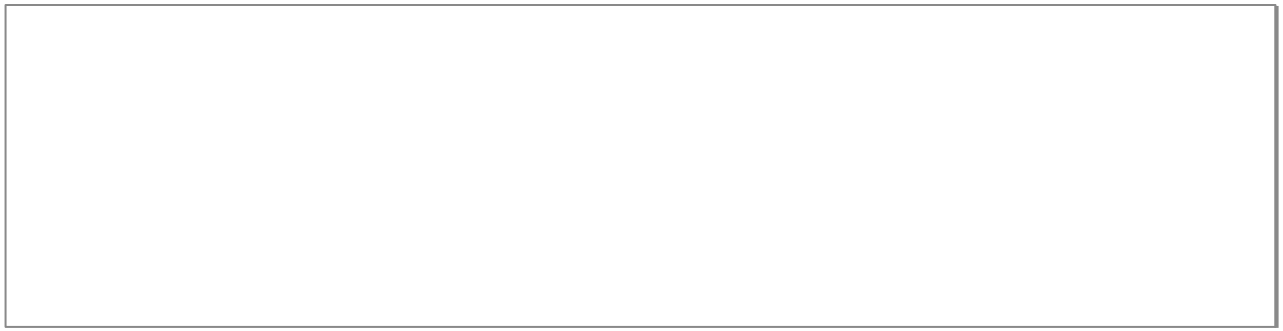
3.8 ñ25/50/25ò Open-Hole Compression 1 Properties (OHC1)



4. Raw Data

4.1 Warp Tension Properties (WT)

normalizing t_{ply}



normalizing t_{ply} [in]
0.0077

Specimen Number	NIAR Batch #	NIAR

normalizing t_{ply} [in]
0.0077

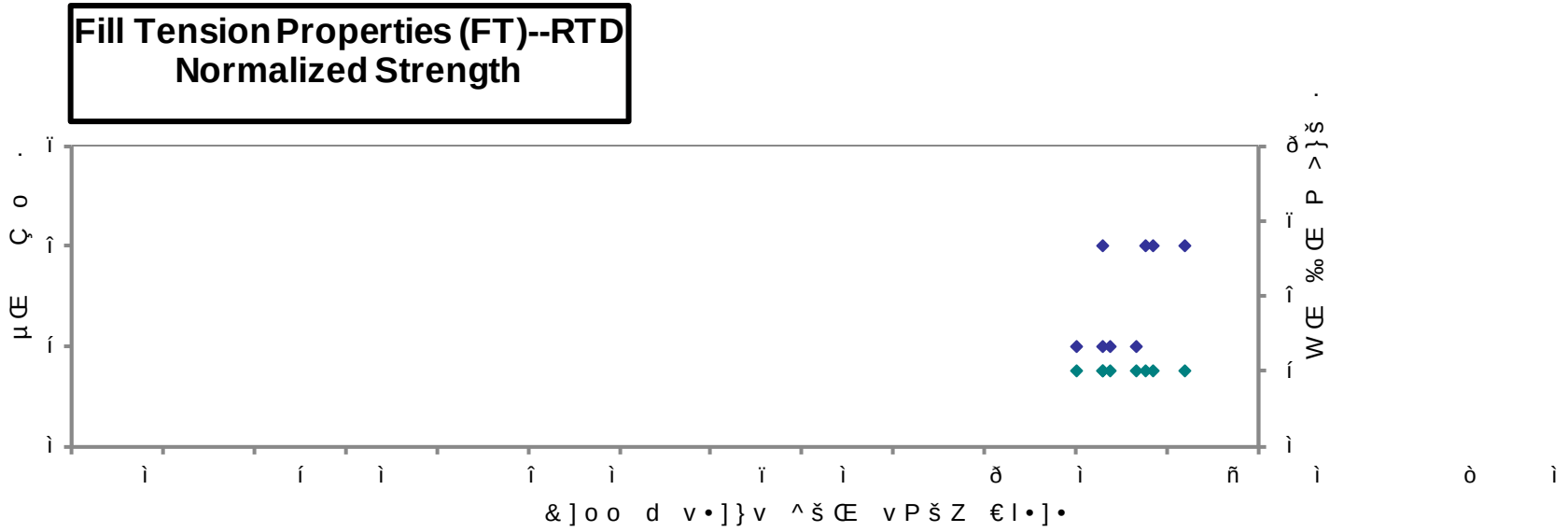
Specimen Number	NIAR Batch #	NIAR Cure Cycle	Prepreg Lot #	Cure Cycle #	Strength [ksi]	Modulus [Msi]	Poisson's Ratio	Avg. Specimen Thickness [in]	# Plies in Laminate	Failure Mode	Avg. t_{ply} [in]	$Strength_{norm}$ [ksi]	$Modulus_{norm}$ [Msi]
NTP-5325QRI-SOL-S36-NIAR-WT-A-C1-1-ETW2-1*	A	C1	1	1	130.488	10.083		0.114	15	LGB	0.0076	129.038	9.971
NTP-5325QRI-SOL-S36-NIAR-WT-A-C1-1-ETW2-2*	A	C1	1	1	142.794	9.946		0.114	15	LGB	0.0076	140.404	9.780

4.2 Fill Tension Properties (FT)

Fill Tension Properties (FT)--CTD
Strength & Modulus
Solvay 5320-1 T650 3k-PW fabric with 36% RC

normalizing t_{ply} [in]
0.0077

Specimen Number	NIAR Batch #	NIAR Cure Cycle	Prepreg Lot #	Cure Cycle #	Strength [ksi]	Modulus [Msi]	Avg. Specimen Thickness [in]	# Plies in Laminate	Failure Mode	Avg. t_{ply} [in]	$Strength_{norm}$ [ksi]	$Modulus_{norm}$ [Msi]
NTP5325QR1-SOL-S36-NIAR-FT-A-C1-1R-CTD-1	A	C1	1	1	103.236	9.953	0.114	15	LGT	0.0076	102.089	9.842
NTP5325QR1-SOL-S36-NIAR-FT-A-C1-1R-CTD-2	A	C1	1	1	105.968	9.986	0.114	15	LGM	0.0076	104.790	9.875
NTP5325QR1-SOL-S36-NIAR-FT-A-C1-1R-CTD-3	A	C1	1	1	106.253	9.974	0.114	15	LGB	0.0076	104.827	9.840
NTP5325QR1-SOL-S36-NIAR-FT-A-C1-1R-CTD-4	A	C1	1	1	106.223	9.938	0.114	15	LGM	0.0076	104.721	9.797
NTP5325QR1-SOL-S36-NIAR-FT-A-C2-1R-CTD-1	A	C2	1	2	101.153	9.780	0.116	15	LAB	0.0077	101.474	9.811
NTP5325QR1-SOL-S36-NIAR-FT-A-C2-1R-CTD-2	A	C2	1	2	107.948	9.816	0.116	15	LGM	0.0077	108.229	9.842
NTP5325QR1-SOL-S36-NIAR-FT-A-C2-1R-CTD-3	A	C2	1	2	107.751	9.671	0.115	15	LGB	0.0077	107.580	9.656
NTP5325QR1-SOL-S36-NIAR-FT-A-C2-1R-CTD-4	A	C2	1	2	99.708	9.738	0.116	15	LGB	0.0077	100.111	9.778
				Average	**104.780**	**9.857**			**$Average_{norm}$**	**0.0077**	**104.228**	**9.805**
				Standard Dev.	**3.066**	**0.121**			**Standard $Dev._{norm}$**		**2.860**	**0.068**
				Coeff. of Var. [%]	**2.926**	**1.227**			**Coeff. of Var. $[\%]_{norm}$**		**2.744**	**0.690**
				Min.	**99.708**	**9.671**			**Min.**	**0.0076**	**100.111**	**9.656**
				Max.	**107.948**	**9.986**			**Max.**	**0.0077**	**108.229**	**9.875**
				Number of Spec.	**8**	**8**			**Number of Spec.**	**8**	**8**	**8**

