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Advanced Fiber Reinforced Polymer Materials Guidelines for Aircraft Design Certification Process

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JAMS 2019 Technical Review
May 22 - 23, 2019

NIAR
Wichita State University
National Institute for Aviation Research

- Motivation and Key Issues
  - Aircraft manufacturers and airlines are investigating methods to reduce manufacturing costs and increase operational efficiency.
  - Major OEMs beginning to incorporate new processes for part manufacturing into production using advanced technologies.
  - Advances in vehicle development will likely accelerate during the next decade as new emerging technologies are applied to design and placed into production throughout the aircraft industry.
  - Research needed to prove the safety and integrity of these aircraft and advanced materials for the general public.

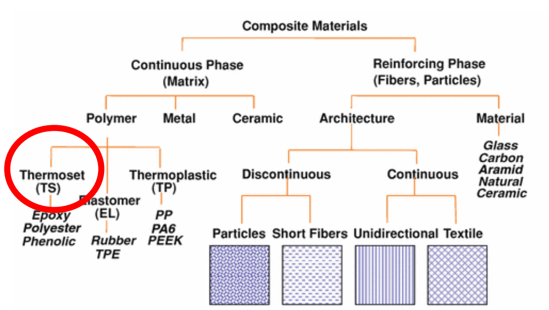

Figure 1. Composite Material Classes (Source: Friedrich, Composite Materials)

TODAY, IF YOU LOOK AT EVERY AIRPLANE FLYING IN THE COMMERCIAL FLEETS AROUND THE WORLD,

26,000 AIRCRAFT

IN THE NEXT 20 YEARS WE ARE GOING TO BUILD

40,000 MORE.

Thermoplastics in Aviation

NIAR WICHITA STATE UNIVERSITY NATIONAL INSTITUTE FOR AVIATION RESEARCH

- Why thermoplastics?
  - Environmental resistance: Impact, chemical, flame resistance, lower moisture absorption; no shelf life
  - Cost: Less clean stringent cleanroom requirements and lower cost (as long as traditional autoclaves are not used for consolidation)
  - Manufacturing benefits: Good candidate for automated processes, ability to retain significant portion of strength above Tg, can be melted and remolded and therefore have the ability to be welded (eliminating need for bonding and riveting)
- Current Applications:
  - *Gulfstream 650* aircraft. This twin-engine business jet, which began production in 2012, is the first commercial airplane to use critical control surfaces made from thermoplastic composites. Its elevator and vertical tail rudder are made with carbon fiber/PPS composite and then assembled using induction welding via an FAA-certified process.
  - *Airbus* (Toulouse, France) has successfully employed thermoplastic composites on the leading edges of its A300-series aircraft for decades (not critical control surfaces).
- Market Growth:
  - Several suppliers investing in thermoplastics such as Toray, Hexcel, Arkema
  - Replacement parts now being made with thermoplastics (Daher contracted to supply thermoplastic composite structural parts for the Boeing 787)

Source: https://www.compositesworld.com/columns/thermoplastic-composites-in-aerospace-past-present-and-future

Overall Program Information

- **FAA Technical Monitor**: Ahmet Oztekin
- **FAA AVS Sponsor**: Cindy Ashforth

- **NIAR Contacts**: John Tomblin, Royal Lovingfoss, Rachael Andrulonis
- **Industry Partners**: Toray (TenCate), several steering committee members

- **Overall Goals**
  - Primary goal: To develop a framework for the qualification of new and innovative composite material systems including guidelines and recommendations for their characterization, testing, design and utilization.
  - Secondary goal: To transition the test data and guidelines generated in this program into shared databases, such as CMH-17.

Tasks

- **FY2016: Qualification**
  - **Overall process**
  - **Trial test matrix**
  - **Development of specs, test plan**
  - **Prepreg and panel fabrication**
  - **Testing and resulting data**
  - **Transition plans**

- FY2018:
  - Equivalency on original qualification material
  - Thermoplastic chopped fiber characterization

Technical Approach

- Develop a framework to advance thermoplastic composite materials into the aerospace industry.
- Utilize the experience and framework of the NCAMP composite program as an example of process sensitive material characterization.
- Assess the validity with equivalency testing.

TASKS 1 & 2: Survey & Establish Steering Committee → TASK 3: Develop Qualification Framework → TASK 3: Validate framework with selected materials → TASK 4: Establish statistical guidelines → TASK 5: Transition - Material property data - Guidelines

Task 3: Development of Qualification Program

GOAL: Generate the framework for a qualification test program including material and process specifications, test matrices, and documentation requirements.

Objectives:

- Select advanced fiber thermoplastic PMC material and process to initially develop this framework. The material was selected with input from the steering committee.
- Address quality aspects of the manufacturing process and the framework for a quality assurance program.
- Draft material and process specifications for selected material.
- Develop a test matrix including required physical and mechanical data.
- Generate substantial mechanical property test data necessary for development of statistical guidelines using accepted test standards for the selected material.

Project Status

- **Material Selection**
  - Toray (TenCate) - TC1225 (PAEK) unidirectional tape (semi-crystalline engineered polyaryletherketone resin)
  - Fiber form – originally AS4D → now changed to T700 due to acquisition by Toray
- **Current Activity**
  - Screening Studies assisted in development of test matrix
  - Documentation – material and process specifications complete
  - Test Plan complete
  - Qualification Production
    - Audit at TenCate (December 2017) – signed and complete
    - Panels fabricated by TenCate Netherlands facility
    - Nearly all testing is now complete (data reduction and statistics are in progress)

March 23, 2018 NTP 1225Q1 Rev -

Material Supplier Contact:	Panel Fabricator Contact:
Dan Leeser Technology Manager, Thermoplastics TenCate Advanced Composites 18410 Butterfield Blvd Morgan Hill, CA 95037 Tel: (508) 641-0659 Email: d.leeser@tcac-usa.com	Erwin Veldman TenCate Campbellweg 30 7443 PV Nijverdal Netherlands Tel: :+31 548 633714 Email: e.veldman@tencate.com

NCAMP Test Plan Number: NTP 1225Q1

NCAMP Project Number: NPN 061701

Material Property Data Acquisition and Qualification Test Plan For High Toughness PAEK thermoplastics TenCate Cetex® TC1225 (LM PAEK) HexTow AS4D 12k Unidirectional Tape 145 gsm 34% RC

Prepared by: Rachael Andrulonis (NIAR), Royal Lovingfoss (NIAR), John Tomblin (NIAR)

Reviewed by: Dan Leeser (TenCate), Terry Hines (TenCate), Benjamin Fox (TenCate), Scott Unger (TenCate), Daniel Coyle (TenCate), Handi Handi (TenCate), Rick Cole (NRC), Steve Ward (UTAS), Jonathan Garhart (Sikorsky), Max Warden (Honeywell), Jose Sanchez (Airbus), Ric Abbott (Consultant)

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NMS 122 Rev A
Date: December 7, 2017

Document No.: NMS 122, Revision A, December 7, 2017

NCAMP Material Specification
This specification is generated and maintained in accordance with NCAMP Standard Operating Procedures, NSP 100

High Toughness PAEK thermoplastics
Cetex® TC1225 (LM PAEK) AS4D 145 gsm 34% RC

FOR TEST USE ONLY
Because this version does not contain all the specifications limits

Prepared by: Rachael Andrulonis (NCAMP/NIAR), Royal Lovingfoss (NCAMP/NIAR), John Tomblin (NCAMP/NIAR)

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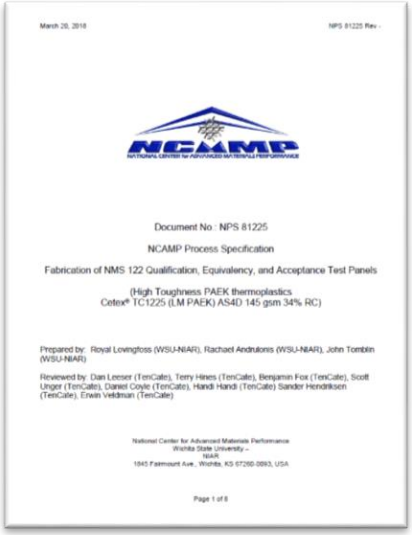

