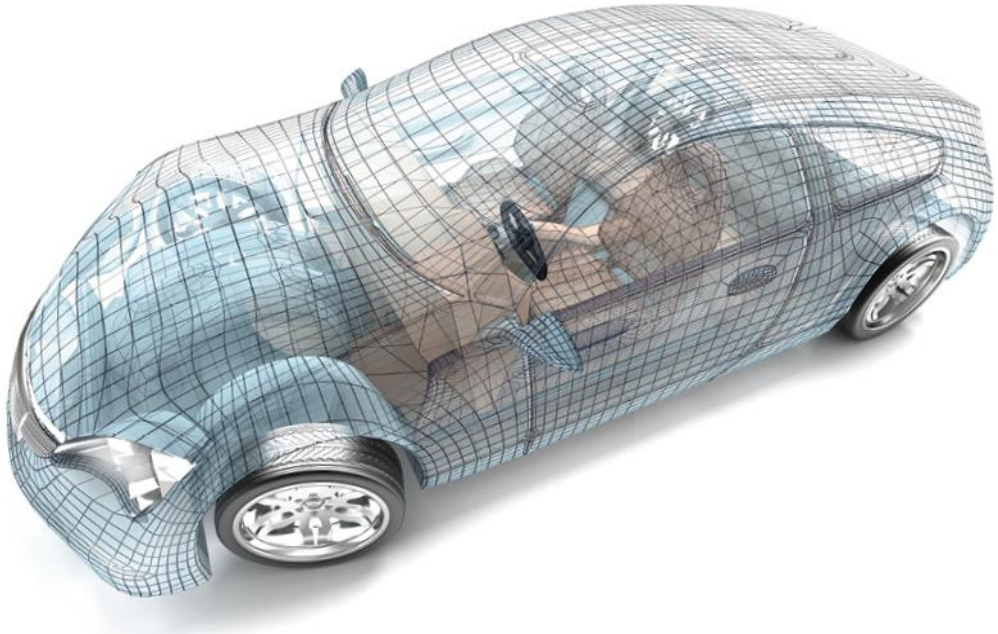
TCC 2020
THERMOPLASTIC COMPOSITES CONFERENCE

A VIRTUAL EVENT
APRIL 29 – MAY 1, 2020



Baseline and Long-term Properties of Continuous Fiber Reinforced Thermoplastic Composites

Presented By: **David Erb**, B. Abdel-Magid, A. Moran, R. Lopez-Anido
Senior Research & Development Program Manager
Advanced Structures and Composites Center, University of Maine

Scope of the Project

- Researchers have indicated that the properties of CFRTP composites are comparable to those of reinforced thermoset composites.
- Target industries of this study are automotive and infrastructure, therefore CFRTP materials in the low to medium range in cost and properties are selected.
- Establish a database of baseline tensile, compression, flexure, shear, impact and thermo-mechanical properties of these materials for the target industries.
- Investigate the long-term viability of these materials in various applications environments.

Objectives

- Compare the baseline mechanical properties of the selected CFRTP with properties after exposure to UV, moisture, and thermal cycling.
- Use baseline properties in finite element analysis and design.
- Use the long-term properties after exposure in durability analysis and design.
- Determine fire resistance properties in terms of flame, smoke, and toxicity to be used in materials selection.
- Testing of long-term properties is still in progress and complete results are not available to present here today.
- Preliminary results of processing parameters, fabrication, and baseline data will be presented.

Outline

- Testing program
- Material Selection
- Matrix and fiber materials
- Determination of Processing Parameters
- Fabrication of Samples
- Baseline properties
- Summary and Concluding Remarks

TESTING

Sample	Tests	ASTM Standards	Post Environmental Conditioning
Control	Tensile Properties (L, T Q)	ASTM 3039	Repeat
	Flexure Properties (L, Q)	ASTM D790 or D6272	Repeat
	In-Plane Shear ±45	ASTM D3518	Repeat
	Short-Beam Shear (L, Q)	ASTM D2344	Repeat
	Izod Impact (L, Q)	ASTM D256	Repeat
	DMA for T_g and change in moduli	ASTM D7028	
Environmental Conditioning	UV	ASTM G154	
	Moisture	ASTM D5229	
	Thermal Cycling	?	
	Abrasion	ASTM D3702 ?	
FST	Flame	ASTM E162	
	Smoke	ASTM E1354	
	Toxicity	ASTM E1354	
Bonding	Lap Shear Test (composite and aluminum)	ASTM D5868/D7998	Repeat test
Failure Analysis	SEM failure analysis of tested specimens.		

L = Longitudinal properties; T = Transverse Properties; Q = Quasi-isotropic layup

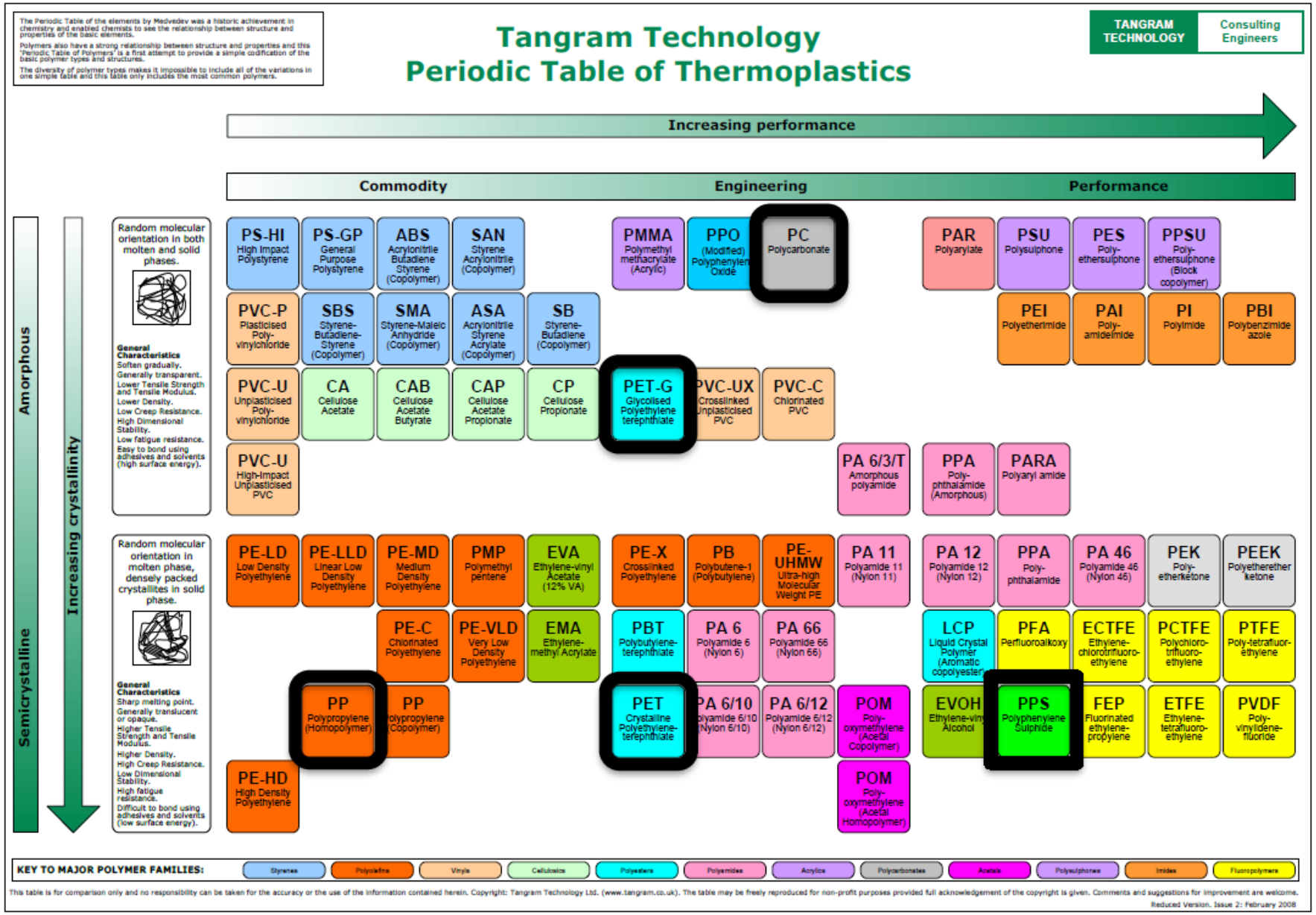
Note: All control tests will be repeated after samples are exposed to UV, moisture, and thermal cycling