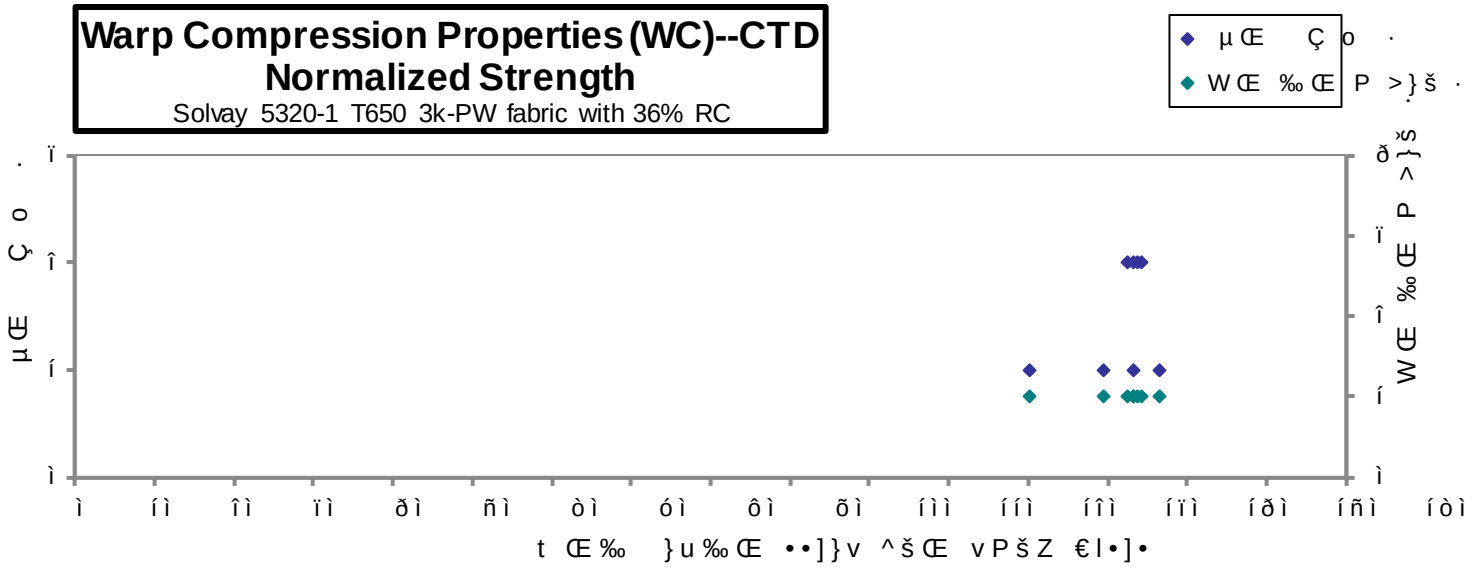

Fill Tension Properties (FT)--RTD
Normalized Strength
ï
î
í
ì
ì
í
ì
î
ì
ï
ì
ð
ì
ñ
ì
ò
ì

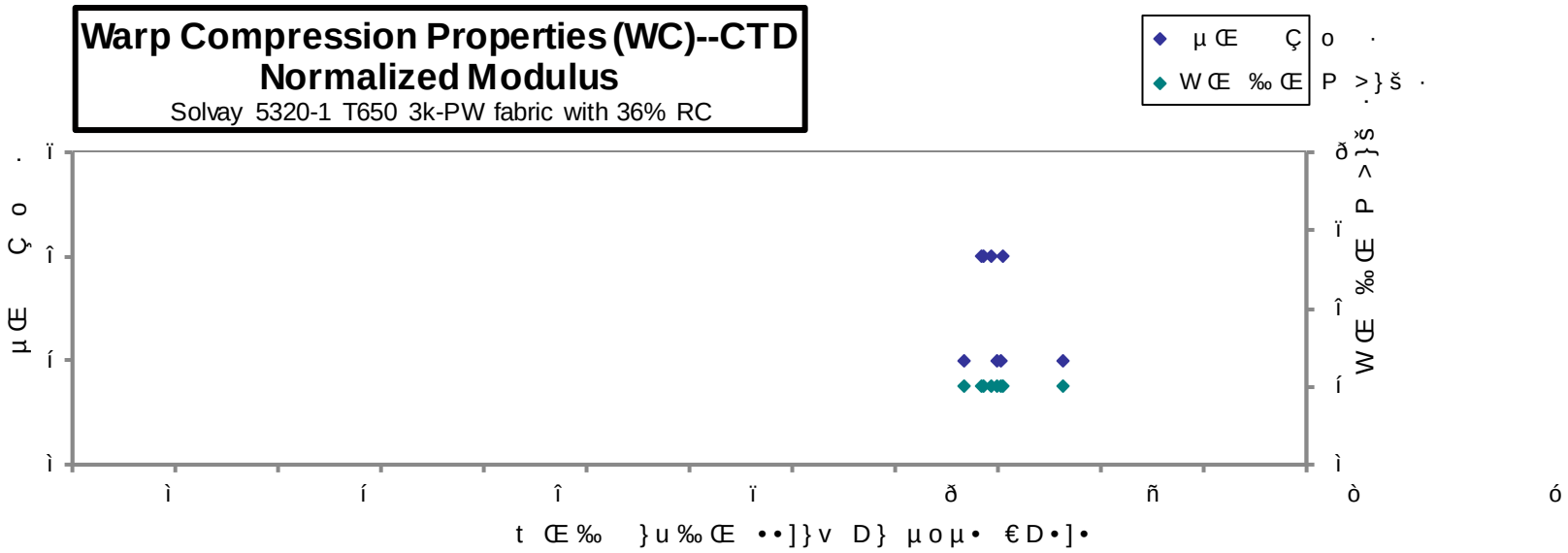
December 19, 2019

4.3 Warp Compression Properties (WC)

normalizing t_{ply} [in]
0.0077

Specimen Number	NIAR Batch #	NIAR Cure Cycle	Prepreg Lot #	Cure Cycle #	Strength [ksi]	Modulus [Msi]	Avg. Specimen Thickness [in]	# Plies in Laminate	Failure Mode	Avg. t_{ply} [in]	$Strength_{norm}$ [ksi]	$Modulus_{norm}$ [Msi]
NTP-5325QRI-SOL-S36-NIAR-WC-A-C1-1-CTD-1	A	C1	1	1	122.677	9.211	0.113	15	BGM	0.0075	120.146	9.021
NTP-5325QRI-SOL-S36-NIAR-WC-A-C1-1-CTD-2	A	C1	1	1	138.578	9.126	0.114	15	BGM	0.0076	136.498	8.989
NTP-5325QRI-SOL-S36-NIAR-WC-A-C1-1-CTD-3	A	C1	1	1	135.480	8.806	0.114	15	BGM	0.0076	133.349	8.667


Warp Compression Properties (WC)--CTD
Normalized Strength
Solvay 5320-1 T650 3k-PW fabric with 36% RC


Warp Compression Properties (WC)--CTD
Normalized Modulus
Solvay 5320-1 T650 3k-PW fabric with 36% RC

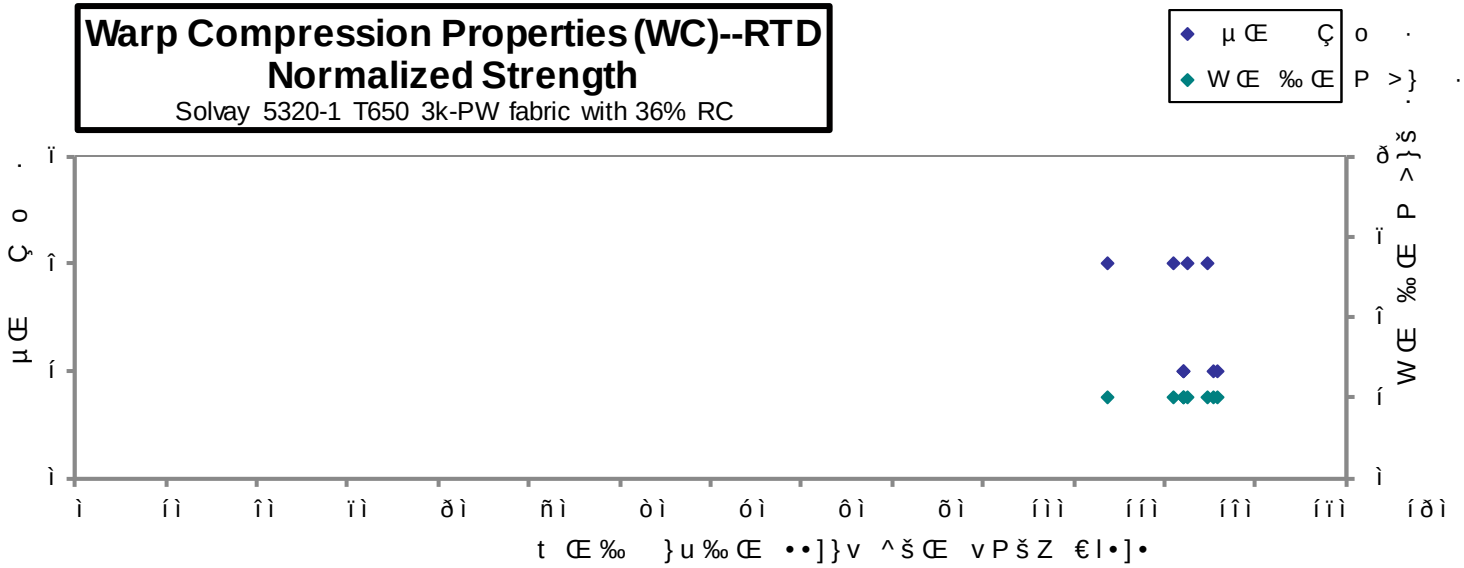
Warp Compression Properties (WC)--RTD
Strength & Modulus