March 20, 2018 NPS 81225 Rev -

Document No.: NPS 81225

NCAMP Process Specification

Fabrication of NMS 122 Qualification, Equivalency, and Acceptance Test Panels

(High Toughness PAEK thermoplastics
Cetex® TC1225 (LM PAEK) AS4D 145 gsm 34% RC)

Prepared by: Royal Lovingfoss (WSU-NIAR), Rachael Andrulonis (WSU-NIAR), John Tomblin (WSU-NIAR)

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Material Specification (NMS 122)

- Scope – form, application, classification
- Applicable Documents
- Technical Requirements
  - Detail specification
  - Constituent Material Requirements
  - Prepreg physical and chemical requirements
- Quality Assurance
- Preparation for Delivery

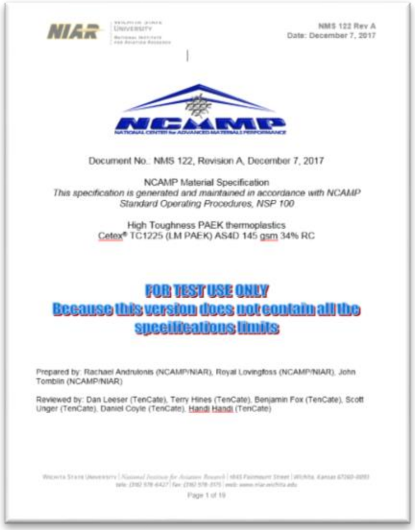
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Table 1 – Prepreg Physical and Chemical Properties

Property	Product Form	Test Method(1)	Number of Replicates
Fiber Areal Weight	Prepreg	ASTM D3776 or SACMA SRM 23R-94	Each Lot/Batch(2)
Resin Content	Prepreg	ASTM D3171	Each Lot/Batch(2)
Differential Scanning Calorimetry (DSC) Glass Transition Temperature Melt Temperature Crystallization Temperature	Prepreg	ASTM D3418 or SACMA SRM 25R-94	Each Lot/Batch(3)

(1) Specific procedures should be identical to those used in the original material qualification program.
(2) Three specimens minimum should be taken across the width of each prepreg lot.
(3) Three specimens minimum should be taken for each prepreg lot.

TABLE 2 - Molded Laminate Physical Properties

Property	Test Method	Number of Replicates
Molded Ply Thickness	ASTM D3171-11	10 measurements per panel
Laminate Density	ASTM D792-08	2 per batch/lot minimum
Fiber Volume, % by Volume	ASTM D3171-11	2 per batch/lot minimum
Resin Content, % by Weight	ASTM D3171-11	2 per batch/lot minimum
Void Content, % by Volume	ASTM D3171-11	2 per batch/lot minimum
DSC (dry) - Glass transition Temp(1) - Melt Temperature - Crystallization Temperature	ASTM D3418-15	2 per batch/lot minimum

(1) Optional to use either method. Specific procedures should be identical to those used in the original material qualification program.

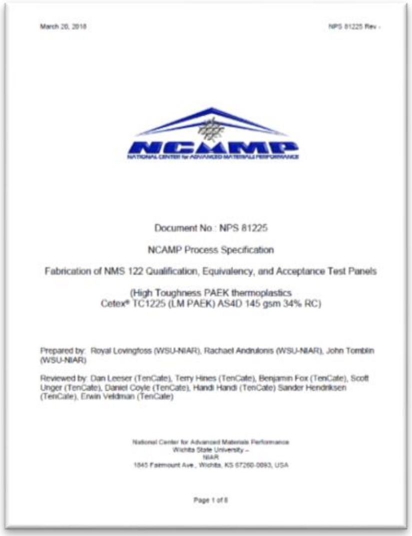
TABLE 3 - Required Molded Laminate Tests for Mechanical Properties (Class 1 Only)

Property	Test Temperature	Test Method(1)	Number of Replicates
0° Tension Strength and Modulus	RT	ASTM D3039	5
90/0° Compression Strength	RT	ASTM D6641	5
90 Flex Strength	RT	ASTM D790-5	5
SBS Strength	RT	ASTM D2344	5

(1) Specific procedures should be identical to those used in the original material qualification program

Process Specification (NPS 81225)

- Scope
- Applicable Documents
- Materials
- Test Laminate Fabrication (compression molding)
- Quality Assurance



March 20, 2018 NPS 81225 Rev -

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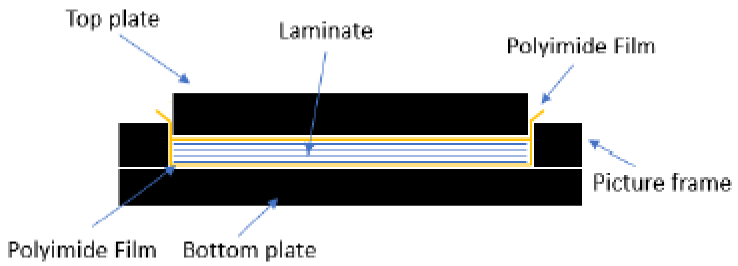


Figure 1. Molding Test Panels Schematic for TC1225

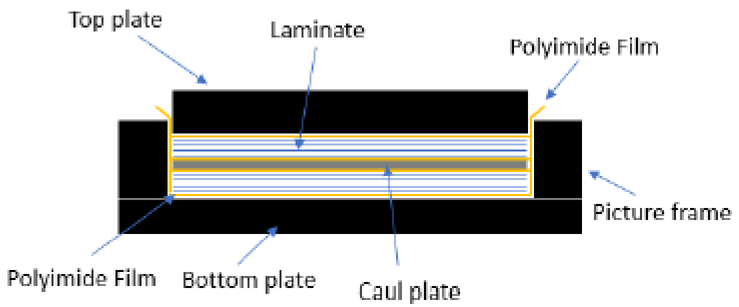


Figure 2. Molding Test Panels Schematic for TC1225 (Multiple panels)

Screening Studies

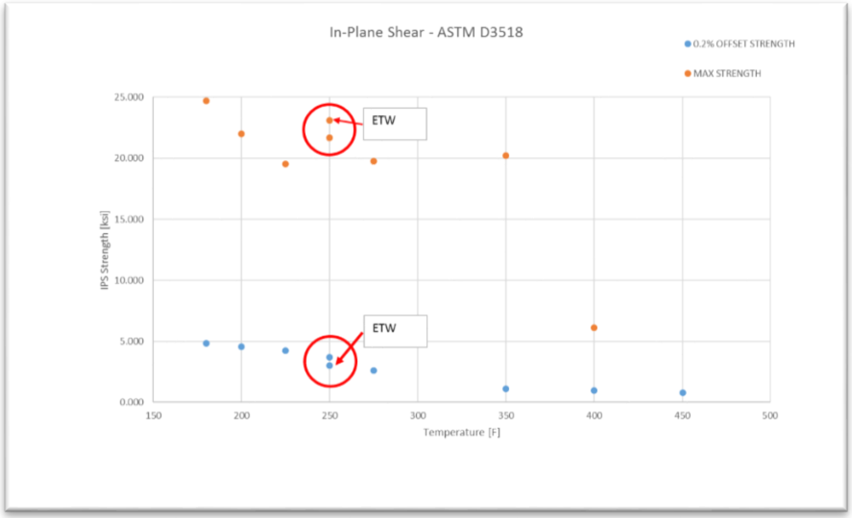
- **Trial screening test program was conducted per recommendation of the Steering Committee**:
  - Does moisture uptake affect strength properties significantly? *If not, consider removing ETW from test matrix.*
  - What elevated temperature(s) should be selected for qualification testing? *Full 3 batch or single batch recommendations.*

