Relationship Between 3-D Printed Materials and Flammability

Presented to: Ninth Triennial International Aircraft Fire and Cabin Safety Research Conference
By: Steve Rehn
Date: 10/30/2019

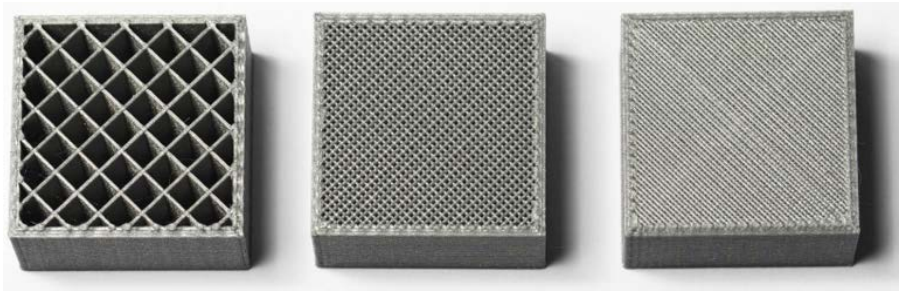
Introduction

- **Aircraft manufacturers have expressed interest in using 3D printed parts in aircraft interiors**
- **3D printing introduces all new variables in material construction**
- **Focused on Fused Deposition Modeling (FDM) which deposits thin extrusions of thermoplastic layer-by-layer into desired shape**

3D Printer at FAA Tech Center

Introduction

- **Variables include:**
  - Printing orientation
  - Layer thickness
  - Raster width
  - Raster angle
  - Infill percentage

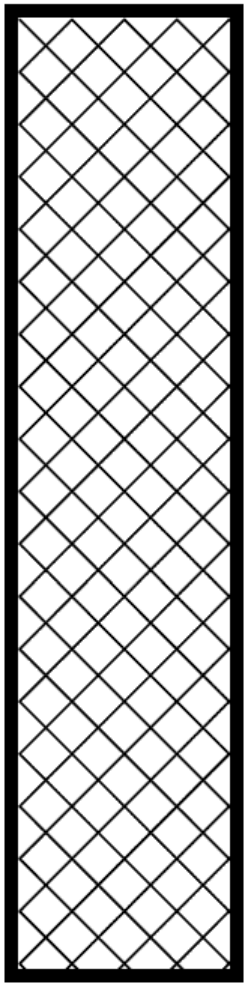


Test Plan

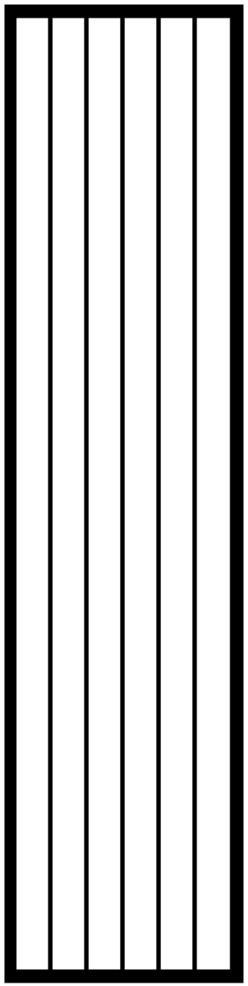
- **Determine worst case scenario for each variable in flammability testing in order to simplify future testing**
- **Vary printing parameters in several different materials and sample thicknesses**
- **Test using vertical Bunsen Burner**
- **Analyze test results to determine how future testing can be simplified and reduced**

Printing Orientations

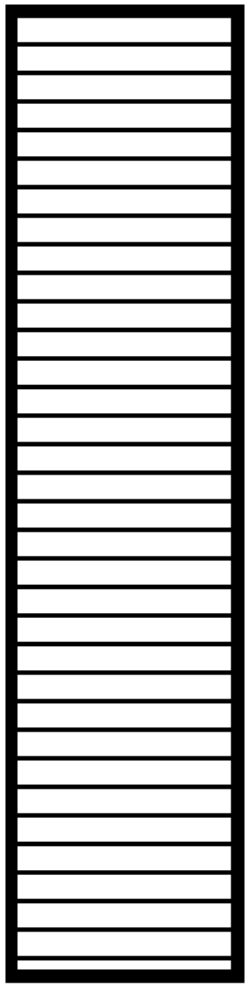
- 3 orientations
- 0.10” slice height
- 0.20” printing width
- 5 materials
- 0.060” sample thickness
  (some 0.10”)