normalizing t_{ply} [in]
0.0077

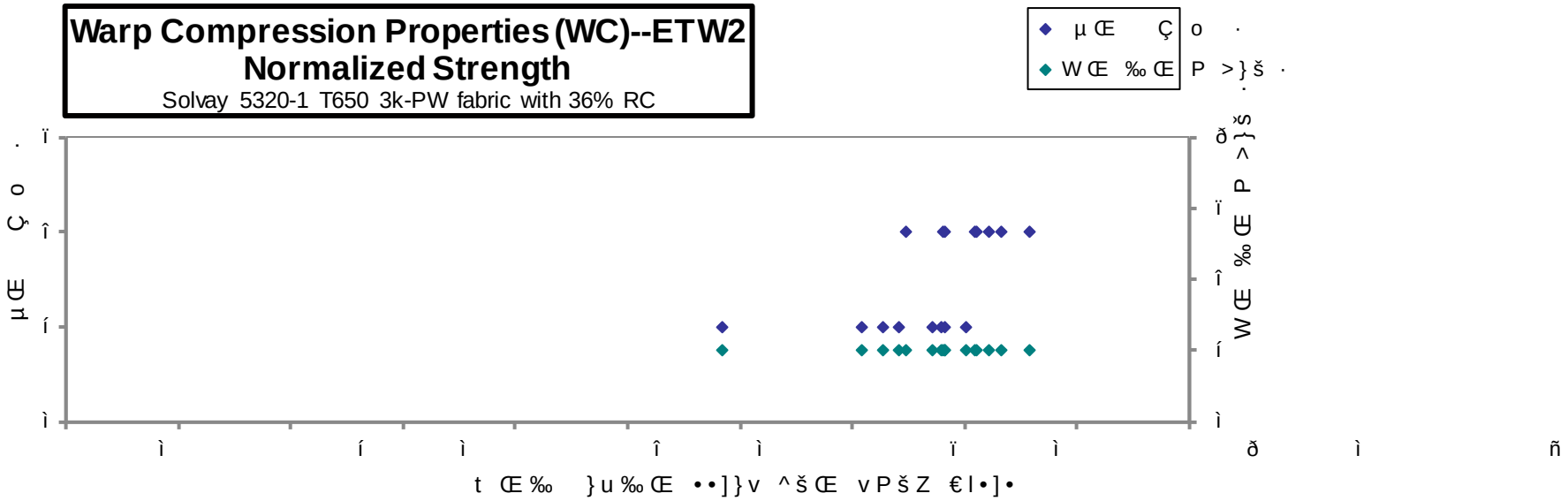
Specimen Number	NIAR Batch #	NIAR Cure Cycle	Prepreg Lot #	Cure Cycle #	Strength [ksi]	Modulus [Msi]	Avg. Specimen Thickness [in]	# Plies in Laminate	Failure Mode	Avg. t_{ply} [in]	$Strength_{norm}$ [ksi]	$Modulus_{norm}$ [Msi]
NTP-5325QRI-SOL-S36-NIAR-WC-A-C1-1-RTD-1*	A	C1	1	1	126.786	8.919	0.115	15	BGM	0.0076	125.890	8.856
NTP-5325QRI-SOL-S36-NIAR-WC-A-C1-1-RTD-2*	A	C1	1	1	122.642	8.946	0.115	15	BGM	0.0077	122.164	8.911
NTP-5325QRI-SOL-S36-NIAR-WC-A-C1-1-RTD-3	A	C1	1	1	126.631	9.322	0.114	15	BGM	0.0076	125.370	9.229
NTP-5325QRI-SOL-S36-NIAR-WC-A-C1-1-RTD-4	A	C1	1	1	123.297	9.339	0.114	15	BGM	0.0076	121.980	9.239
NTP-5325QRI-SOL-S36-NIAR-WC-A-C2-1-RTD-1*	A	C2	1	2	125.575	8.942	0.115	15	HAT, BAT	0.0076	124.723	8.881
NTP-5325QRI-SOL-S36-NIAR-WC-A-C2-1-RTD-2**/***	A	C2	1	2		8.988	0.114	15	HIT	0.0076		8.898
NTP-5325QRI-SOL-S36-NIAR-WC-A-C2-1-RTD-3	A	C2	1	2	114.577	9.007	0.115	15	BGM, HAT	0.0076	113.701	8.938
NTP-5325QRI-SOL-S36-NIAR-WC-A-C2-1-RTD-4	A	C2	1	2	121.965	8.969	0.115	15	BGM, HAT	0.0076	120.926	8.893
NTP-5325QRI-SOL-S36-NIAR-WC-A-C2-1-RTD-5***	A	C2	1	2	123.497		0.115	15	HAT, BGM	0.0076	122.553	

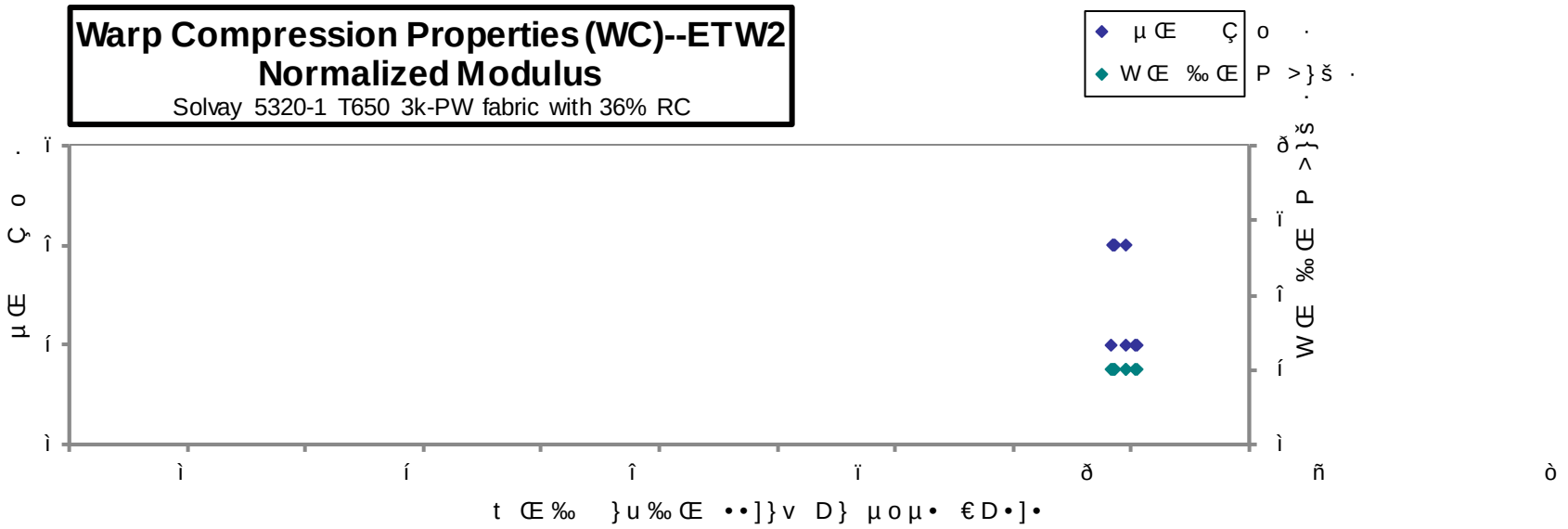
*Modulus are averaged values of 2 strain gages.
**Strength not reported due to unacceptable failure mode.
***Specimen was not gaged, only strength is tested.

	Strength [ksi]	Modulus [Msi]		$Strength_{norm}$ [ksi]	$Modulus_{norm}$ [Msi]
Average	**123.121**	**9.054**	**Average$_{norm}$**	**0.0076**	**122.163**	**8.981**
Standard Dev.	**3.901**	**0.173**	**Standard Dev.$_{norm}$**		**3.855**	**0.158**
Coeff. of Var. [%]	**3.168**	**1.909**	**Coeff. of Var. [%]$_{norm}$**		**3.156**	**1.761**
Min.	**114.577**	**8.919**	**Min.**	**0.0076**	**113.701**	**8.856**
Max.	**126.786**	**9.339**	**Max.**	**0.0077**	**125.890**	**9.239**
Number of Spec.	**8**	**8**	**Number of Spec.**	**9**	**8**	**8**


Warp Compression Properties (WC)--RTD
Normalized Strength
Solvay 5320-1 T650 3k-PW fabric with 36% RC
µ Œ Ç o ·
W Œ ‰ Œ P > } ·
ï
î
í
ì
ð
ï
î
í
ì
ì íì îì ïì ðì ñì òì óì ôì õì íìì ííì íîì íïì íðì
t Œ ‰ }u ‰ Œ ••]}v ^š Œ vPšZ €l•]•