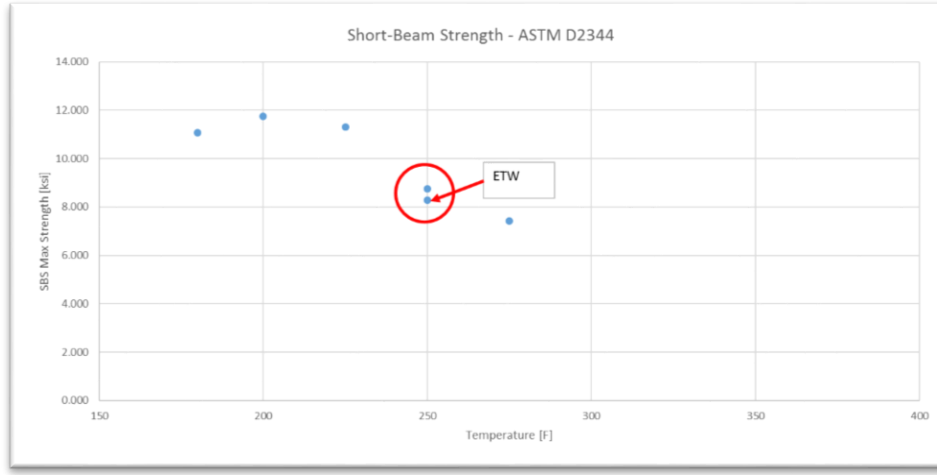
- Test Temperatures:
  - Phase 1: 180°F, 250°F, and 350°F
  - Phase 2: 200°F, 225°F, 275°F
  - Phase 3: 400°F and 450°F

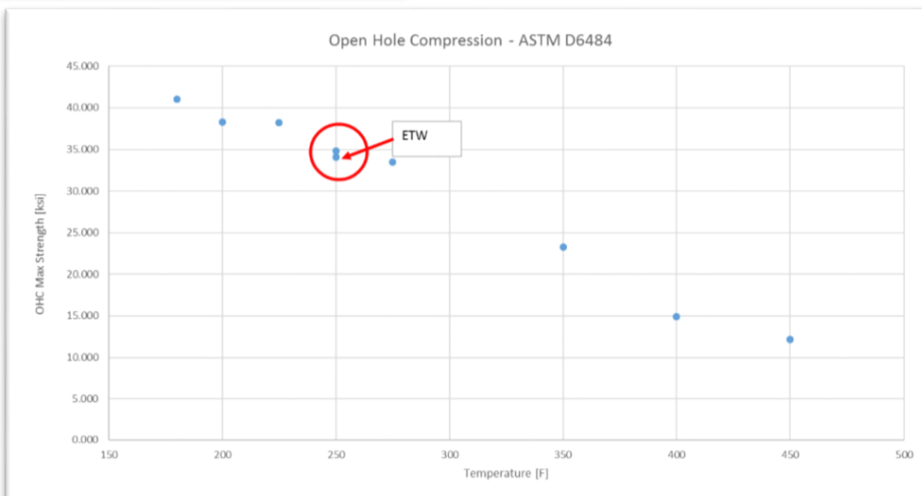
- Mechanical Properties:
  - IPS: $[+45/-45]_{4S}$
  - SBS: $[0]_{34}$
  - OHC: $[+45/0/-45/90]_{3S}$

- Physical Properties: DSC/DMA were evaluated

Screening Results Overview







Test Plan

- Test Methods
- Panel and Specimen Identification
- Prepreg and Resin Testing
- Molded Laminate Physical Testing
- Molded Lamina and Laminate Mechanical Property Testing
- Inspection, conformance, witnessing, shipping
- Data reduction and reporting


March 23, 2018 NTP 1225Q1 Rev -

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Physical Test Results

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	Specific Gravity (Relative Density)	Fiber Content by Matrix Digestion		Void Content
	ASTM D792-13	**ASTM D3171-15 (Test Method I, Procedure B)**		**ASTM D2734-16**
	Specimen Density [g/cc]	Fiber Volume [%]	Resin Content Volume [%]	Void Content Volume [%]
AVERAGE	1.5680	58.54	40.01	1.45
STANDARD DEVIATION	0.0063	1.21	1.36	0.36
COEFF. OF VARIATION	0.4031	2.06	3.40	24.66
MINIMUM	1.5545	56.06	36.63	0.25
MAXIMUM	1.5867	61.48	42.66	2.08
NUMBER OF SPECIMENS	111	111	111	111

Results include approximately 1/3 of all physical test coupons.
Other results are similar.

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A Center of Excellence AMTAS Advanced Materials in Transport Aircraft Structures

Lamina Test Matrix

NIAR Wichita State University
National Institute for Aviation Research

Layup	Test Type and Direction	Property	Number of Batches x Number of Panels x Number of Test Specimens				
			Test Temperature/Moisture Condition				
			CTA	RTA	ETA1	ETA2	ETW
$[0]_8$	ASTM D3039 0° Tension	Strength, Poisson's Ratio, and Modulus	3x2x3	3x2x3	3x2x3	1x2x3	1x2x3
$[0]_{20}$	ASTM D6641 0° Compression	Poisson's Ratio and Modulus	3x2x3	3x2x3	3x2x3	1x2x3	1x2x3
$[90°]_{16}$	ASTM D3039 90° Tension	Strength and Modulus	3x2x3	3x2x3	3x2x3	1x2x3	1x2x3
$[90°]_{20}$	ASTM D6641 90° Compression	Strength and Modulus	3x2x3	3x2x3	3x2x3	1x2x3	1x2x3
[90/0]4s	ASTM D6641 0° Compression	Strength and Modulus	3x2x3	3x2x3	3x2x3	1x2x3	1x2x3
$[+45/-45°]_{4s}$	ASTM D3518 In-Plane Shear	Strength and Modulus	3x2x3	3x2x3	3x2x3	1x2x3	1x2x3
$[0°]_{22}$	ASTM D790 Flex	Strength	3x2x3	3x2x3	3x2x3	1x2x3	1x2x3
$[0]_{34}$	ASTM D2344 Short Beam	Strength	3x2x3	3x2x3	3x2x3	1x2x3	1x2x3

Test environments are defined as:
CTA = -65±5°F, ambient
RTA = 70±10°F, room temperature ambient
ETA1 = 275±5°F, ambient
ETA2 = 400±5°F, ambient
ETW = 275±5°F, wet (equilibrium moisture content per section 6.1)

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AMTAS Advanced Materials in Transport Aircraft Structures