Materials Selection

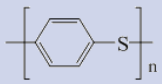
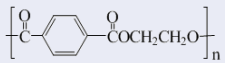
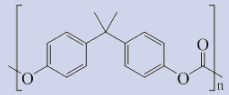
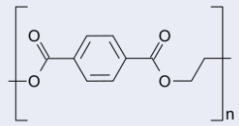
Based on:

- Light weight - Thermoplastic composites materials
- Sound mechanical properties – Continuously reinforced thermoplastics
- Moisture resistance – minimum or no moisture absorption/damage
- UV resistance – chemically stable matrix
- Thermal cycling – good fiber/matrix interface
- FST – fiber/matrix with good fire performance, safe and nontoxic smoke
- Cost – Mid-range of engineered thermoplastics

Matrix Material Selection



Matrix Materials

Polymer	Structure	A/C	Chemical Stability	Upper Use Temp.	FST
PPS		Semi-Crystalline	Very Good	200 °C	Very Good
PET		Semi-Crystalline	Good	150 °C	Combustible, clean smoke
PC		Amorphous	Fair	135 °C	Good w/fire retardant
PETG		Amorphous	Good	150 °C	Good fire resistance
PP		Semi-Crystalline	Fair	85 °C	Good w/fire retardant

Thermoplastic Tape Fiber/Matrix

Celanese Materials

CF/PPS; GF/PPS; GF/PET

PolyOne Materials

GF/PC; GF/PETG; GF/PP (FR)

Manufacturer's Properties

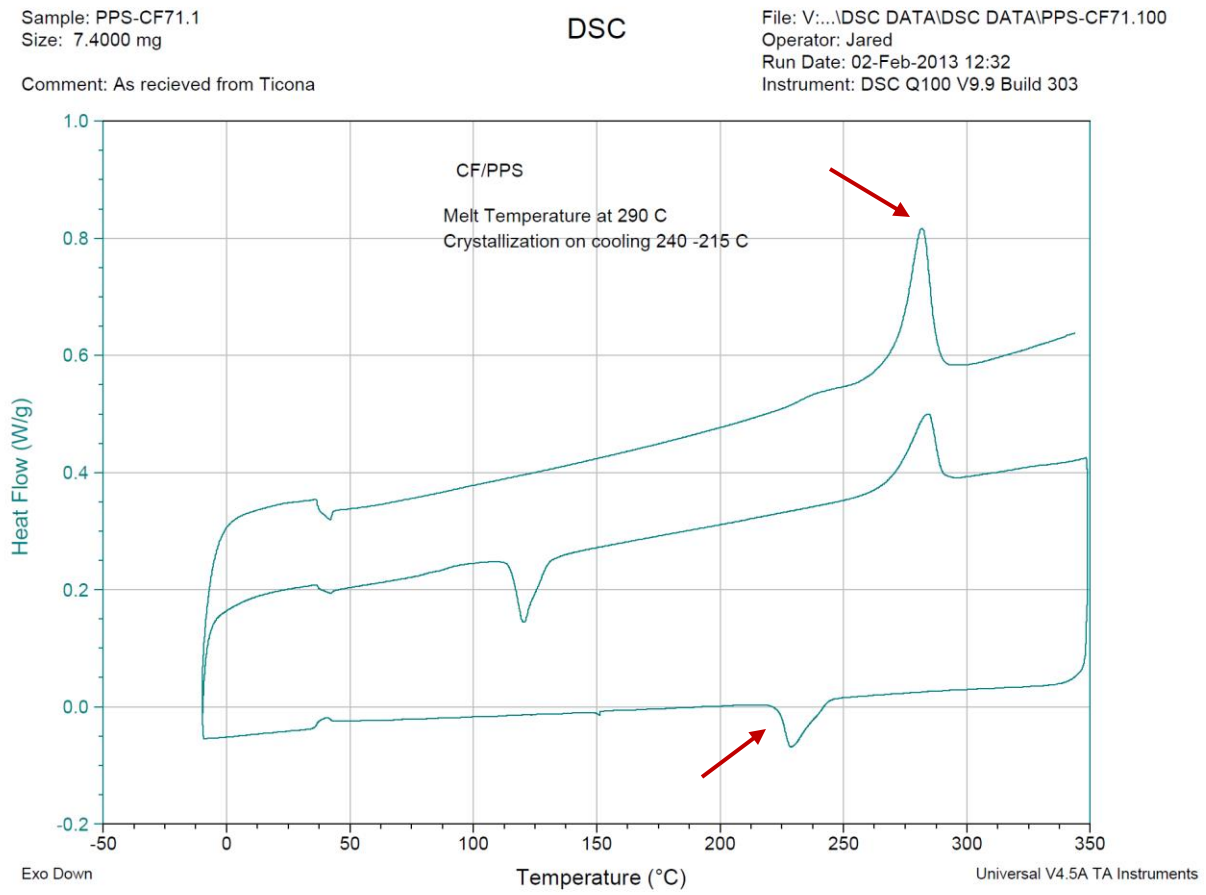
Material	Celanese			PolyOne		
Property	CF/PPS	GF/PPS	GF/PET	GF/PC*	GF/PETG	GF/PP*$_{(FR)}$
Fiber content wt.%	60	60	60	58	58	60
Tensile Strength 0°(MPa)	2030	782	688	TBD	571	TBD
Tensile Modulus 0°(GPa)	101	34.7	30.1	TBD	28.5	TBD
Tensile Strain at Failure 0° (%)	1.79	2.41	2.46	TBD	TBD	TBD
Flexure Strength 0°(MPa)	1220	866	759	TBD	602	TBD
Flexure Modulus 0°(GPa)	105	37.5	34.3	TBD	29	TBD
Flexure Strain at Failure 0° (%)	1.2	3.22	2.94	TBD	TBD	TBD
Tg (°C)	90	90	80	TBD	TBD	TBD