XY-Direction



YZ-Direction

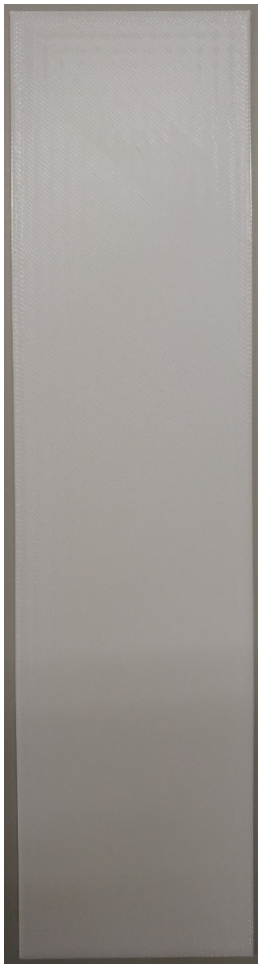


ZX Direction

Five Materials

Ultem 9085 (PEI)

Nylon-12



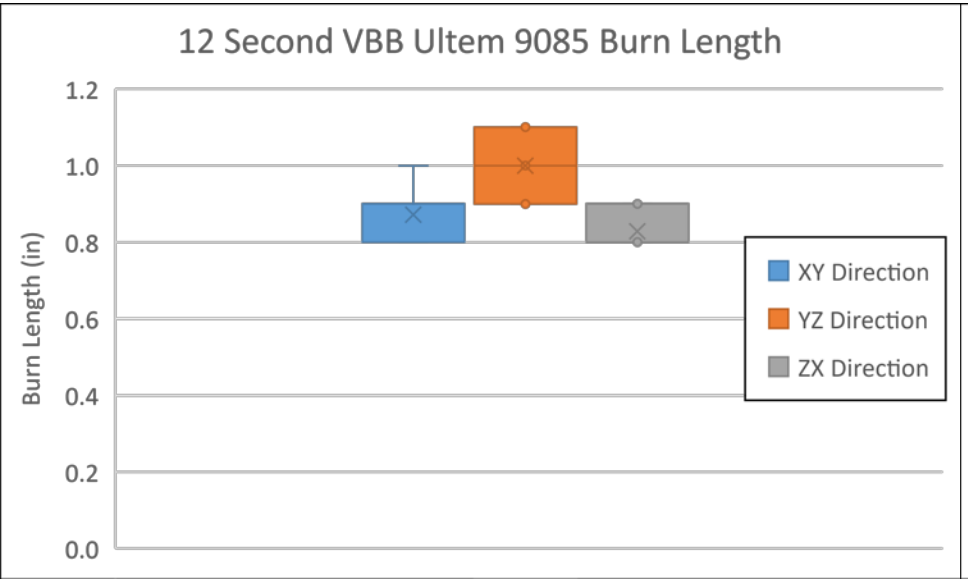
Polycarbonate

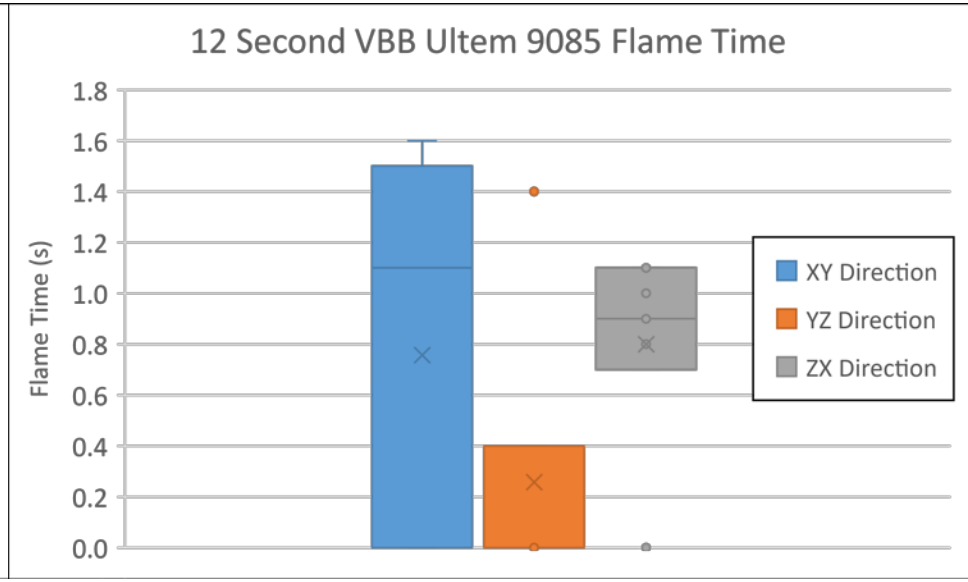
PC-ABS

Ultem Support (PES)