Laminate Test Matrix

(%0º/%±45º/%90º) Actual Test Type	Test Type and Layup	Property	Number of Batches x Number of Panels x Number of Test Specimens — Test Temperature/Moisture Condition: CTA	RTA	ETA1	ETA2	ETW
(25/50/25 - QI) UNT1	ASTM D3039 Un-notched Tension [45/0/-45/90]2S	Strength & modulus	3x2x3	3x2x3	3x2x3	1x2x3	1x2x3
(10/80/10) UNT2	ASTM D3039 Un-notched Tension [45/-45/0/45/-45/90/45/-45/45/-45]S	Strength & modulus	3x2x3	3x2x3	3x2x3		
(50/40/10) UNT3	ASTM D3039 Un-notched Tension [0/45/0/90/0/-45/0/45/0/-45]S	Strength & modulus	3x2x3	3x2x3	3x2x3		
(25/50/25 - QI) UNC1	ASTM D6641 Un-notched Compression [45/0/-45/90]3S	Strength & modulus		3x2x3	3x2x3	1x2x3	1x2x3
(10/80/10) UNC2	ASTM D6641 Un-notched Compression [45/-45/0/45/-45/90/45/-45/45/-45]S	Strength & modulus		3x2x3	3x2x3		
(50/40/10) UNC3	ASTM D6641 Un-notched Compression [0/45/0/90/0/-45/0/45/0/-45]S	Strength & modulus		3x2x3	3x2x3		
(25/50/25 - QI) SBS1	ASTM D2344 Short Beam [45/0/-45/90]3S	Strength		3x2x3	3x2x3	1x2x3	1x2x3
(25/50/25 - QI) OHT1	ASTM D5766 Open Hole Tension [45/0/-45/90]2S	Strength	3x2x3	3x2x3	3x2x3	1x2x3	1x2x3
(10/80/10) OHT2	ASTM D5766 Open Hole Tension [45/-45/0/45/-45/90/45/-45/45/-45]S	Strength	3x2x3	3x2x3	3x2x3		
(50/40/10) OHT3	ASTM D5766 Open Hole Tension [0/45/0/90/0/-45/0/45/0/-45]S	Strength	3x2x3	3x2x3	3x2x3		
(25/50/25 - QI) FHT1	ASTM D6742 Filled Hole Tension [45/0/-45/90]2S	Strength	3x2x3	3x2x3	3x2x3	1x2x3	1x2x3
(10/80/10) FHT2	ASTM D6742 Filled Hole Tension [45/-45/0/45/-45/90/45/-45/45/-45]S	Strength	3x2x3	3x2x3	3x2x3		
(50/40/10) FHT3	ASTM D6742 Filled Hole Tension [0/45/0/90/0/-45/0/45/0/-45]S	Strength	3x2x3	3x2x3	3x2x3		
(25/50/25 - QI) OHC1	ASTM D6484 Open Hole Compression [45/0/-45/90]4S	Strength		3x2x3	3x2x3	1x2x3	1x2x3
(10/80/10) OHC2	ASTM D6484 Open Hole Compression [45/-45/0/45/-45/90/45/-45/45/-45]2S	Strength		3x2x3	3x2x3		
(50/40/10) OHC3	ASTM D6484 Open Hole Compression [0/45/0/90/0/-45/0/45/0/-45]2S	Strength		3x2x3	3x2x3		
(25/50/25 - QI) FHC1	ASTM D6484 Filled Hole Compression [45/0/-45/90]4S	Strength		3x2x3	3x2x3	1x2x3	1x2x3
(10/80/10) FHC2	ASTM D6484 Filled Hole Compression [45/-45/0/45/-45/90/45/-45/45/-45]2S	Strength		3x2x3	3x2x3		
(50/40/10) FHC3	ASTM D6484 Filled Hole Compression [0/45/0/90/0/-45/0/45/0/-45]2S	Strength		3x2x3	3x2x3		
(25/50/25 - QI) SSB1	ASTM D5961 Single Shear Bearing [45/0/-45/90]2S	Strength & Deformation		3x2x3	3x2x3	1x2x3	1x2x3
(10/80/10) SSB2	ASTM D5961 Single Shear Bearing [45/-45/0/45/-45/90/45/-45/45/-45]S	Strength & Deformation		3x2x3	3x2x3		
(50/40/10) SSB3	ASTM D5961 Single Shear Bearing [0/45/0/90/0/-45/0/45/0/-45]S	Strength & Deformation		3x2x3	3x2x3		
(100/0/0) ILT	ASTM D6415 Interlaminar Tension Strength [0]30 (note: curved panel)	Strength	1x1x6	1x1x6	1x1x6	1x1x6	1x1x6
(25/50/25 - QI) CAI1	ASTM D7136 & D7137 Compression After Impact (1500 in.lb/in) [45/0/-45/90]4S	Strength		1x1x6	1x1x6	1x1x6	1x1x6

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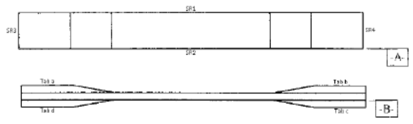
CTA = -65±5°F, ambient
RTA = 70±10°F, room temperatur
ETA1 = 275±5°F, ambient
ETA2 = 400±5°F, ambient
ETW = 275±5°F, wet (equilibrium

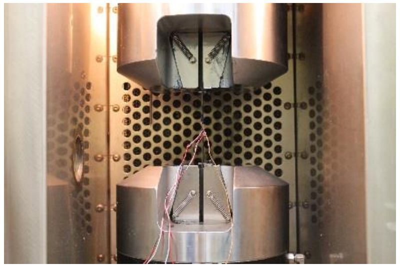
Overall Observations

- Flex, SBS, and ILT tests at certain conditions did not exhibit significant load drops and often were not taken to failure → offset strengths presented.
- Coefficients of variation are well within typical thermoset values (~2-7%).
- Overall batch to batch variation does not appear significant, however statistics still need to be calculated.
- Decreasing strength values as temperatures increased was not consistent across properties.

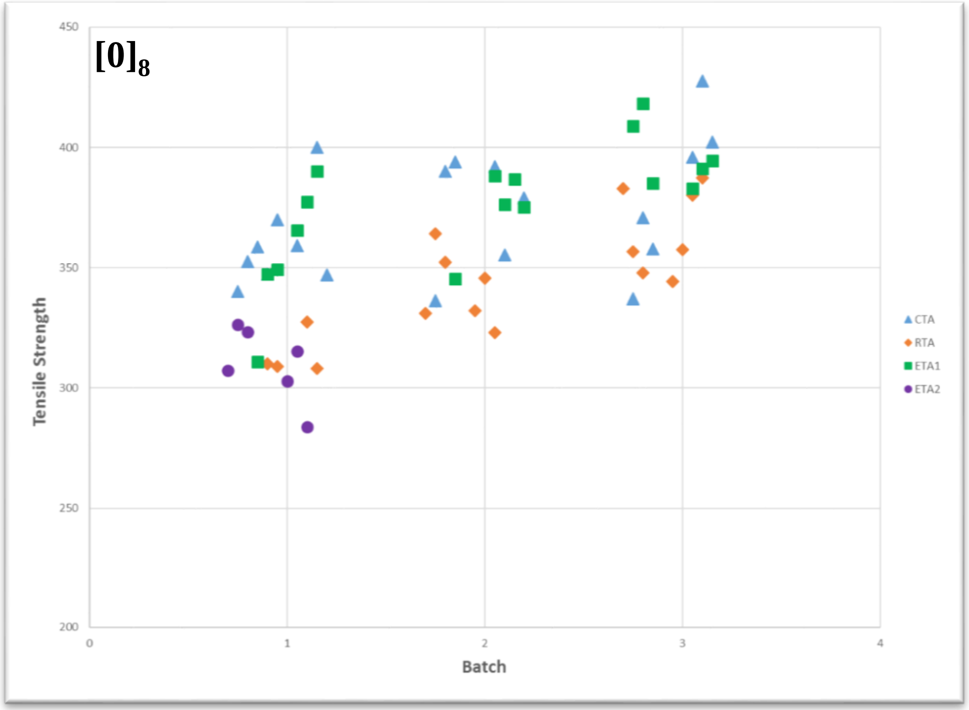
0° Tension

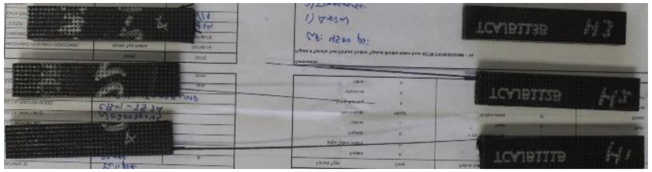
ASTM D3039
TENSILE PROPERTIES OF POLYMER MATRIX COMPOSITE MATERIALS



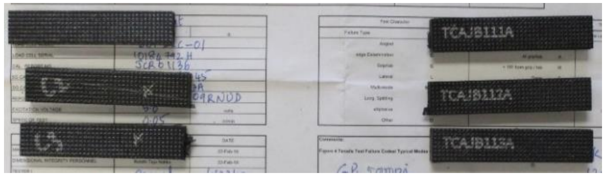


	Tensile Strength [ksi]		Modulus [Msi]		Poisson's Ratio
	Mean	CV	Mean	CV	Mean
CTA	370.66	6.94%	19.14	2.09%	0.33
RTA	344.68	7.33%	18.93	2.27%	0.34
ETA1	376.05	6.92%	18.36	2.45%	0.33
ETA2	309.82	5.04%	18.86	2.10%	0.50