* These are experimental materials being developed by the manufacturer and their properties are not established yet. Our lab will be the first to establish these properties.

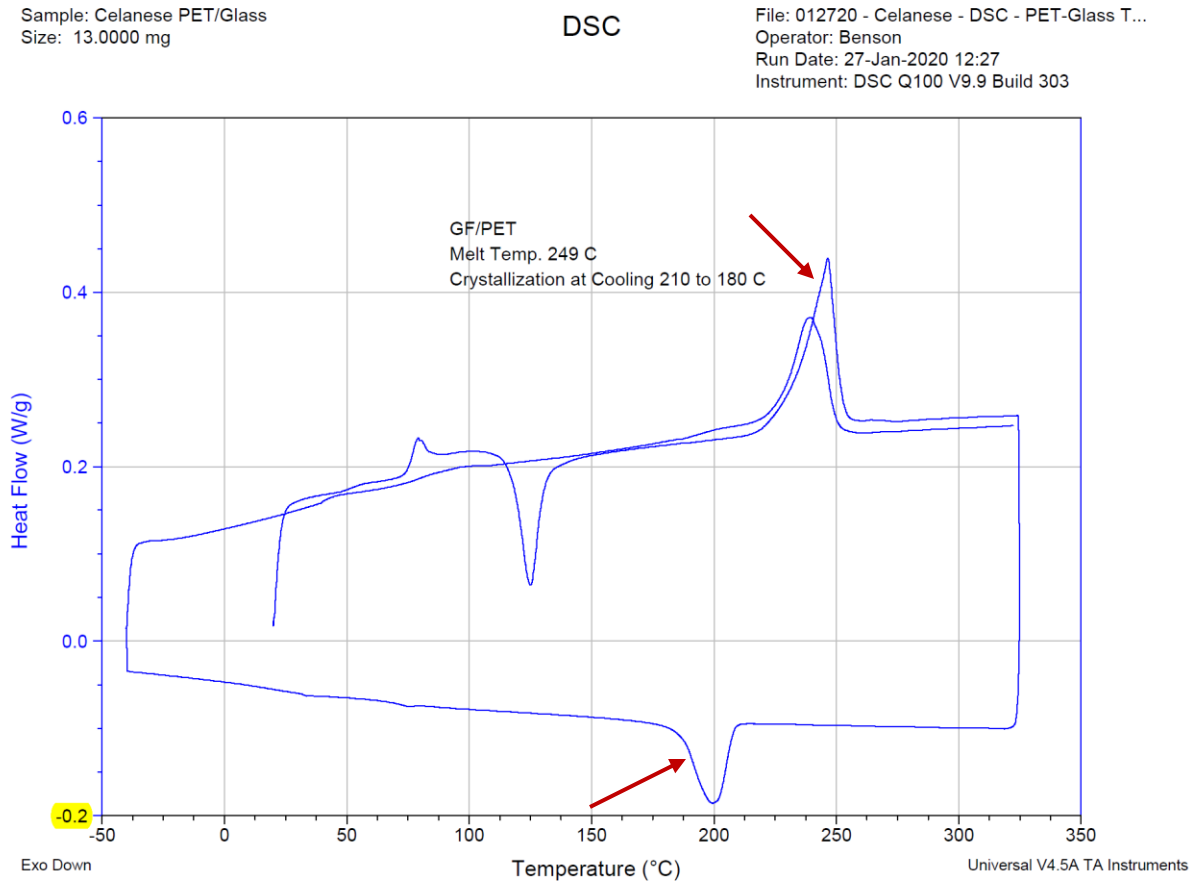
Determination of Processing Parameters

- DSC Tests to determine:
  - Melting Temperature
  - End of crystallinity temperature
- TGA Tests to determine:
  - Onset of degradation temperature
  - Degradation temperature
  - Fiber/matrix and filler contents

