Advanced Fiber Reinforced Polymer Materials Guidelines for Aircraft Design Certification Process

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Thermoplastics in Aviation

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- 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

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AMTAS

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
  -

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

Task 3: Development of Qualification Program

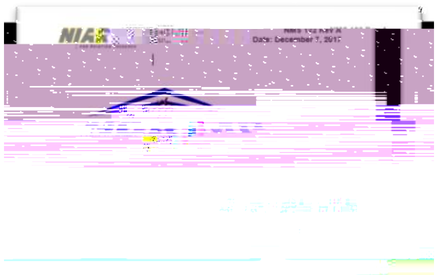
GOAL: Generate the framework for a qualification test program including material and process specifications, test matrices, and documentation requirements.

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.
-

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



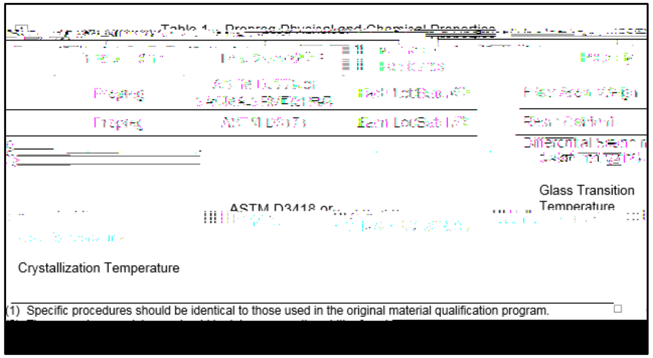
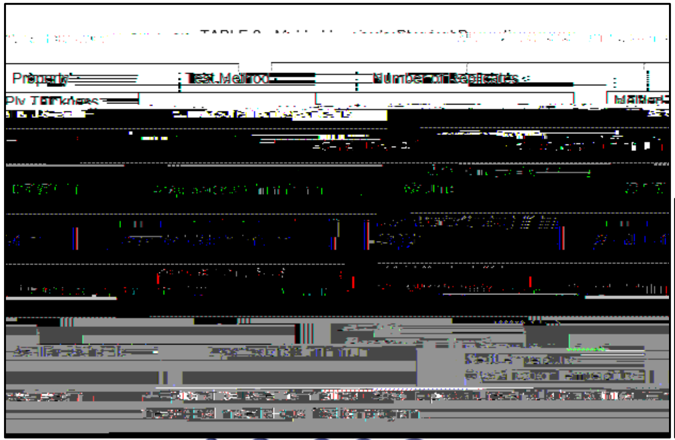


Table 1 - Prepreg Physical and Chemical Properties

	ASTM D3418 or		Glass Transition Temperature
Crystallization Temperature			

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



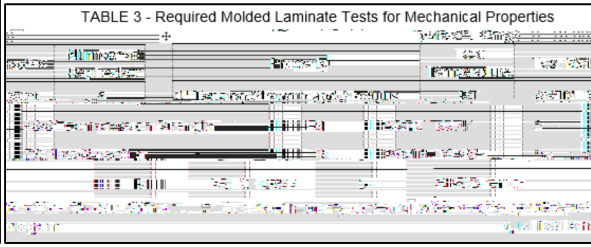
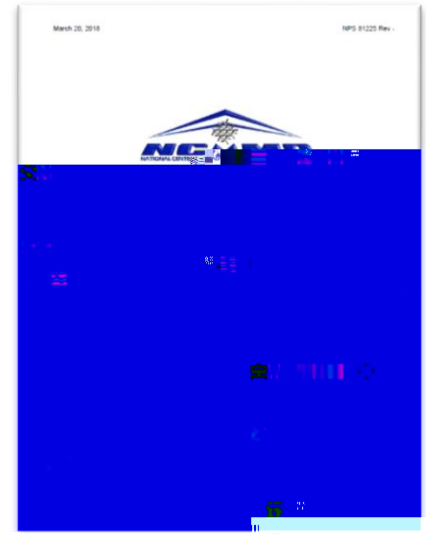
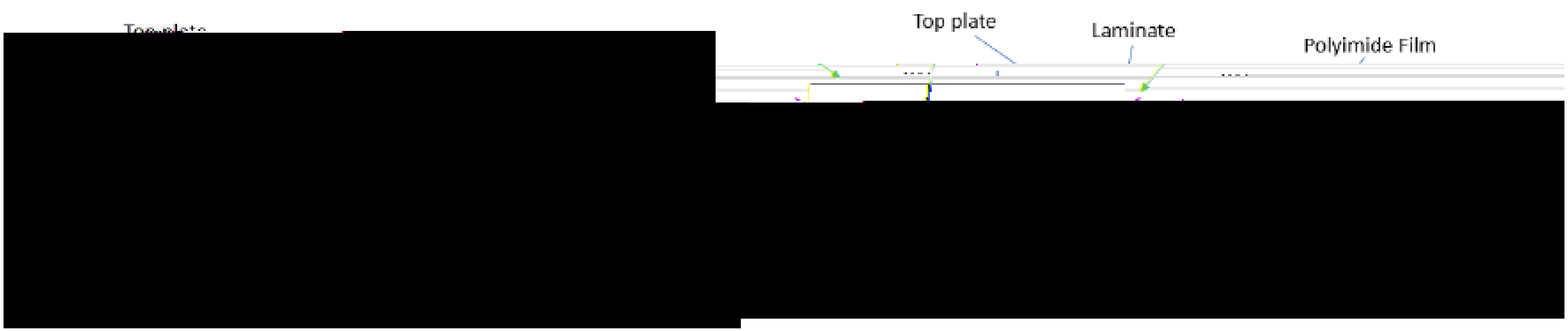