Post Test: -65F/A

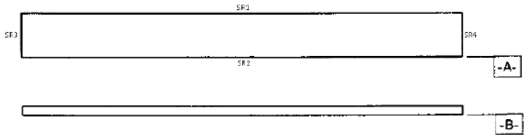


Post Test: RTA

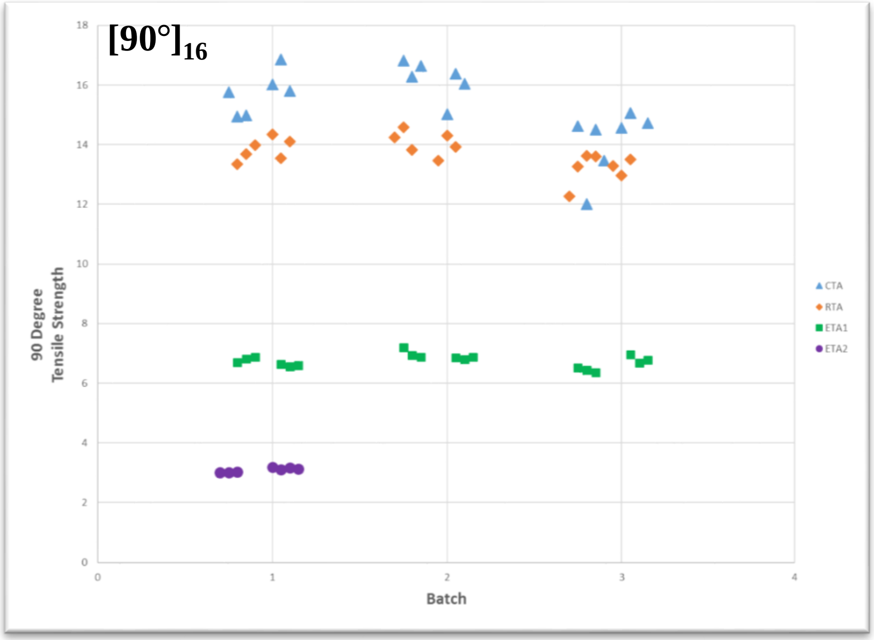
Post Test: 400F

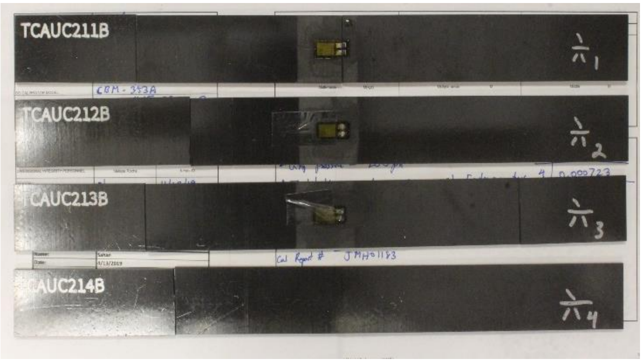
90° Tension

ASTM D3039
TENSILE PROPERTIES OF POLYMER MATRIX COMPOSITE MATERIALS



	Tensile Strength [ksi]		Modulus [Msi]	
	Mean	CV	Mean	CV
CTA	15.29	7.96%	1.41	3.18%
RTA	13.68	3.99%	1.32	2.93%
ETA1	6.75	3.04%	1.01	3.65%
ETA2	3.09	2.40%	0.26	2.77%



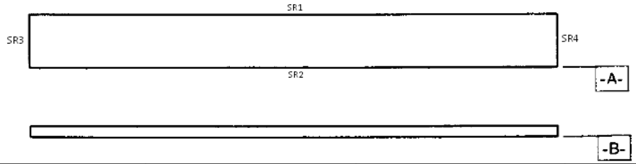


Post Test: -65F/A

Post Test: RTA

In-Plane Shear

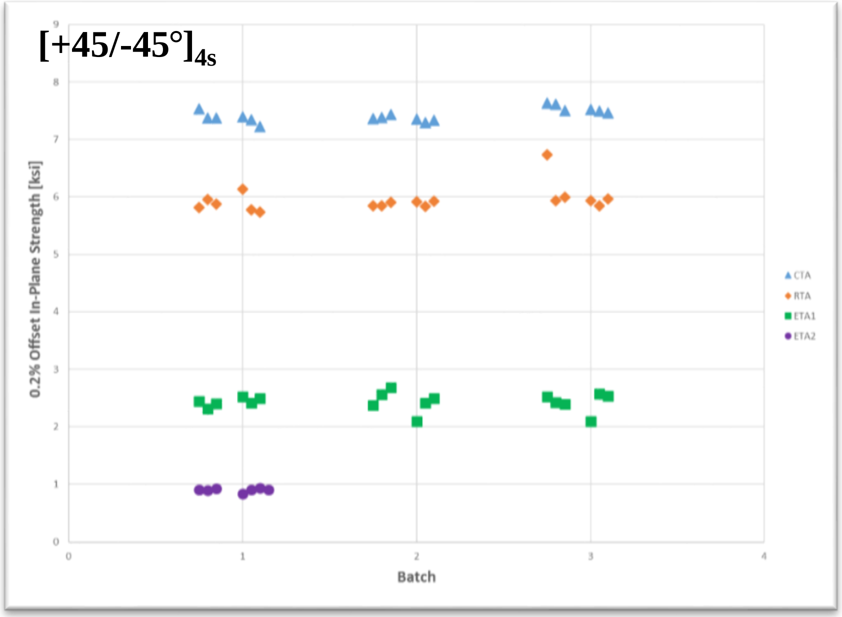
ASTM D 3518
IN-PLANE SHEAR RESPONSE OF POLYMER MATRIX COMPOSITE MATERIALS BY TENSILE TEST OF A ±45° LAMINATE



	0.2% Offset Strength [ksi]		Strength @ 5% Strain [ksi]		Ultimate Strength [ksi]		Shear Modulus [Msi]	
	Mean	CV	Mean	CV	Mean	CV	Mean	CV
CTA	7.42	1.47%	13.14	1.60%	32.07	3.02%	0.67	1.87%
RTA	5.94	3.66%	9.51	1.20%	28.42	4.80%	0.59	1.70%
ETA1	2.43	6.17%	4.57	3.85%	25.79	4.90%	0.24	7.86%
ETA2	0.90	3.76%	(1)	(1)	(2)	(2)	0.07	3.96%

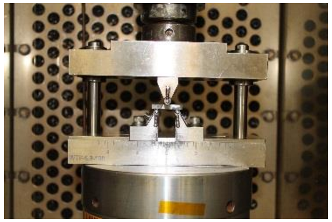
(1) SHEAR STRENGTH AT 5% STRAIN IS NOT REPORTED FOR ALL SPECIMENS DUE TO STRAIN GAGE FAILURE BEFORE OBTAINING A SHEAR STRAIN OF 50000 MICROSTRAIN

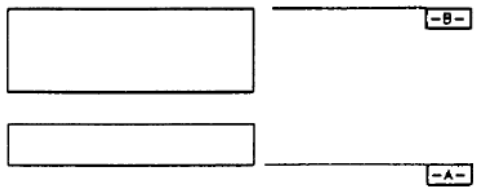
(2) SPECIMENS NOT TESTED TO FAILURE DUE TO MAXING OUT LOAD FRAME'S FIXTURE TRAVEL