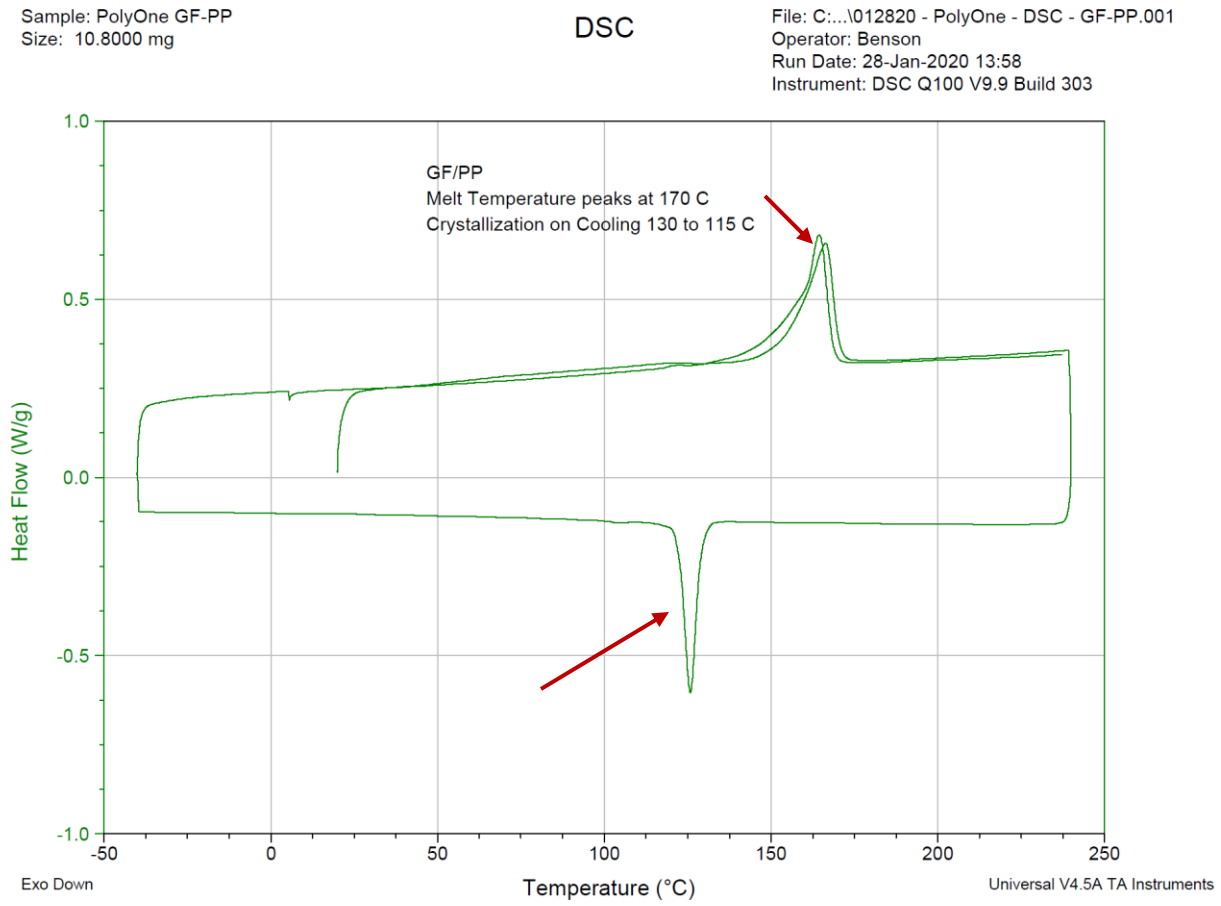
CF/PPS Processing Parameters



GF/PET Processing Parameters

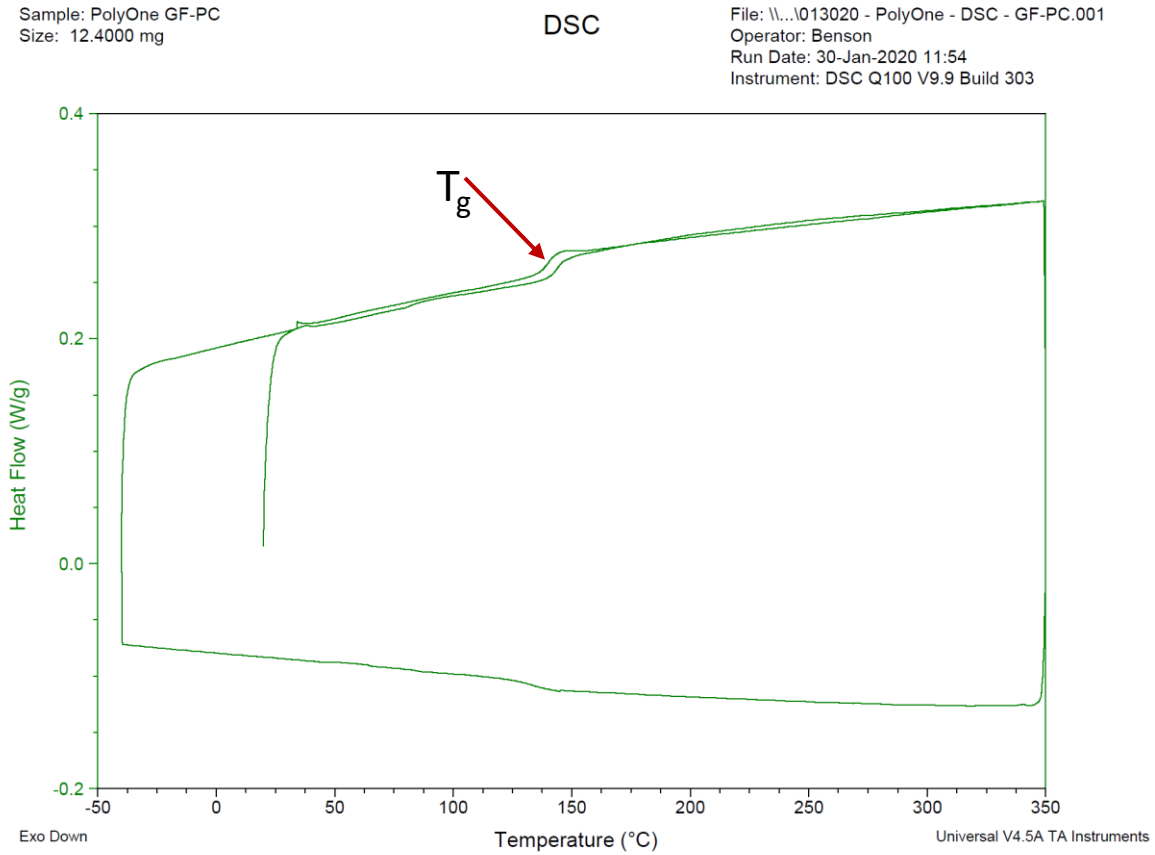


GF/PP Processing Parameters