December E

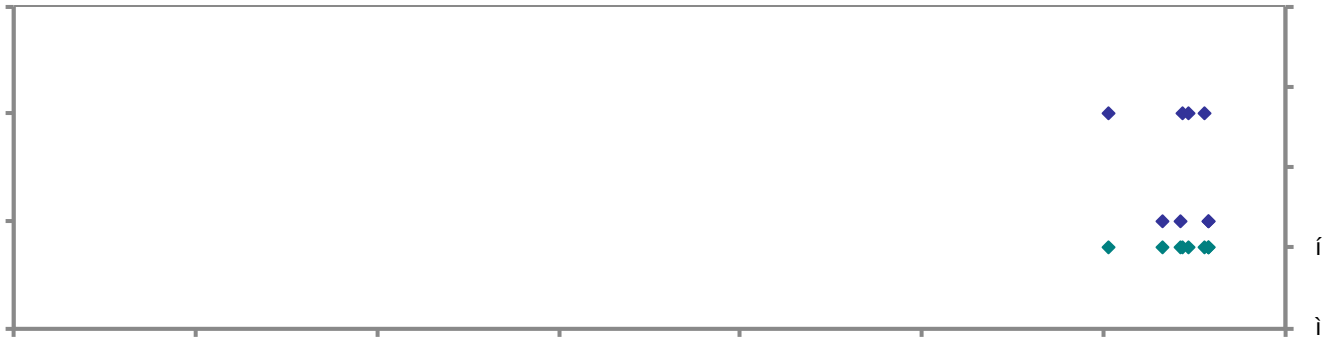

Warp Compression Properties (WC)--ETW2
Normalized Strength
Solvay 5320-1 T650 3k-PW fabric with 36% RC
µ Œ Ç o ·
W Œ ‰ Œ P >} š ·
ì í ì î ì ï ì ð ì ñ

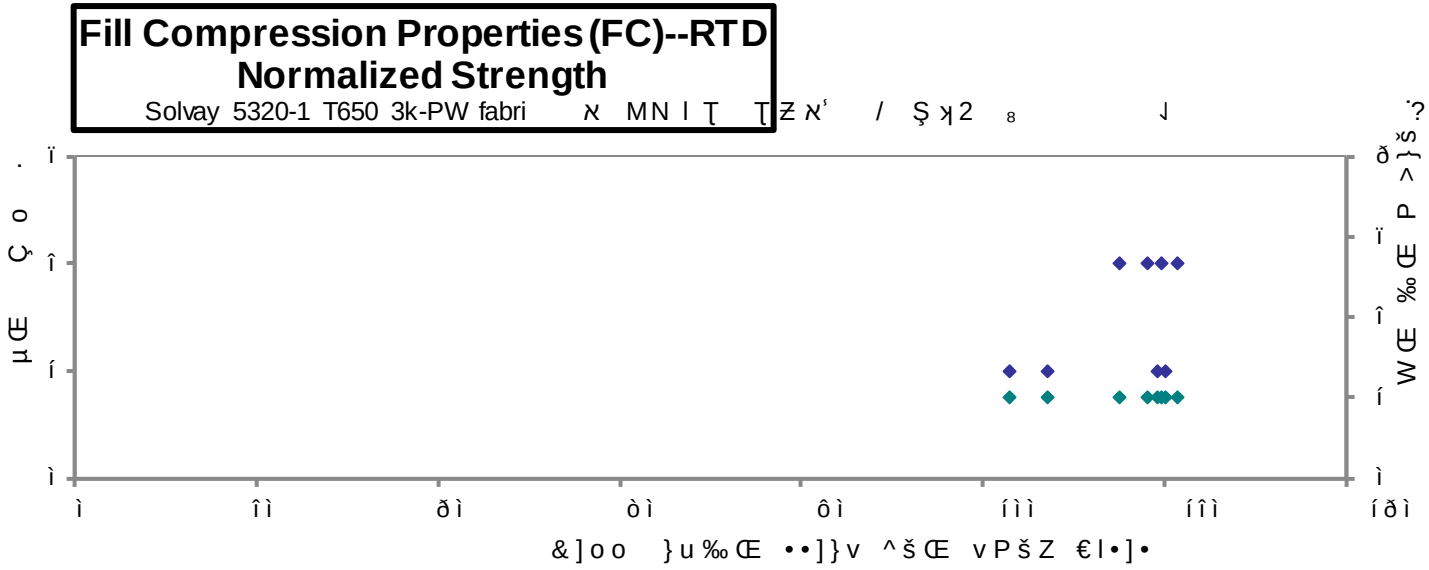

Warp Compression Properties (WC)--ETW2
Normalized Modulus
Solvay 5320-1 T650 3k-PW fabric with 36% RC
µ Œ Ç o ·
W Œ ‰ Œ P >} š ·
ì í î ï ð ñ ò

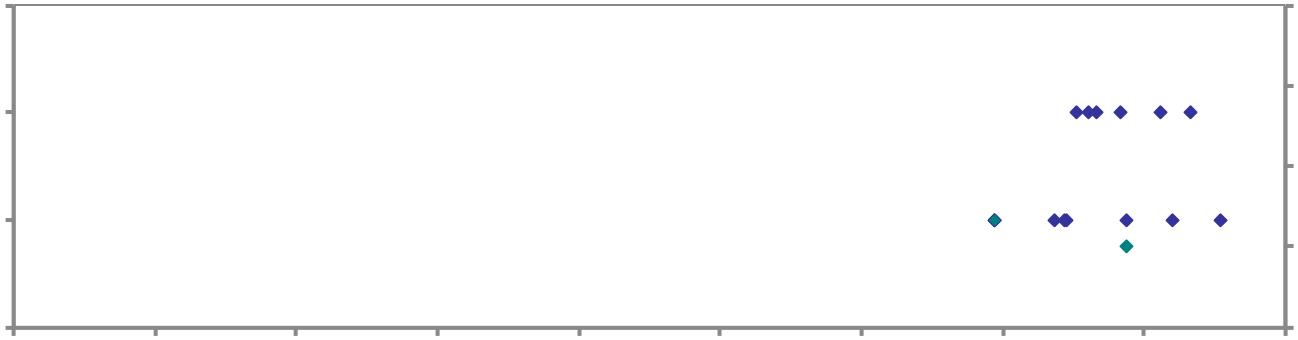
4.4 Fill Compression Properties (FC)