Lamina Short Beam Shear

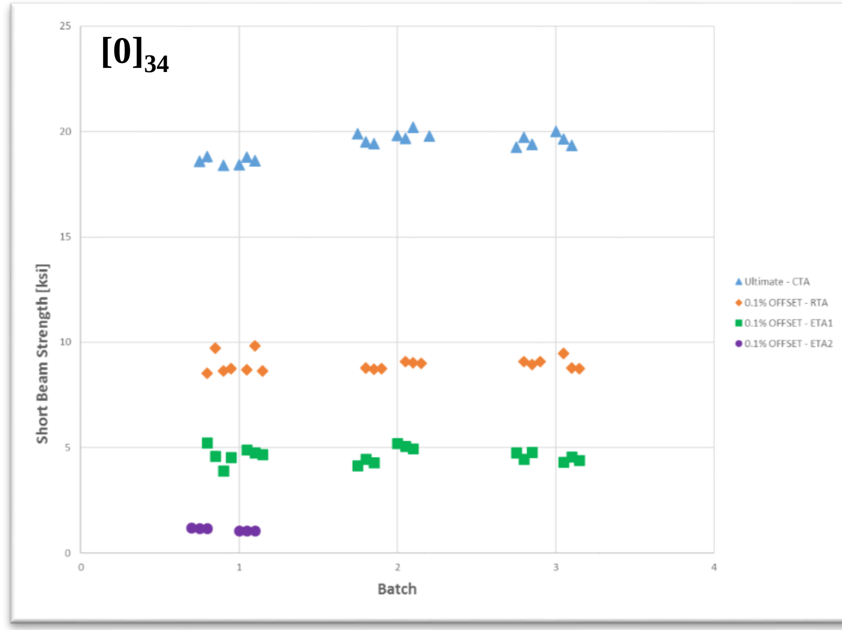
ASTM D2344
SHORT-BEAM STRENGTH OF POLYMER MATRIX COMPOSITE MATERIALS AND THEIR LAMINATES





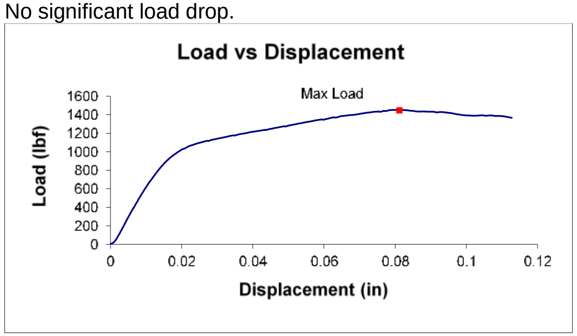
	0.1% OFFSET SBS [ksi]		0.2% OFFSET SBS [ksi]	
	Mean	CV	Mean	CV
CTA (1)	19.34	2.91%	N/A	N/A
RTA	8.96	4.03%	10.31	2.90%
ETA1	4.63	7.65%	5.24	6.00%
ETA2	1.13	6.45%	1.35	3.28%

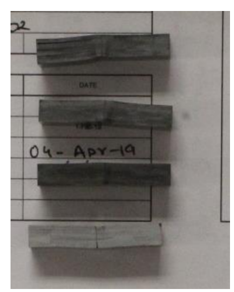
(1) Ultimate strength reported for CTA (not offset)



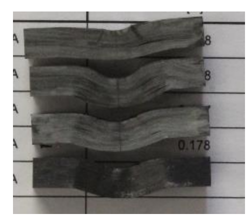
Lamina SBS RTA

- No significant load drop.

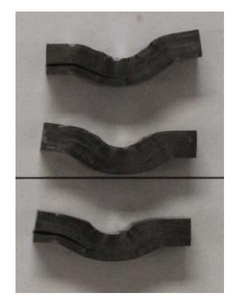




Post Test: -65F/A



Post Test: RTA

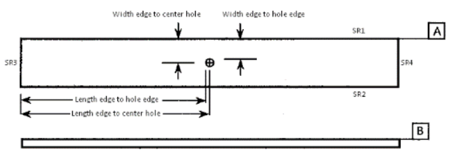


Post Test: 275F/A

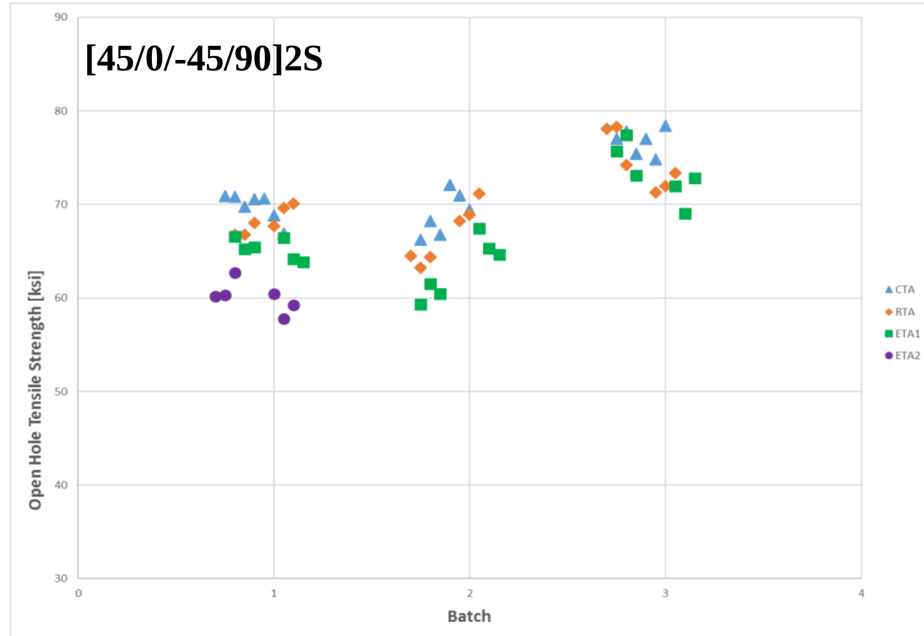
Post Test: 400F/A

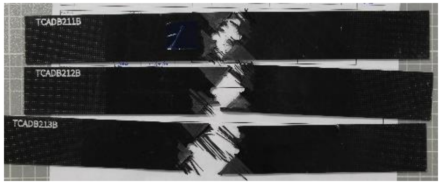
Open Hole Tension (25/50/25)

ASTM D5766
OPEN HOLE TENSILE STRENGTH OF POLYMER MATRIX COMPOSITE LAMINATES

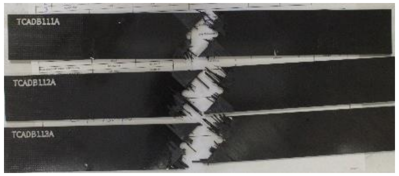


	OHT Strength [ksi]	
	Mean	CV
CTA	71.72	5.44%
RTA	69.82	6.14%
ETA1	67.24	7.62%
ETA2	60.12	2.70%