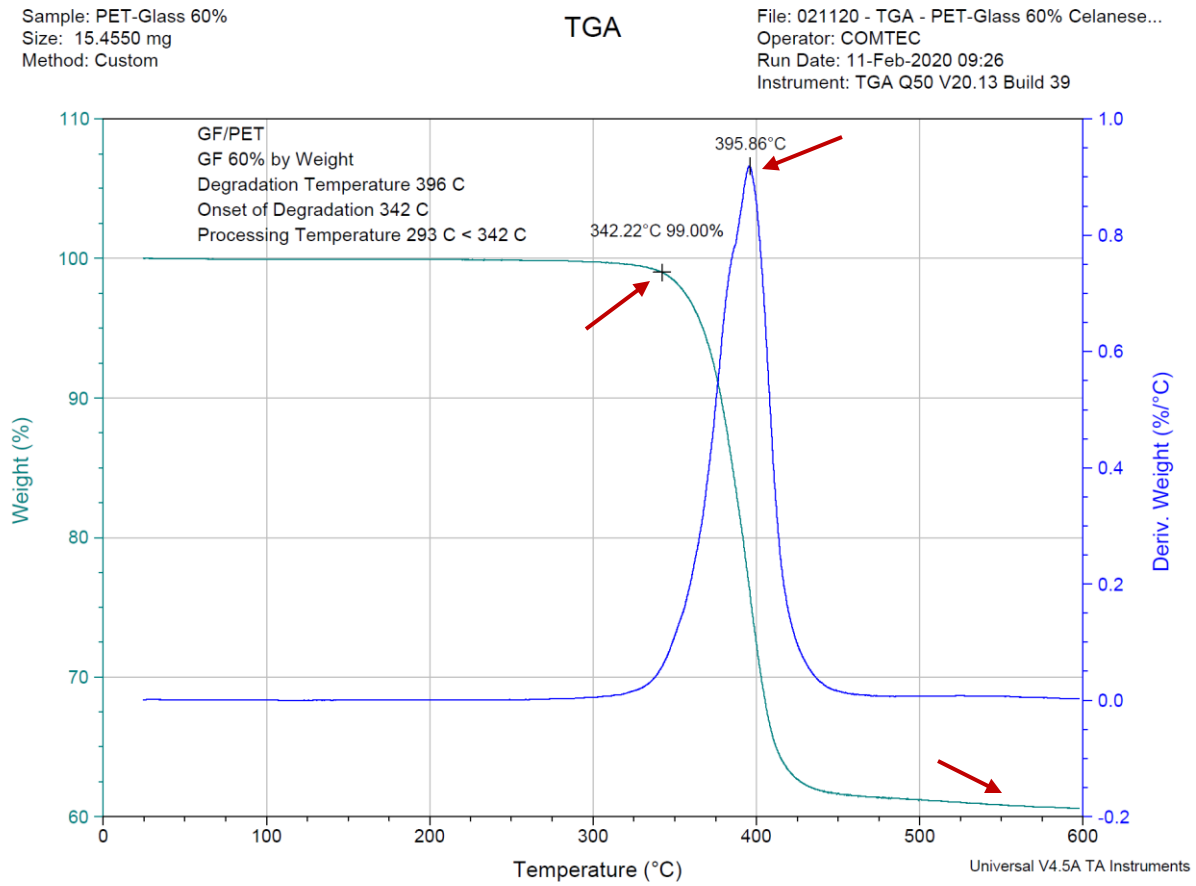


GF/PC Processing Parameters

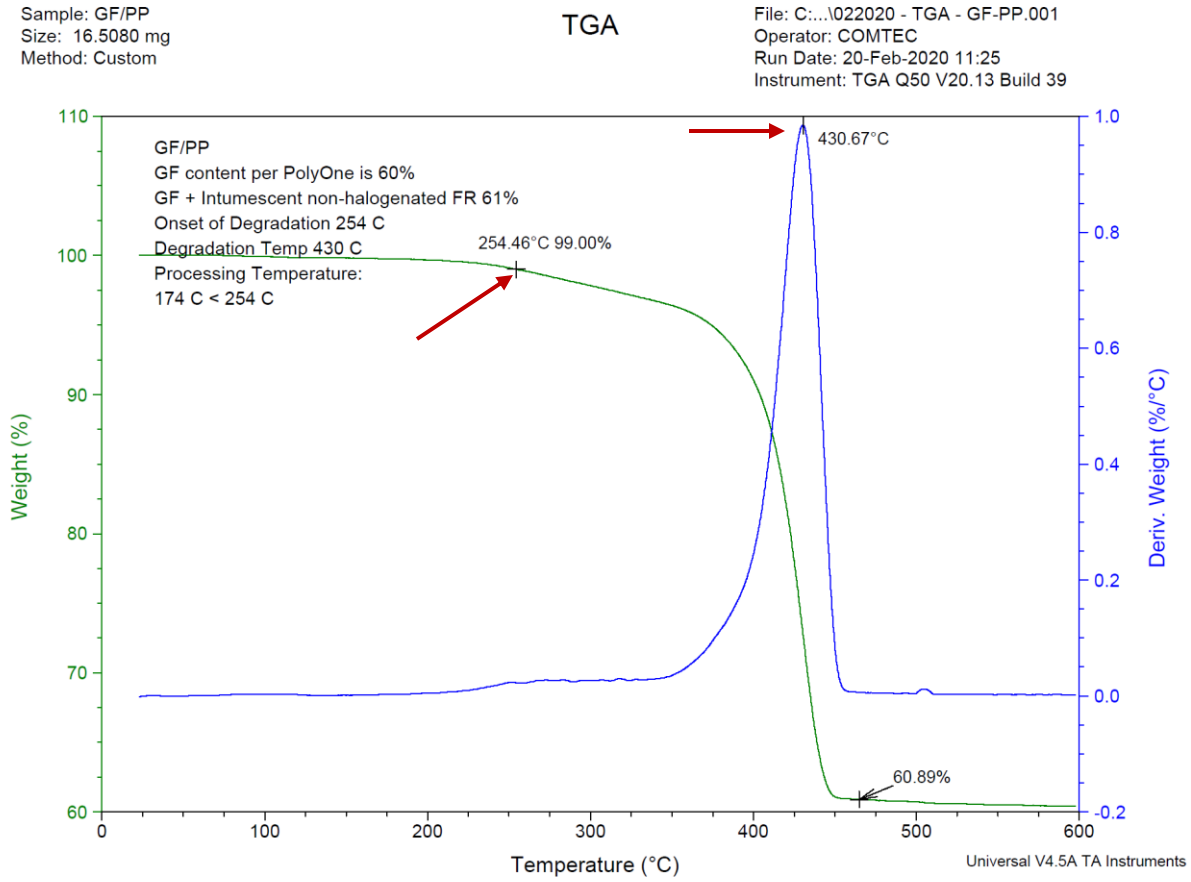
Amorphous material: no defined melting temperature (T_m) and crystallization temperature (T_c).