normalizing t_{ply} [in]
0.0077

Specimen Number	NIAR Batch #	NIAR Cure Cycle	Prepreg Lot #

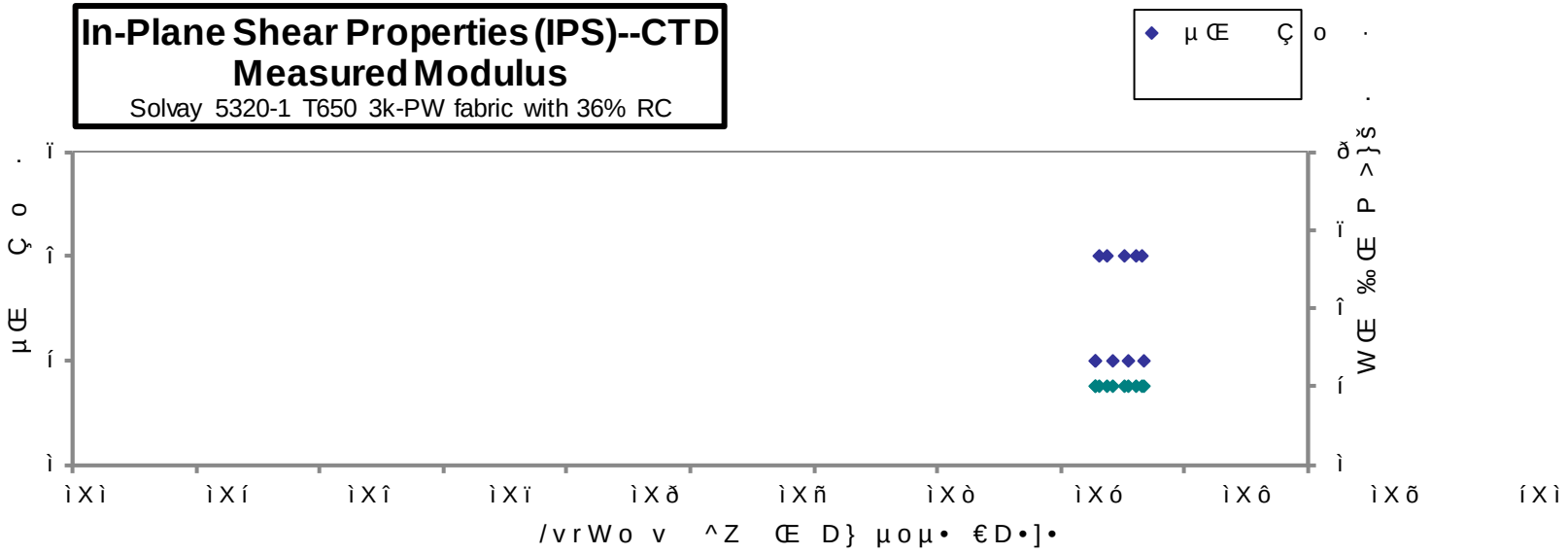


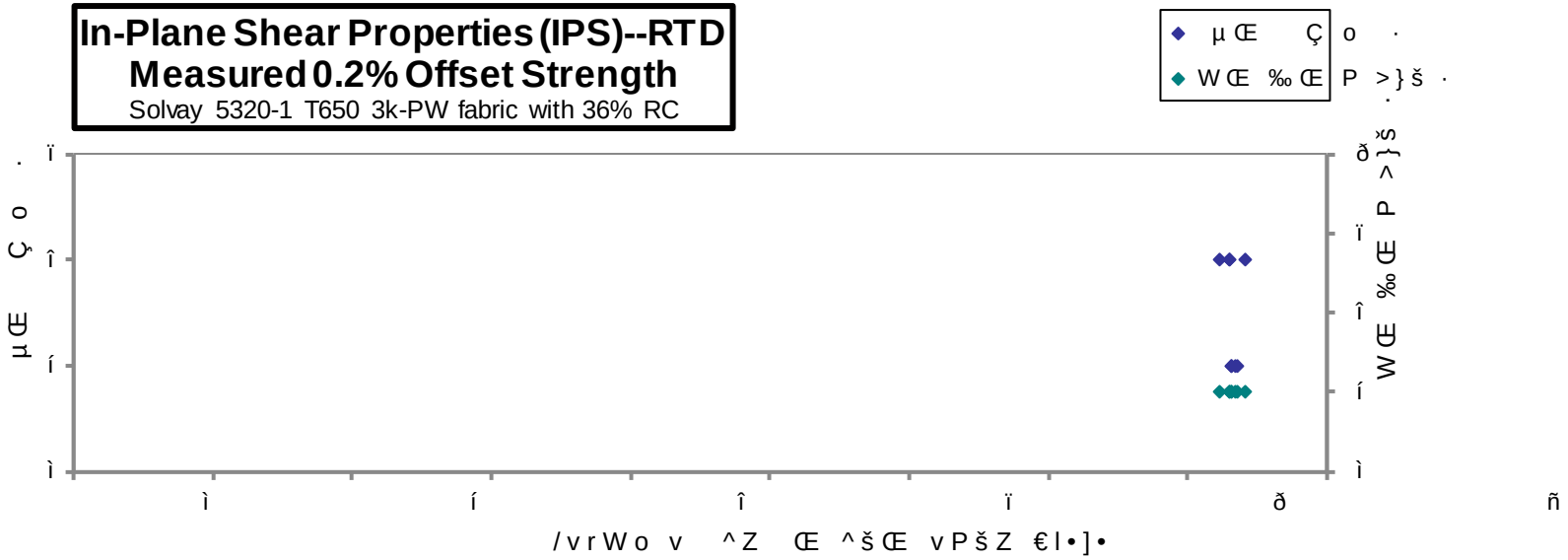

Fill Compression Properties (FC)--RTD
Normalized Strength
Solvay 5320-1 T650 3k-PW fabri
ì
îì
ðì
òì
ôì
íìì
íîì
íðì

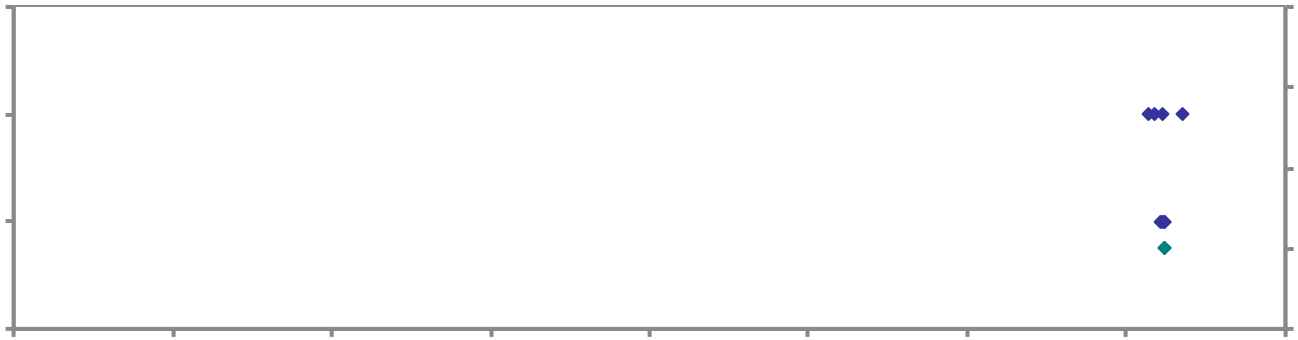


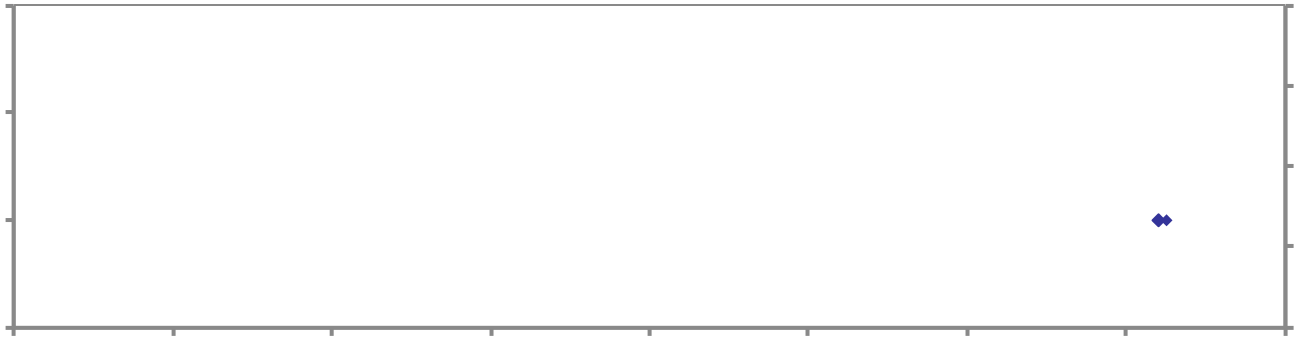
4.5 In-Plane Shear Properties (IPS)

Specimen Number	NIAR Batch #	NIAR Cure Cycle	Prepreg Lot #	Cure Cycle #	0.2% Offset Strength [ksi]	Strength at 5% Strain [ksi]	Modulus [Msi]	Avg. Specimen Thickness [in]	# Plies in Laminate	Avg. t_{ply} [in]

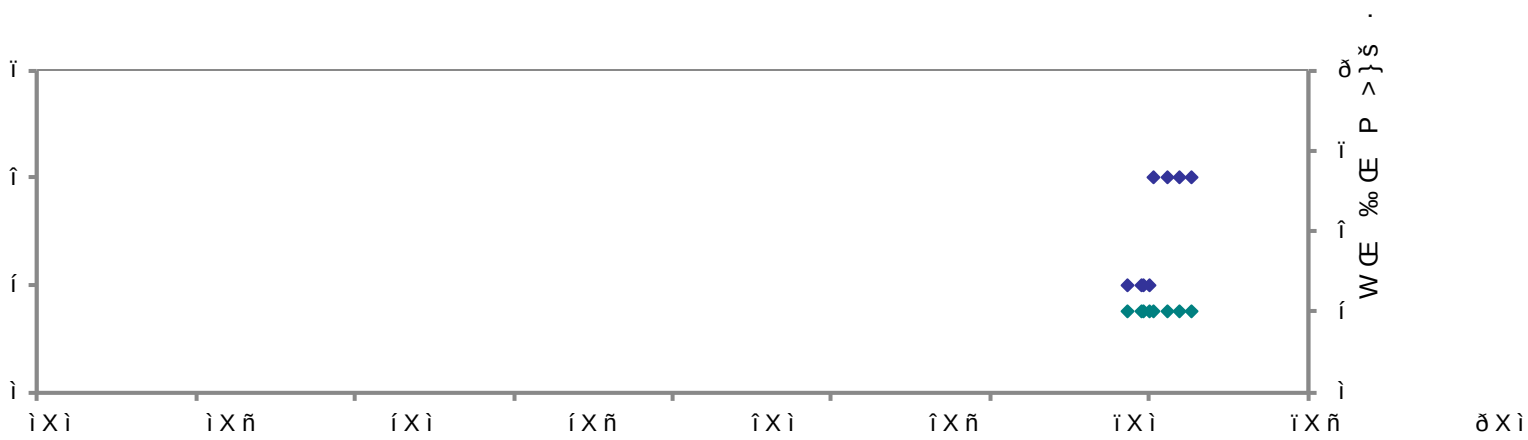

In-Plane Shear Properties (IPS)--CTD
Measured Modulus
Solvay 5320-1 T650 3k-PW fabric with 36% RC
µ Œ Ç o .
ì X ì
ì X í
ì X î
ì X ï
ì X ð
ì X ñ
ì X ò
ì X ó
ì X ô
ì X õ
í X ì
/ v r W o v ^ Z Œ D } µ o µ • € D •] •


In-Plane Shear Properties (IPS)--RTD
Measured 0.2% Offset Strength
Solvay 5320-1 T650 3k-PW fabric with 36% RC





December 19, 2019


ï
î
í
ì
ì X ì
ì X ñ
í X ì
í X ñ
î X ì
î X ñ
ï X ì
ï X ñ
ð X ì
ð
ï
î
í
ì

4.6 Lamina Short-Beam Strength Properties (SBS)

Short-Beam Strength Properties (SBS)--CTD
Solvay 5320-1 T650 3k-PW fabric with 36% RC