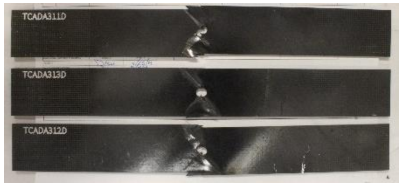


Post Test: -65F/A



Post Test: RTA

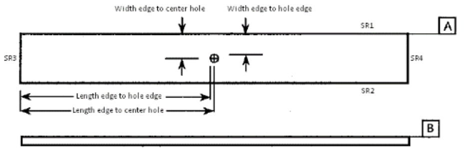
Post Test: 275F/A



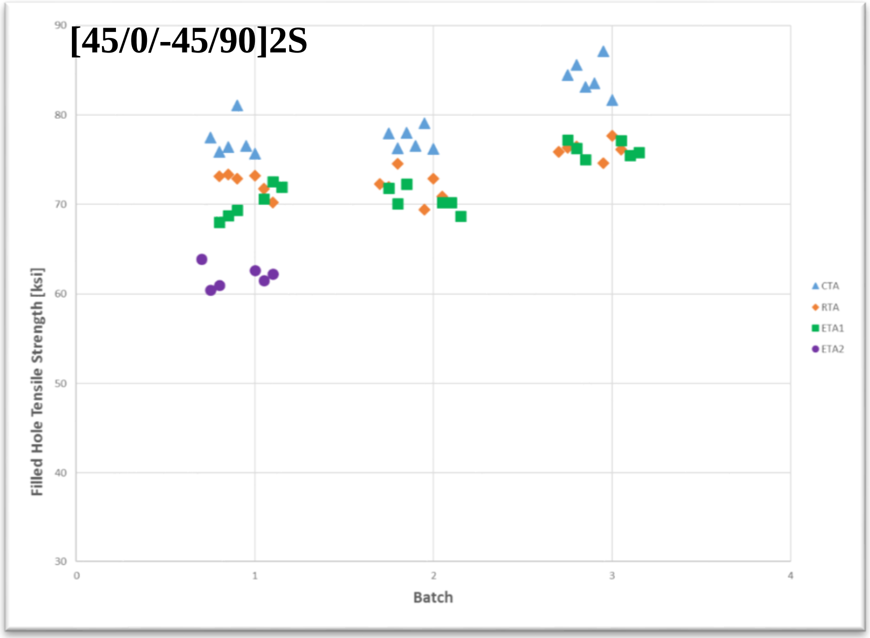
Post Test: 400F/A

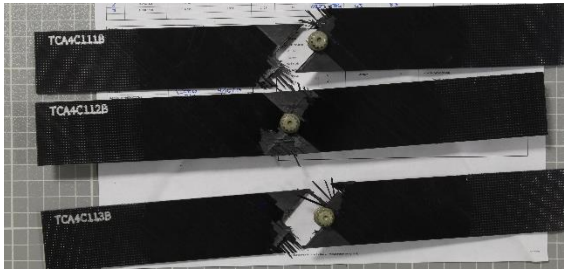
Filled Hole Tension (25/50/25)

ASTM D6742
FILLED-HOLE TENSION TESTING OF POLYMER MATRIX COMPOSITE LAMINATES

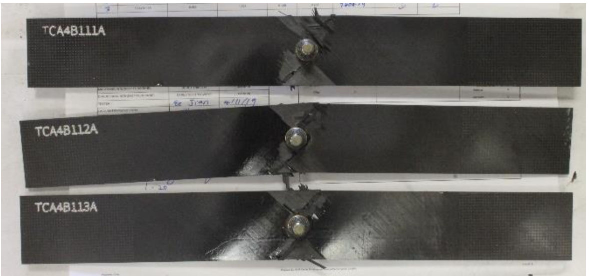


	FHT Strength [ksi]	
	Mean	CV
CTA	79.60	4.74%
RTA	73.54	3.15%
ETA1	72.31	4.27%
ETA2	61.96	2.04%





Post Test: -65F/A



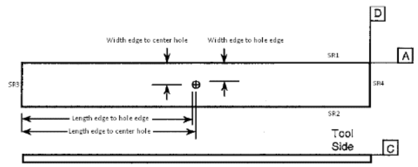
Post Test: RTA

Post Test: 275F/A

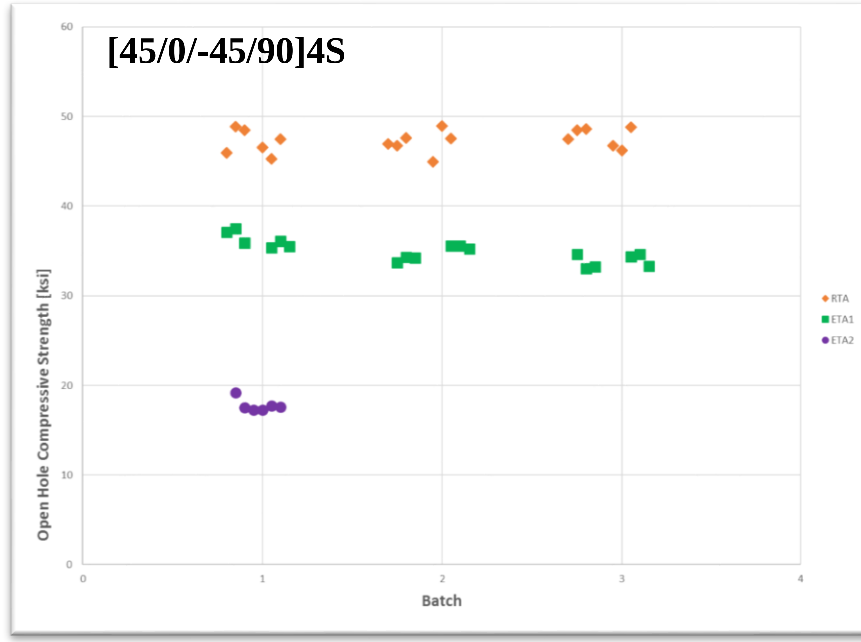
Open Hole Compression (25/50/25)

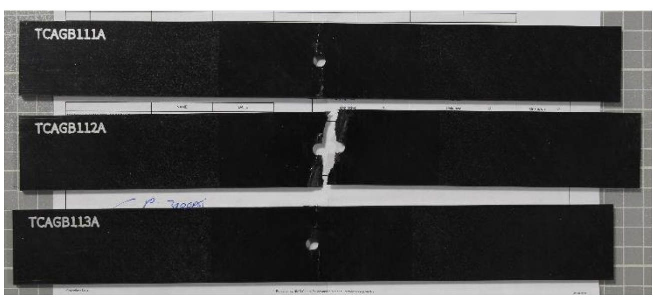
NIAR Wichita State University National Institute for Aviation Research