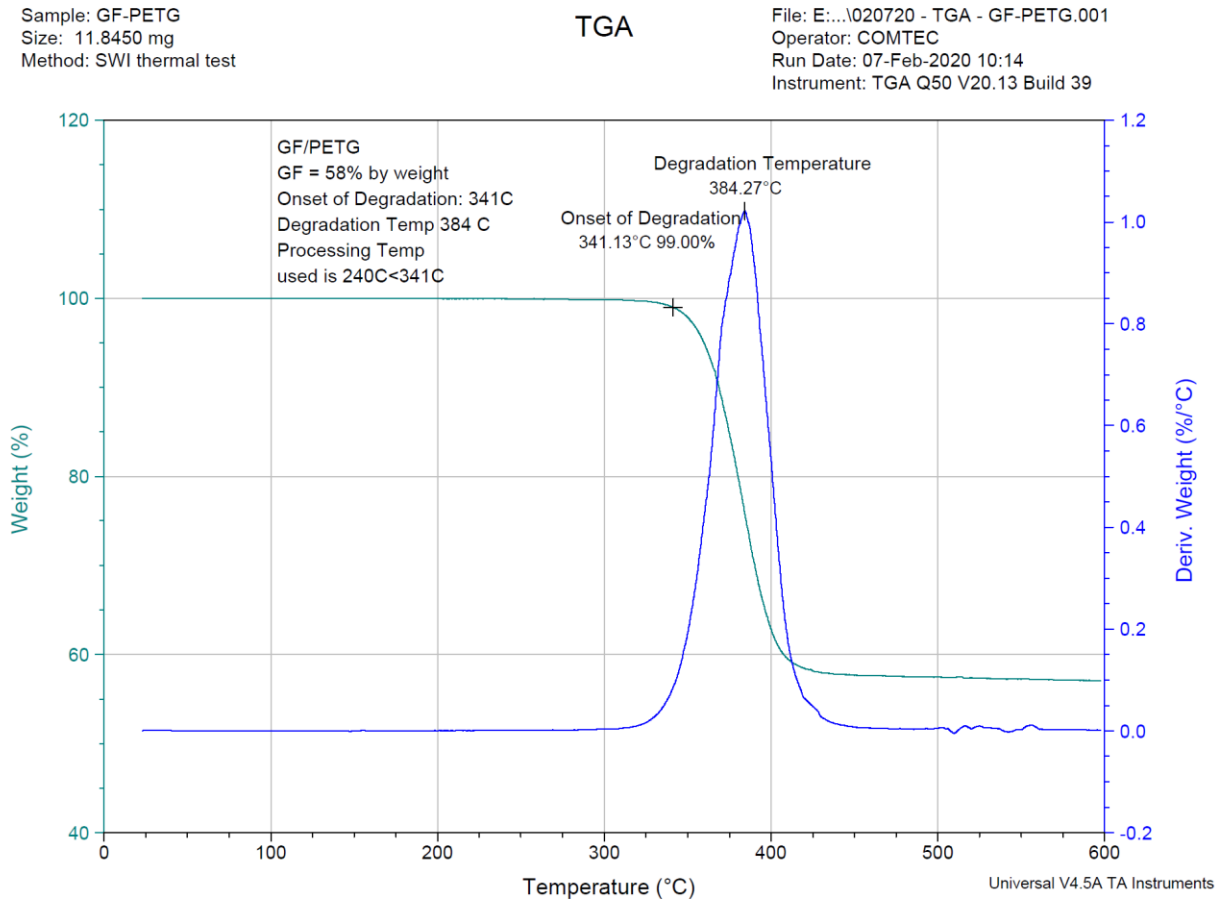
GF/PET Fiber Content and Processing Temp.



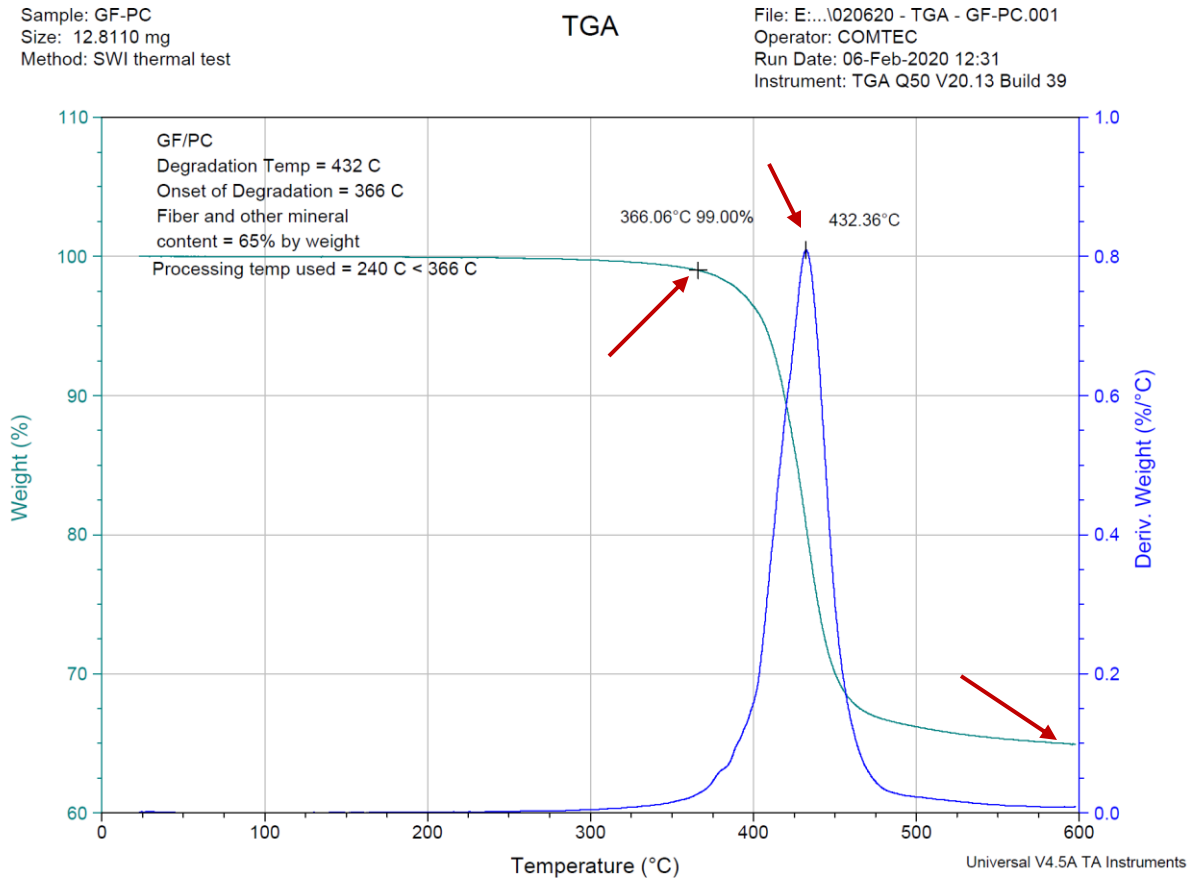
GF/PP Fiber Content and Processing Temp.



GF/PETG Fiber Content and Processing Temp.



GF/PC Fiber Content and Processing Temp.