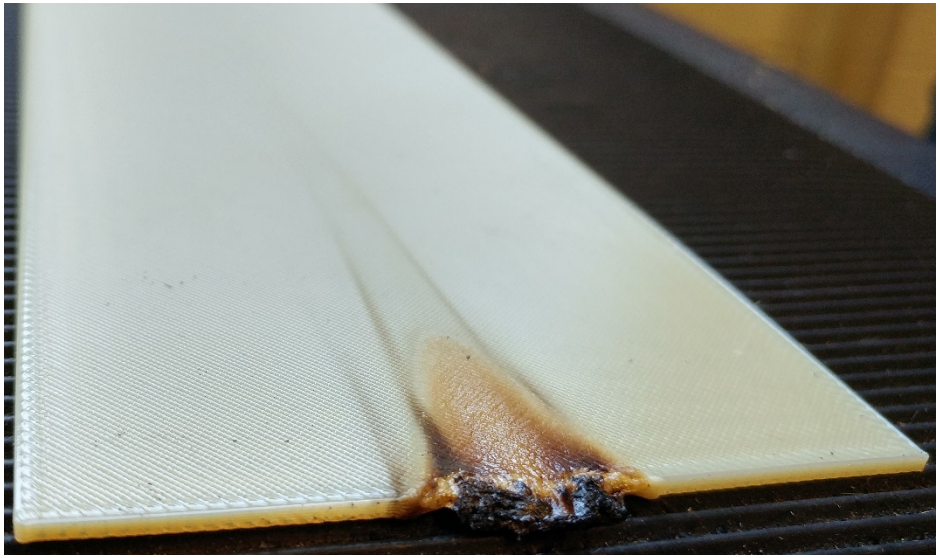
Ultem 9085

- 12-second Vertical Bunsen Burner
- 0.060 inch thick material
- 7 samples per orientation