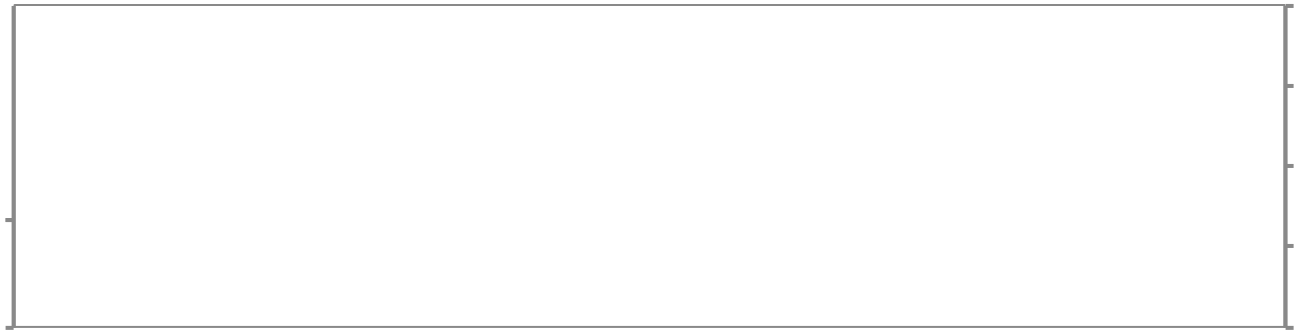
Specimen Number	NIAR Batch #	NIAR Cure Cycle	Prepreg Lot #	Cure Cycle #	Strength [ksi]	Avg. Specimen Thickness [in]	# Plies in Laminate	Avg. t_{ply} [in]	Failure Mode
NTP-5325QRI-SOL-S36-NIAR-SBS-A-C1-1-CTD-1	A	C1	1	1	14.385	0.244	32	0.0076	INTERLAMINAR SHEAR, TENSION
NTP-5325QRI-SOL-S36-NIAR-SBS-A-C1-1-CTD-2	A	C1	1	1	15.070	0.243	32	0.0076	INTERLAMINAR SHEAR, TENSION
NTP-5325QRI-SOL-S36-NIAR-SBS-A-C1-1-CTD-3	A	C1	1	1	13.810	0.243	32	0.0076	INTERLAMINAR SHEAR, TENSION
NTP-5325QRI-SOL-S36-NIAR-SBS-A-C1-1-CTD-4	A	C1	1	1	14.816	0.243	32	0.0076	INTERLAMINAR SHEAR
NTP-5325QRI-SOL-S36-NIAR-SBS-A-C2-1-CTD-1	A	C2	1	2	13.845	0.246	32	0.0077	INTERLAMINAR SHEAR, TENSION
NTP-5325QRI-SOL-S36-NIAR-SBS-A-C2-1-CTD-2	A	C2	1	2	14.250	0.245	32	0.0077	INTERLAMINAR SHEAR, TENSION
NTP-5325QRI-SOL-S36-NIAR-SBS-A-C2-1-CTD-3	A	C2	1	2	14.227	0.245	32	0.0077	INTERLAMINAR SHEAR, TENSION
NTP-5325QRI-SOL-S36-NIAR-SBS-A-C2-1-CTD-4	A	C2	1	2	14.444	0.246	32	0.0077	INTERLAMINAR SHEAR, TENSION

Average	**14.356**	**0.0076**
Standard Dev.	**0.434**	
Coeff. of Var. [%]	**3.022**	
Min.	**13.810**	**0.0076**
Max.	**15.070**	**0.0077**
Number of Spec.	**8**	**8**

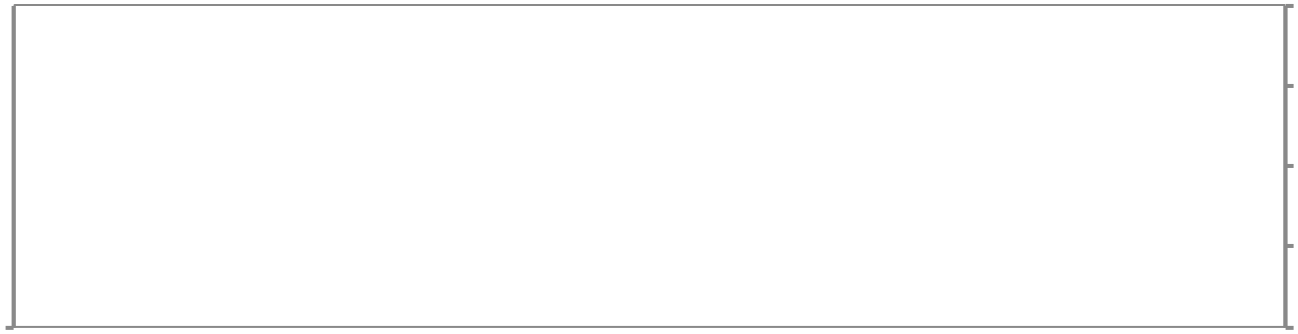
Short-Beam Strength Properties (SBS)--RTD

Solvay 5320-1 T650 3k-PW fabric with 36% RC

Specimen Number	NIAR Batch #	NIAR Cure Cycle	Prepreg Lot #	Cure Cycle #	Strength [ksi]	Avg. Specimen Thickness [in]	# Plies in Laminate	Avg. t_{ply} [in]	Failure Mode
NTP-5325QRI-SOL-S36-NIAR-SBS-A-C1-1-RTD-1	A	C1	1	1	12.760	0.243	32	0.0076	INTERLAMINAR SHEAR
NTP-5325QRI-SOL-S36-NIAR-SBS-A-C1-1-RTD-2	A	C1	1	1	12.932	0.243	32	0.0076	INTERLAMINAR SHEAR, TENSION
NTP-5325QRI-SOL-S36-NIAR-SBS-A-C1-1-RTD-3	A	C1	1	1	12.948	0.244	32	0.0076	INTERLAMINAR SHEAR
NTP-5325QRI-SOL-S36-NIAR-SBS-A-C1-1-RTD-4	A	C1	1	1	12.945	0.243	32	0.0076	INTERLAMINAR SHEAR
NTP-5325QRI-SOL-S36-NIAR-SBS-A-C2-1-RTD-1	A	C2	1	2	13.180	0.244	32	0.0076	INTERLAMINAR SHEAR
NTP-5325QRI-SOL-S36-NIAR-SBS-A-C2-1-RTD-2	A	C2	1	2	12.887	0.244	32	0.0076	INTERLAMINAR SHEAR
NTP-5325QRI-SOL-S36-NIAR-SBS-A-C2-1-RTD-3	A	C2	1	2	12.779	0.244	32	0.0076	INTERLAMINAR SHEAR
NTP-5325QRI-SOL-S36-NIAR-SBS-A-C2-1-RTD-4	A	C2	1	2	13.433	0.244	32	0.0076	INTERLAMINAR SHEAR
				Average	**12.983**			**0.0076**	
				Standard Dev.	**0.223**				
				Coeff. of Var. [%]	**1.715**				
				Min.	**12.760**			**0.0076**	
				Max.	**13.433**			**0.0076**	
				Number of Spec.	**8**			**8**	

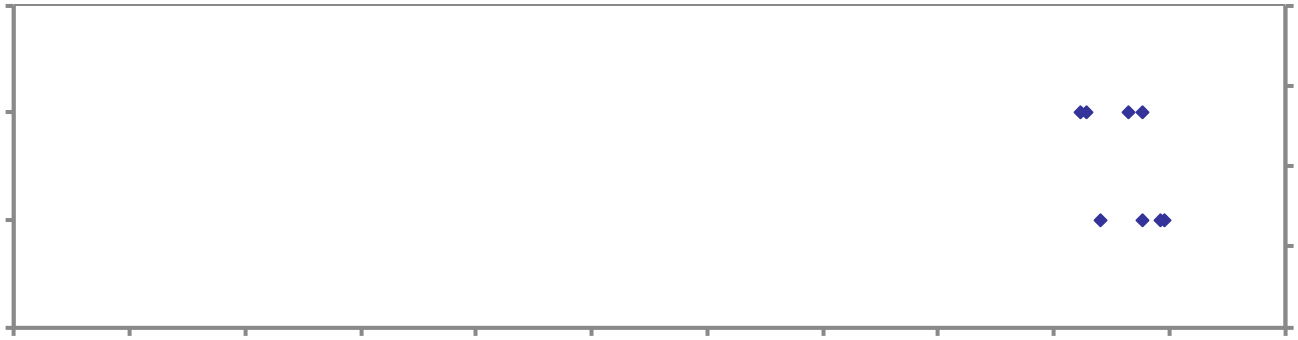


Specimen Number	NIAR Batch #	NIAR Cure Cycle	Prepreg Lot #	Cure Cycle #	Strength [ksi]	Avg. Specimen Thickness [in]	# Plies in Laminate	Avg. t_{ply} [in]	Failure Mode
NTP-5325QRI-SOL-S36-NIAR-SBS-A-C1-1-ETW2-1	A	C1	1	1	6.739	0.245	32	0.0076	INTERLAMINAR SHEAR
NTP-5325QRI-SOL-S36-NIAR-SBS-A-C1-1-ETW2-2	A	C1	1	1	6.762	0.244	32	0.0076	INTERLAMINAR SHEAR
NTP-5325QRI-SOL-S36-NIAR-SBS-A-C1-1-ETW2-3	A	C1	1	1	6.859	0.244	32	0.0076	INTERLAMINAR SHEAR
NTP-5325QRI-SOL-S36-NIAR-SBS-A-C1-1-ETW2-4	A	C1	1	1	6.866	0.244	32	0.0076	INTERLAMINAR SHEAR
NTP-5325QRI-SOL-S36-NIAR-SBS-A-C2-1-ETW2-1	A	C2	1	2	7.391	0.245	32	0.0077	INTERLAMINAR SHEAR
NTP-5325QRI-SOL-S36-NIAR-SBS-A-C2-1-ETW2-2	A	C2	1	2	7.087	0.245	32	0.0076	INTERLAMINAR SHEAR
NTP-5325QRI-SOL-S36-NIAR-SBS-A-C2-1-ETW2-3	A	C2	1	2	6.929	0.244	32	0.0076	INTERLAMINAR SHEAR
NTP-5325QRI-SOL-S36-NIAR-SBS-A-C2-1-ETW2-4	A	C2	1	2	6.923	0.244	32	0.0076	INTERLAMINAR SHEAR
				Average	**6.945**			**0.0076**	
				Standard Dev.	**0.210**				
				Coeff. of Var. [%]	**3.026**				
				Min.	**6.739**			**0.0076**	
				Max.	**7.391**			**0.0077**	
				Number of Spec.	**8**			**8** H + -`0	