TABLE 3 - Required Molded Laminate Tests for Mechanical Properties

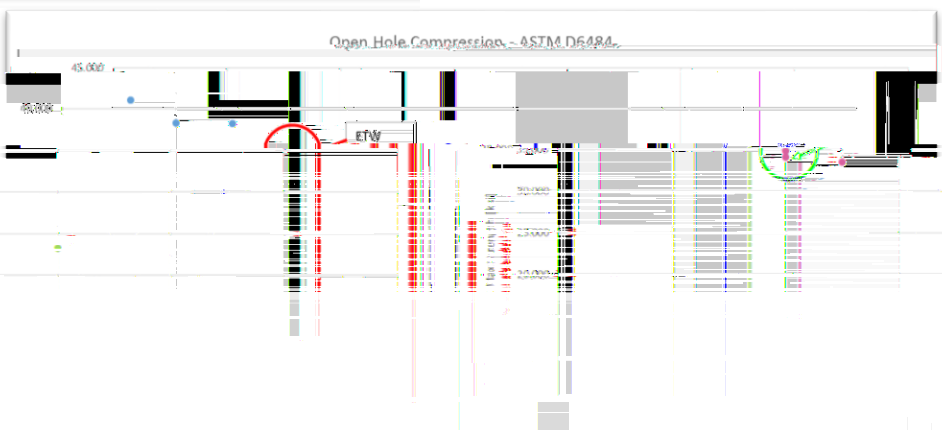
Process Specification (NPS 81225)

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



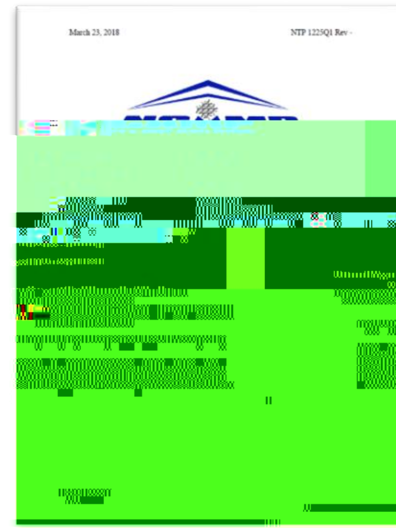


Screening Results Overview



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 -

Physical Test Results

	Specific Gravity (Relative Density)	Fiber Content by Matrix Digestion		Void Content
	ASTM D792-13	ASTM D3171-15 (Test Method I, Procedure B)		

Lamina Test Matrix

Laminate Test Matrix

[redacted]

Overall Observations

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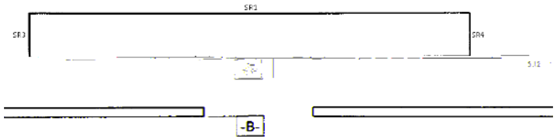
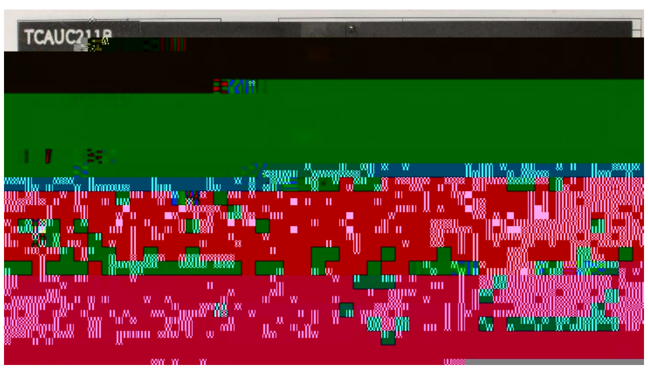
- Flex, SBS, and ILT tests at certain conditions did not exhibit significant load drops and often were not taken to failure offset strengths presented.
- Coefficients of variation are well within typical thermoset values (~2-7%).
- Overall batch to batch variation does not appear significant, however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