Processing Parameters Temp, Pressure, Time

Company	Material	Set Temperature °C (°F)	Pressure kPa (psi)	Dwell Time (Minutes)	Cooling rate °C/min	Removal Temp. °C (°F)	Drying Time** (Hours)	Drying Temp °C (°F)
Celanese	CF/PPS	340 (645)	580 (84)	5	5 (9 ˚F)	135 (275)	0	0
	GF/PPS	340 (645)	580 (84)	5	5 (9 ˚F)	135 (275)	0	0
	GF/PET	290 (555)	580 (84)	2	5 (9 ˚F)	65 (150)	4	93 (200)
PolyOne	GF/PC	240 (465)	193 (28)	3	15 (27 ˚F)	37 (100)	4	82 (180)
	GF/PETG	240 (465)	193 (28)	2	15 (27 ˚F)	37 (100)	4	121(250)
	GF/PP	174 (345)	193 (28)	2	5 (9 ˚F)	52 (125)	0	0

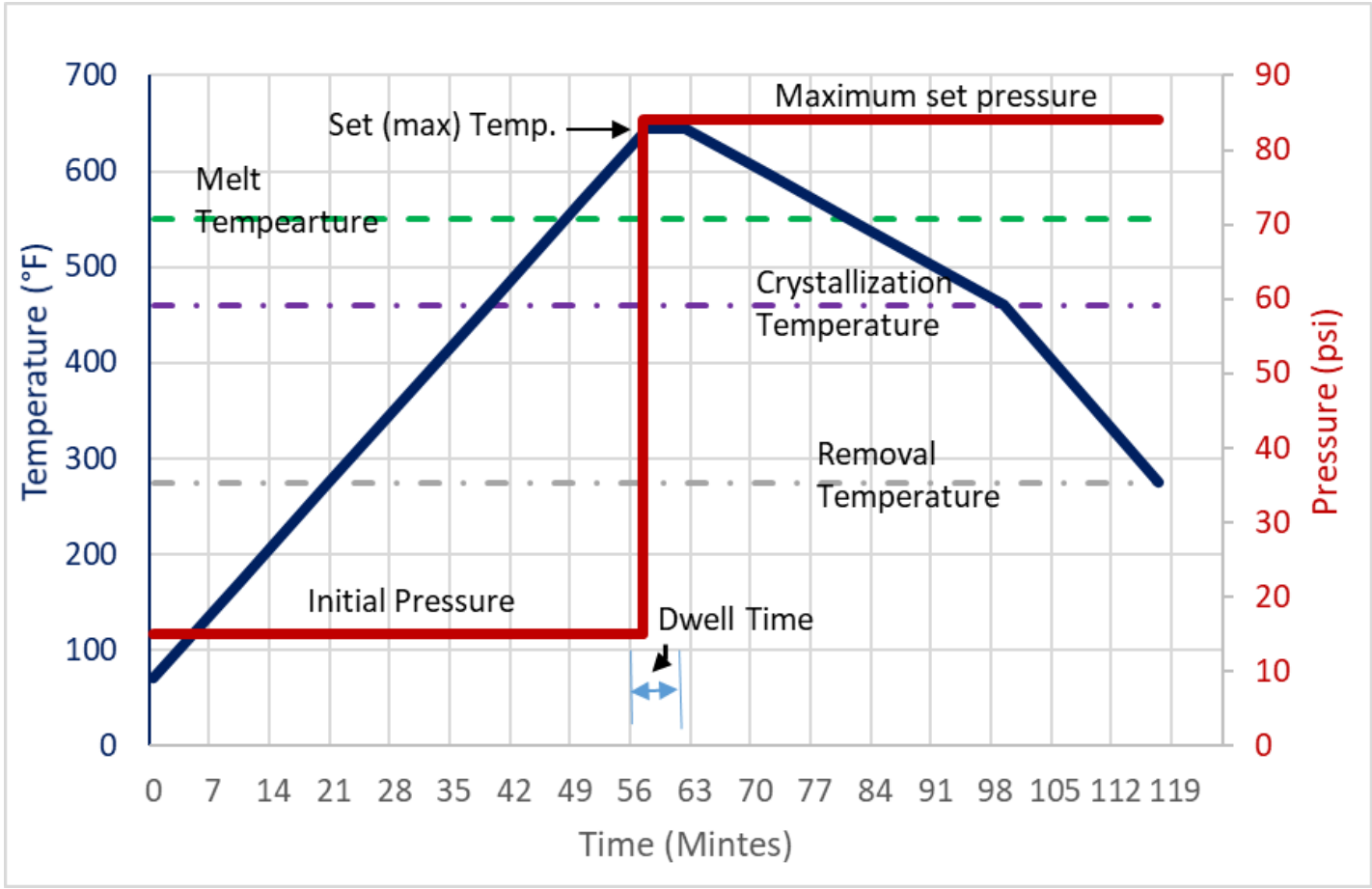
*Use a cooling rate of 5 °C/minute between set temperature and end of crystallization temp.

** Materials that should be dried immediately after removal from the mold

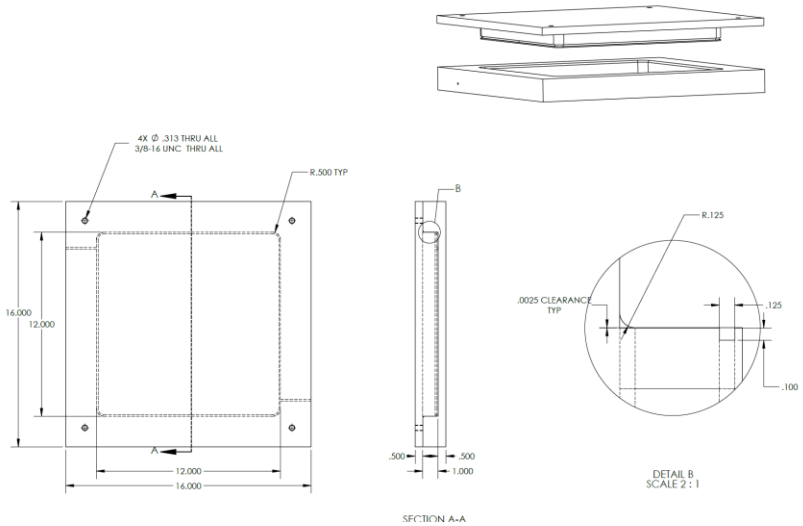
Processing Parameters Temp, Pressure, Time