normalizing t_{ply} [in]
0.0077

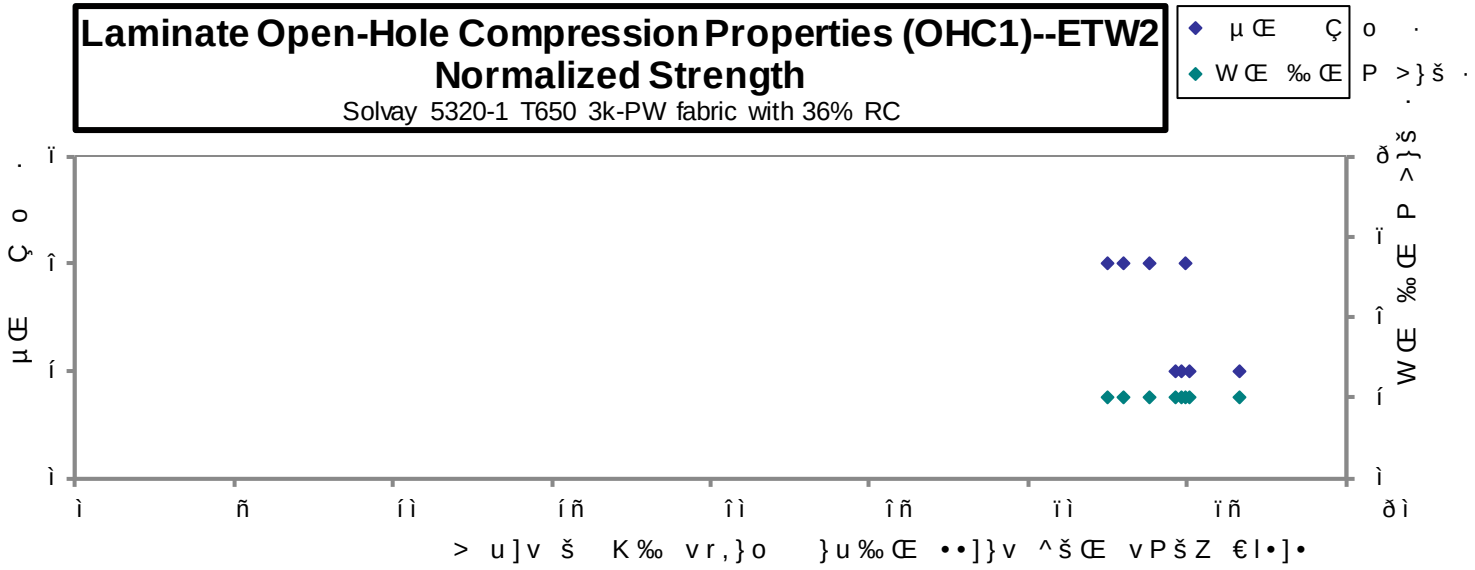
Specimen Number	NIAR Batch #	NIAR Cure Cycle	Prepreg Lot Ð N ώ Ä t



December 19, 2019

normalizing t_{ply} [in]
0.0077

Specimen Number	NIAR Batch #	NIAR Cure Cycle	Prepreg Lot #	Cure Cycle #	Strength [ksi]	Avg. Specimen Thickness [in]	# Plies in Laminate	Failure Mode	Avg. t_{ply} [in]


Laminate Open-Hole Compression Properties (OHC1)--ETW2
Normalized Strength
Solvay 5320-1 T650 3k-PW fabric with 36% RC
µ Œ Ç o ·
W Œ ‰ Œ P > } š ·
. ï î í ì
ì ñ íì íñ îì îñ ïì ïñ ðì
µ Œ Ç o
W Œ ‰ Œ P > } š
> u] v š K ‰ v r , } o } u ‰ Œ ••] } v ^ š Œ v P š Z € l •] •

4.9 ñ25/50/25ò Compression Strength After Impact 1 Properties (CAI1)

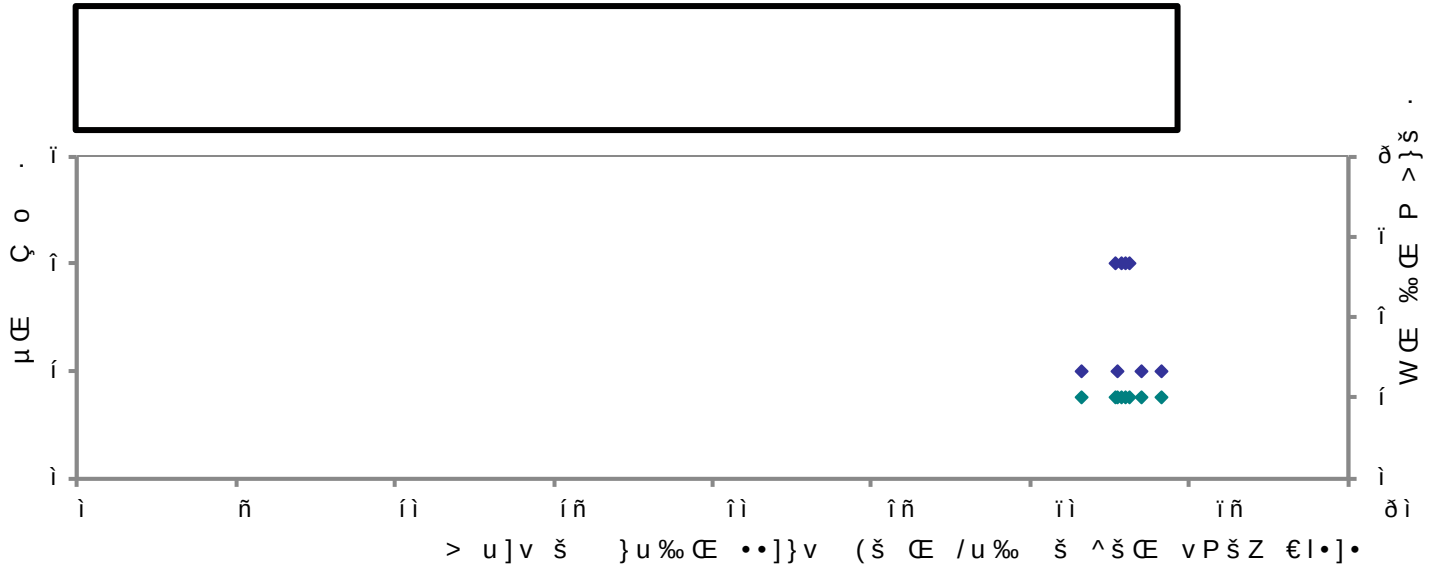
Laminate Compression After Impact 1 Properties (CAI1)--RTD
Strength
Solvay 5320-1 T650 3k-PW fabric with 36% RC

normalizing t_{ply} [in]
0.0077

Specimen Number	NIAR Batch #	NIAR Cure Cycle	Prepreg Lot #	Cure Cycle #	Strength [ksi]	Measured Impact Energy [in-lbf]	Avg. Specimen Thickness [in]	# Plies in Laminate	Failure Mode	Avg. t_{ply} [in]	$Strength_{norm}$ [ksi]
NTP-5325QRI-SOL-S36-NIAR-CAI1-A-C1-1-RTD-1	A	C1	1	1	34.241	273.46	0.184	24	LDM	0.0077	34.104
NTP-5325QRI-SOL-S36-NIAR-CAI1-A-C1-1-RTD-2	A	C1	1	1	32.716	280.41	0.185	24	LDM	0.0077	32.716
NTP-5325QRI-SOL-S36-NIAR-CAI1-A-C1-1-RTD-3	A	C1	1	1	31.537	277.66	0.185	24	LDM	0.0077	31.583
NTP-5325QRI-SOL-S36-NIAR-CAI1-A-C1-1-RTD-4	A	C1	1	1	33.465	280.03	0.185	24	LDM	0.0077	33.478
NTP-5325QRI-SOL-S36-NIAR-CAI1-A-C2-1-RTD-1	A	C2	1	2	32.504	280.79	0.186	24	LDM	0.0077	32.700
NTP-5325QRI-SOL-S36-NIAR-CAI1-A-C2-1-RTD-2	A	C2	1	2	32.908	280.37	0.186	24	LDM	0.0077	33.115
NTP-5325QRI-SOL-S36-NIAR-CAI1-A-C2-1-RTD-3	A	C2	1	2	32.905	280.17	0.185	24	LDM	0.0077	33.008
NTP-5325QRI-SOL-S36-NIAR-CAI1-A-C2-1-RTD-4	A	C2	1	2	32.713	280.07	0.186	24	LDM	0.0077	32.841