90° Tension

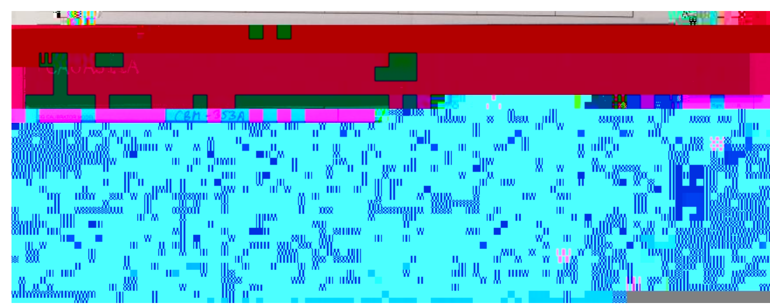
ASTM D3039
TENSILE PROPERTIES OF POLYMER MATRIX COMPOSITE MATERIALS



	Tensile Strength [ksi]		Modulus [Msi]	
	Mean	CV	Mean	CV



Post Test: -65F/A

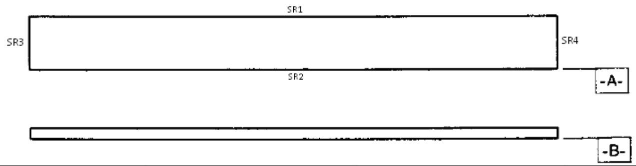


Post Test: RTA

In-Plane Shear

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

$[+45/-45]_{4s}$



	0.2% Offset Strength [ksi]		Strength @ 5% Strain [ksi]		Ultimate Strength [ksi]		Shear Modulus [Msi]	
	Mean	CV	Mean	CV	Mean	CV	Mean	CV

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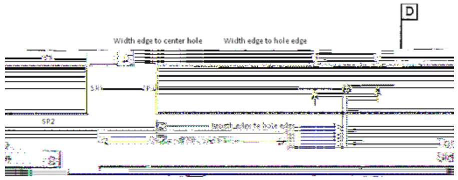
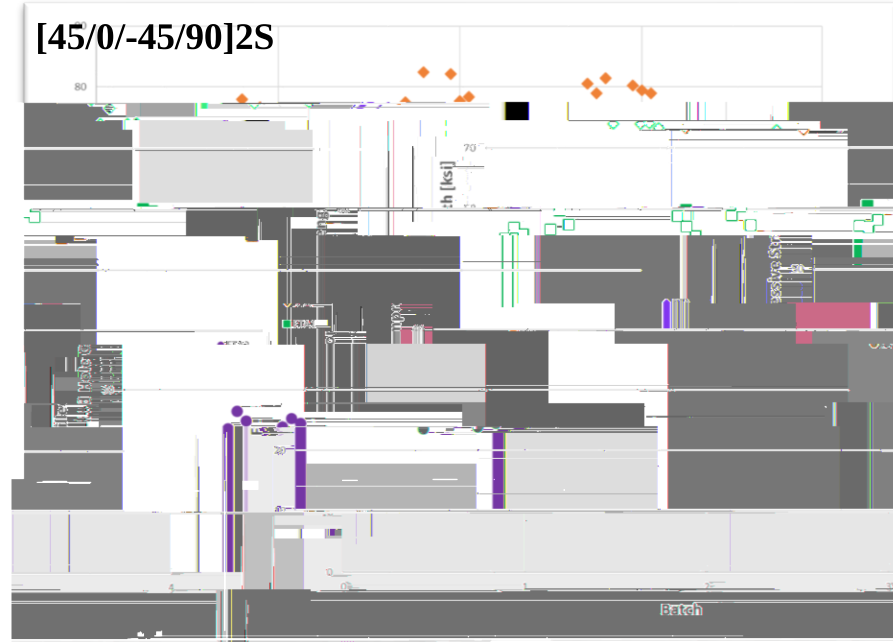
Filled Hole Tension (25/50/25)

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

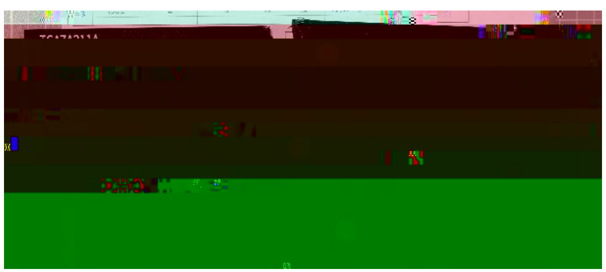
Filled Hole Compression (25/50/25)

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





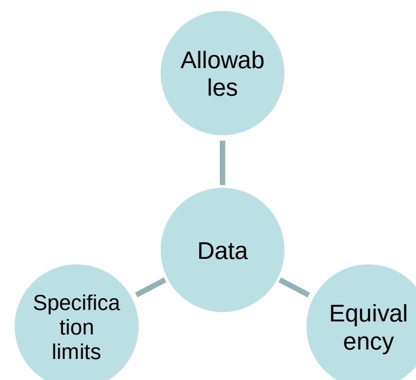
	FHC Strength [ksi]	
	Mean	CV



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

	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	

Looking Forward…

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- 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