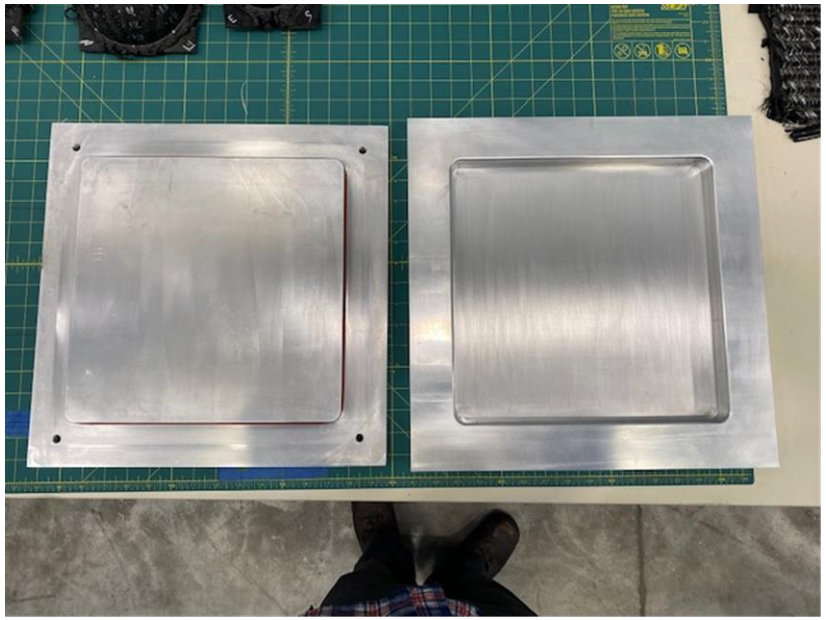
Material	Initial Pressure (psi)	Tg °C (°F)	Set Temperature °C (°F)	Set Pressure (psi)	Dwell Time (Minutes)	Crystalln. Temp °C (°F)	Removal Temp. °C (°F)
CF/PPS	15	90 (194)	340 (645)	84	5	210 (410)	135 (275)
GF/PPS	15	90 (194)	340 (645)	84	5	210 (410)	135 (275)
GF/PET	15	80 (176)	290 (555)	84	2	160 (320)	65 (150)
GF/PC	15	150 (302)	240 (465)	28	3	-	37 (100)
GF/PETG	15	90 (194)	240(465)	28	2	-	37 (100)
GF/PP	15	130 (266)	174 (345)	28	2	110 (130)	52 (125)

Heating and cooling rates, pressure, dwell time, and key temperatures for CF/PPS



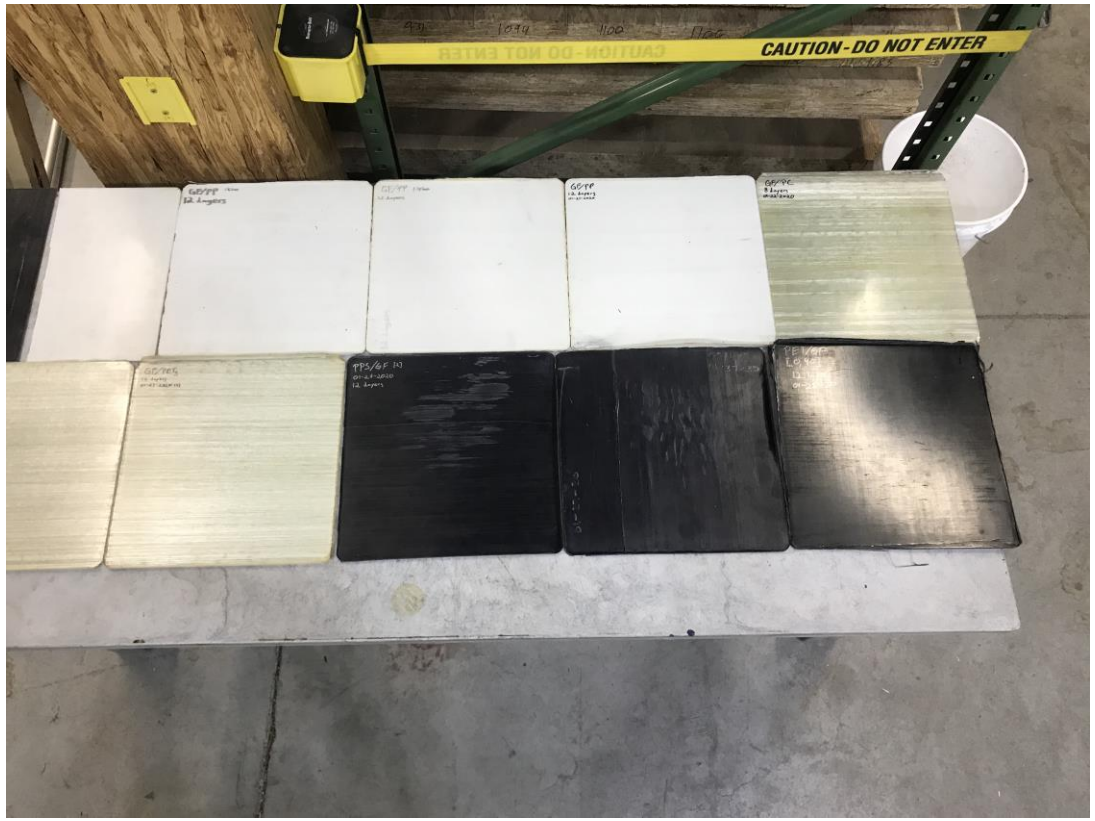
Fabrication of Samples - Mold Design



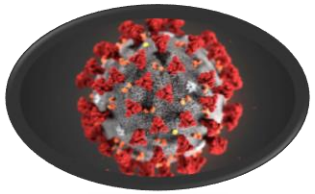


Preparation for Samples Processing

Fabrication and Samples



Enters COVID-19



Summary and Concluding Remarks

- The goal of the study is to determine the long-term properties of continuous fiber reinforced thermoplastic (CFRTP) composites in various environments.
- Materials include CF/PPS, GF/PPS, GF/PET, GF/PC, GF/PETG, and GF/PP
- Differential scanning calorimetry (DSC) and thermogravimetric analysis (TGA) were performed to obtain baseline thermo-mechanical properties.
- These properties were also used to determine the processing temperatures of the materials and to verify the manufacturer's recommendations.

Summary and Concluding Remarks ..

- Samples are being fabricated and an extensive testing program is underway to determine the baseline mechanical properties and long-term properties in various environments.
- The baseline properties will be used to evaluate the degradation of materials in severe environments and will be available to industry for structural analysis, finite element analysis, and design.
- The long-term properties will serve as tools for durability analysis and prediction.
- The flame, smoke and toxicity properties will be used for effective design of materials for fire resistance and safety.
- The results of the experimental study and data generated will be shared with the industry at a following presentation.