	Strength [ksi]
Average	32.873
Standard Dev.	0.774
Coeff. of Var. [%]	2.355
Min.	31.537
Max.	34.241
Number of Spec.	8

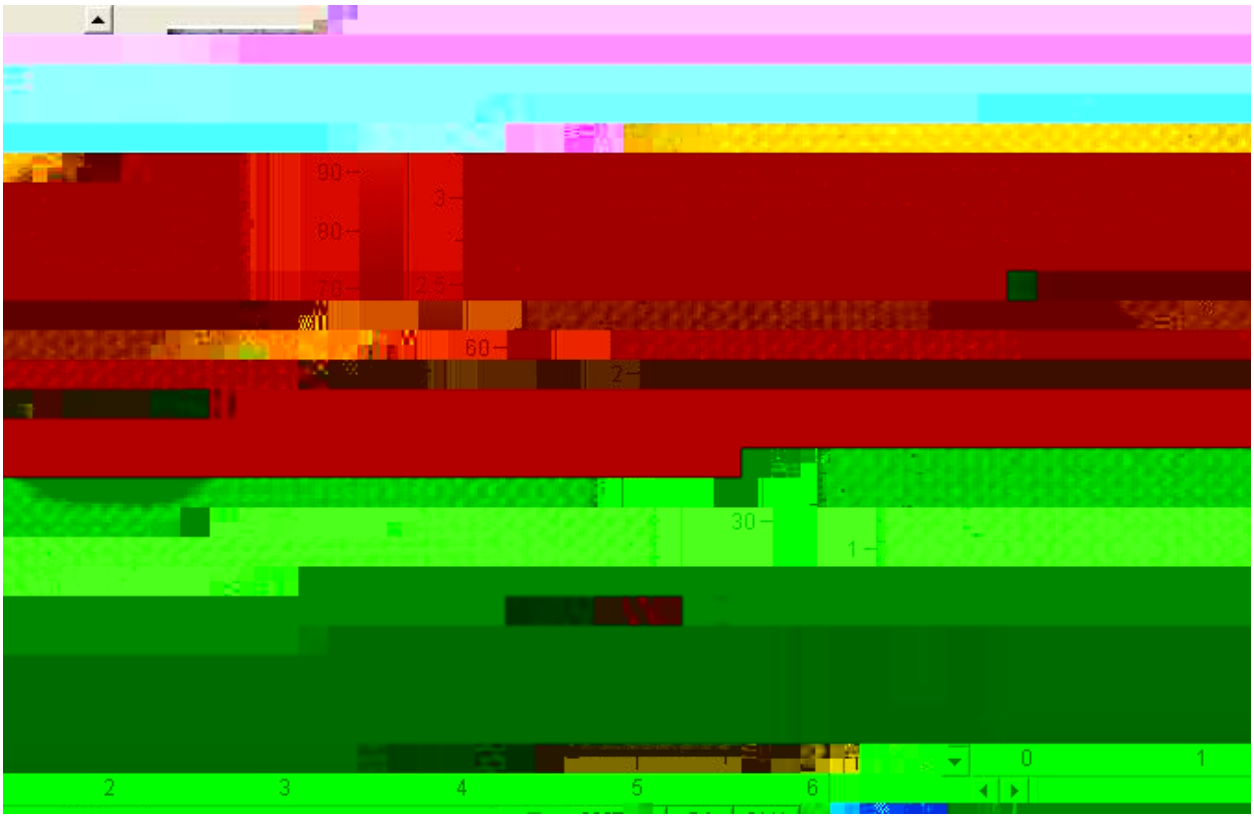
	Avg. t_{ply} [in]	$Strength_{norm}$ [ksi]
$Average_{norm}$	0.0077	32.943
$Standard\ Dev._{norm}$		0.721
$Coeff.\ of\ Var.\ [\%]_{norm}$		2.188
Min.	0.0077	31.583
Max.	0.0077	34.104
Number of Spec.	8	8


ï
î
í
ì
ì
ñ
íì
íñ
îì
îñ
ïì
ïñ
ðì

5. Additional Compression After Impact Data

Impactor Diameter: 0.625”

Representative of Damage Area:



Damage Area and Dent Depth Summary:

Specimen ID	Damage Area (inch^2)	Dent Depth (inch)
NTP-5325QR1-SOL-S36-NIAR-CAI1-A-C1-1-RTD-1	0.0335	1.179
NTP-5325QR1-SOL-S36-NIAR-CAI1-A-C1-1-RTD-2	0.0375	1.403

6.3 Warp Compression ï RTD

6.5 In-Plane Shear ï RTD

7. Moisture Conditioning Charts

7.1 In-Plane Shear ï Thinnest Panel

8. DMA Results

DMA Results Summary - FAA Repair Qualification NTP-5325QRI-SOL-S36-NIAR DMA Dry (Equivalency)				
Sample #	Onset Storage Modulus		Peak of Tangent Delta	
	T_g [ÁC]	T_g [ÁF]	T_g [ÁC]	T_g [ÁF]
CAI1-A-C1-1-DMA-D	200.52	392.94	214.27	417.69
CAI1-A-C2-1-DMA-D	201.11	394.00	214.75	418.55
FC-A-C1-1R-DMA-D	202.72	396.90	220.27	428.49
FC-A-C2-1R-DMA-D	203.52	398.34	221.87	431.37
FT-A-C1-1R-DMA-D	203.11	397.60	220.73	429.31
FT-A-C2-1R-DMA-D	203.50	398.30	220.38	428.68
IPS-A-C1-1-DMA-D	195.17	383.31	211.41	412.54
IPS-A-C2-1-DMA-D	195.76	384.37	212.33	414.19
OHC1-A-C1-1-DMA-D	201.98	395.56	218.12	424.62
OHC1-A-C2-1-DMA-D	199.54	391.17	214.49	418.08
OHT1-A-C1-1-DMA-D	198.05	388.49	215.18	419.32
OHT1-A-C2-1-DMA-D	198.29	388.92	215.73	420.31
SBS-A-C1-1-DMA-D	204.73	400.51	215.03	419.05
SBS-A-C2-1-DMA-D	203.12	397.62	215.32	419.58
WC-A-C1-1-DMA-D	198.89	390.00	214.72	418.50
WC-A-C2-1-DMA-D	201.47	394.65	218.48	425.26
WT-A-C1-1-DMA-D	198.79	389.82	214.59	418.26
WT-A-C2-1-DMA-D	199.99	391.98	216.46	421.63
Average	200.57	393.03	216.34	421.41
Standard Deviation	2.73	4.91	2.97	5.35

DMA Results Summary - FAA Repair Qualification NTP-5325QRI-SOL-S36-NIAR DMA Wet (Equivalency)				
Sample #	Onset Storage Modulus		Peak of Tangent Delta	
	T_g [ÁC]	T_g [ÁF]	T_g [ÁC]	T_g [ÁF]
CAI1-A-C1-1-DMA-W	159.01	318.22	173.93	345.07
CAI1-A-C2-1-DMA-W	158.37	317.07	173.89	345.00
FC-A-C1-1R-DMA-W	156.99	314.58	171.16	340.09
FC-A-C2-1R-DMA-W	156.41	313.54	170.95	339.71
FT-A-C1-1R-DMA-W	157.59	315.66	171.43	340.57
FT-A-C2-1R-DMA-W	158.82	317.88	171.78	341.20
IPS-A-C1-1-DMA-W	145.98	294.76	167.39	333.30
IPS-A-C2-1-DMA-W	145.64	294.15	167.56	333.61
OHC1-A-C1-1-DMA-W	157.96	316.33	173.93	345.07
OHC1-A-C2-1-DMA-W	156.79	314.22	172.69	342.84
OHT1-A-C1-1-DMA-W	156.63	313.93	171.93	341.47
OHT1-A-C2-1-DMA-W	157.01	314.62	173.29	343.92
SBS-A-C1-1-DMA-W	161.88	323.38	174.23	345.61
SBS-A-C2-1-DMA-W	161.14	322.05	174.30	345.74
WC-A-C1-1-DMA-W	158.02	316.44	171.82	341.28
WC-A-C2-1-DMA-W	158.83	317.89	172.98	343.36
WT-A-C1-1-DMA-W	157.61	315.70	170.59	339.06
WT-A-C2-1-DMA-W	157.38	315.28	171.15	340.07
Average	156.78	314.21	171.94	341.50
Standard Deviation	4.25	7.64	2.03	3.66

December 19, 2019