ASTM D6484 (PROCEDURE A)
OPEN HOLE COMPRESSIVE STRENGTH OF POLYMER MATRIX COMPOSITE LAMINATES

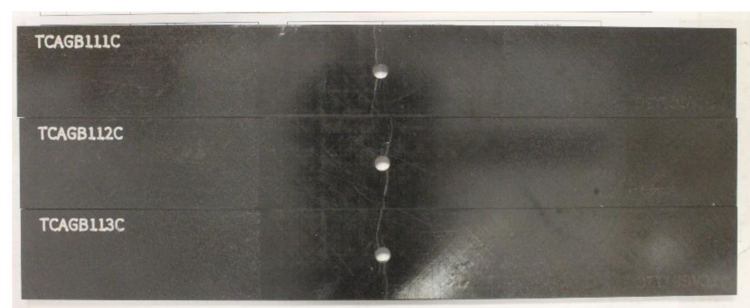


	OHC Strength [ksi]	
	Mean	CV
RTA	47.33	2.61%
ETA1	34.96	3.61%
ETA2	17.77	4.02%





Post Test: RTA

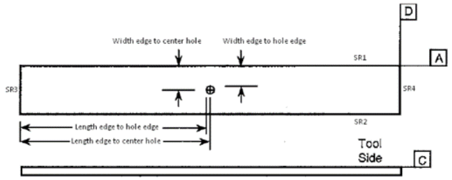


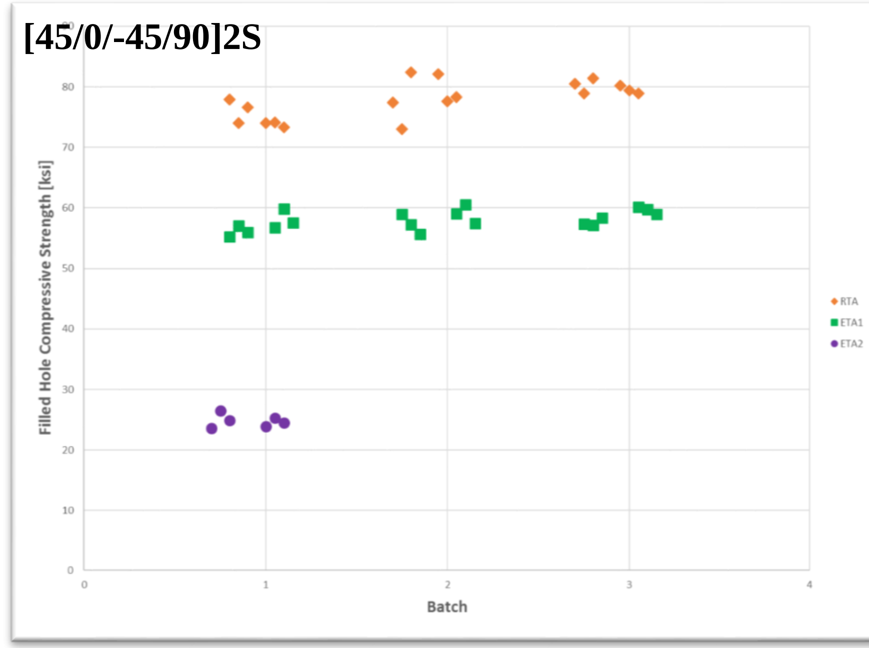
Post Test: 275F/A

CECAM JAMS Joint Advanced Materials & Structures Center of Excellence AMTAS A Center of Excellence Advanced Materials in Transport Aircraft Structures

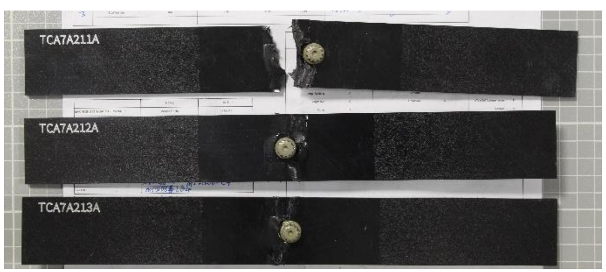
Filled Hole Compression (25/50/25)

ASTM D6742
FILLED-HOLE COMPRESSION TESTING OF POLYMER MATRIX COMPOSITE LAMINATES



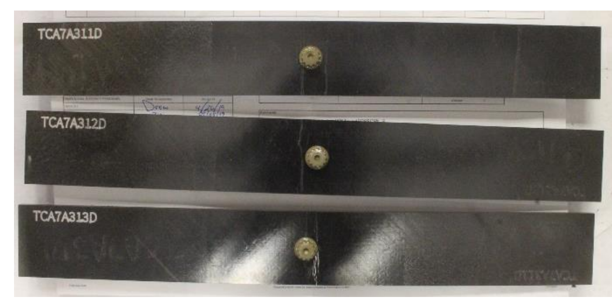


	FHC Strength [ksi]	
	Mean	CV
RTA	77.79	3.91%
ETA1	57.94	2.71%
ETA2	24.60	2.92%



Post Test: RTA

Post Test: 275F/A

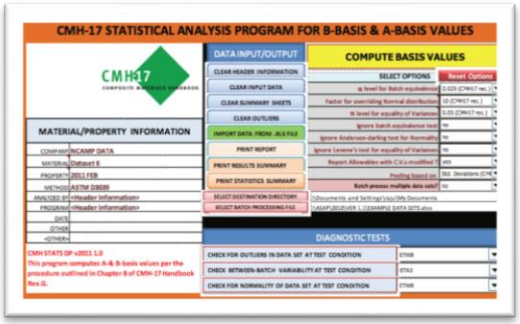


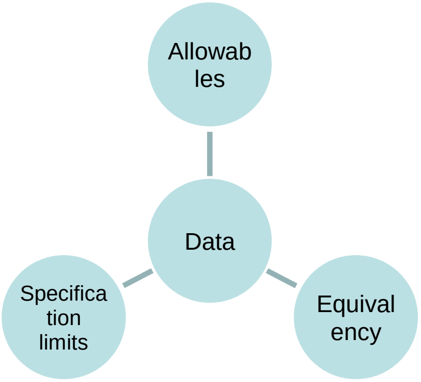
Post Test: 400F/A

Task 4: Development of statistical guidelines

GOAL: Understanding of how parameters interact and affect variability as well as final allowables.

- Establish qualification statistical requirements. The factors affecting variability will be assessed during this task.
- Establish equivalency requirements including specification minimums for acceptance.
- **Status: Data will be analyzed over next 2 months and report drafted**.





Task 5: Guidelines and Recommendations

GOAL: To provide guidelines to industry for the collection of statistically meaningful critical data that designers need to utilize thermoplastic composite materials potentially including:

- Creation of a shared database to include material test data, material and process specifications and analysis methods.
  - **Status: Material and statistical reports will be sent to Steering Committee for review this summer.**
- Development of handbook data and guidelines for CMH-17.
  - **Status: Presentation and submission of data to DRWG at October 2019 meeting.**
- Transition specification to SAE P-17.
  - **Status: SAE P-17 will set up work item once NCAMP specifications are published.**

Timeline for Qualification

	Activity	Completion Date	Milestone / Deliverable	Complete?
1.1	Survey - Develop survey questions and administer to PMC community - Collect survey results and analyze for input on material selection	11/30/2016	Deliverable	✓
1.2	Industry Steering Committee - Establish group of participants - Create online portal for document sharing and data repository	12/1/2016	Milestone	✓
1.3	Preliminary drafts of qualification framework - Material and process specifications - Test plan - Conformity documentation	6/30/2017	Deliverable	✓

Timeline for Qualification

NIAR WICHITA STATE UNIVERSITY
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	Activity	Target Date	Milestone / Deliverable	Complete?
1.1	Trial / Screening Studies (ongoing) - Perform thermal and mechanical tests to assist in test matrix development and selection of elevated test temperature - Present data to FAA, Industry Steering Committee, NCAMP Partners	12/31/2017	Milestone	✓
1.2	Qualification Material - Site audit complete (scheduled for 12/7-12/8/2017) - - Panels built and delivered to NIAR (see next slide)	10/29/2018	Milestone	✓
1.3	Qualification Testing - Perform physical and mechanical testing on qualification panels. – Generate test data for qualification program.	5/31/2019	Milestone	✓
1.4	Develop Statistical Guidelines based on qualification data	7/31/2019	Milestone	
1.5	NCAMP Reports on Qualification Data - Material technical report - Statistical analysis technical report	7/31/2019	Deliverable	
1.6	CMH-17 - Submit content, data, and protocols to Composite Materials Handbook 17 (CMH-17)	10/21/2019	Deliverable	
1.7	Final Report - Final Technical Report on the Guidelines for Thermoplastic Continuous Fiber PMC Qualification	12/31/2019	Deliverable	

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A Center of Excellence AMTAS Advanced Materials in Transport Aircraft Structures

Looking Forward…

- Continuous Fiber Thermoplastic
  - Complete qualification of continuous fiber thermoplastic composite
  - Perform equivalency to ensure repeatability and stability of process

- Discontinuous Fiber Thermoplastic Characterization
  - Steering Committee input and involvement
  - Partner: Teijin (Toho Tenax)
  - Proposed Material: Tenax-E IMS65P12 24K TPUD with PEEK polymer
    - Two forms: 0.5” X 0.5” and 0.06” X 0.5”. The latter is for finer detailed 3D molding of components.
  - Trial Studies: Conduct mechanical testing on both chip sizes to better understand variability, ease of handling and test method applicability. A small test matrix will be generated and the results will help guide future work with chopped fiber thermoplastics.
  - Align program with UW work on discontinuous fiber composites
  - Prepare for a full qualification in future years

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