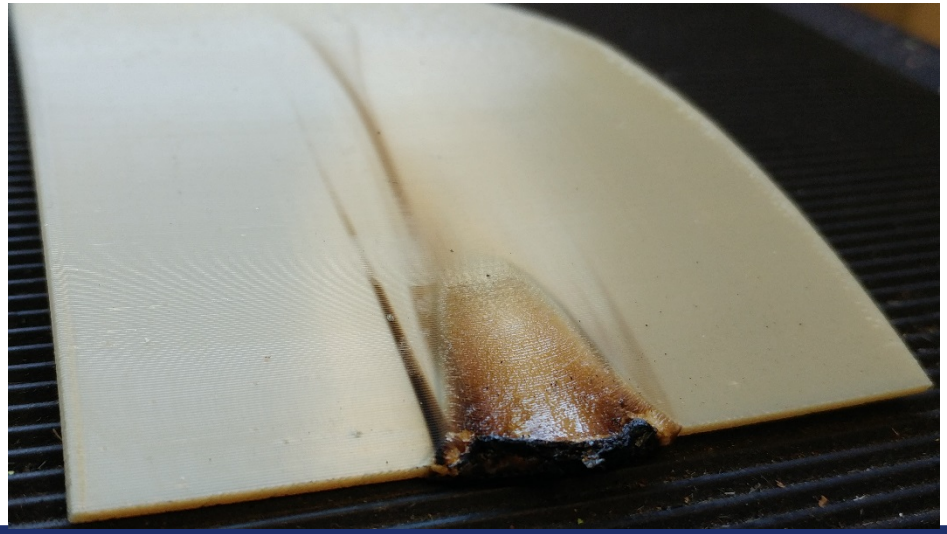


XY-Direction



YZ-Direction

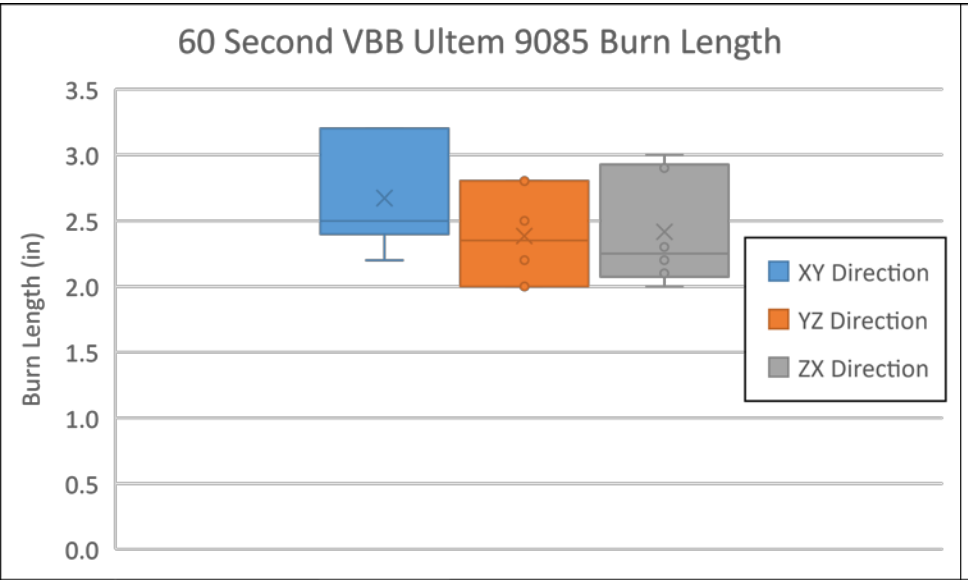
ZX-Direction

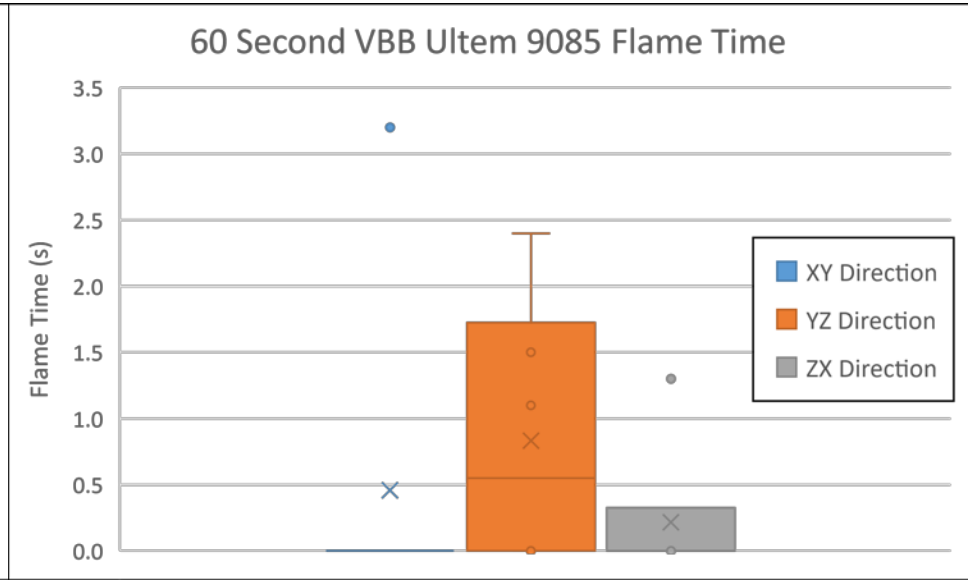


*12-second VBB test

Ultem 9085

- 60-second Vertical Bunsen Burner
- 0.060 inch thick material
- 7 samples per orientation



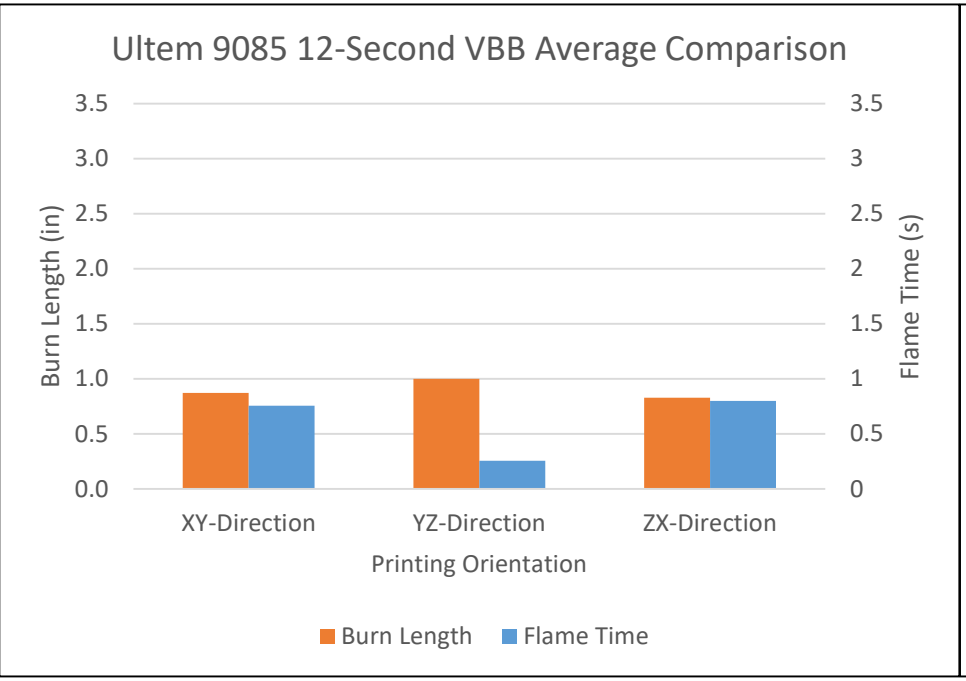


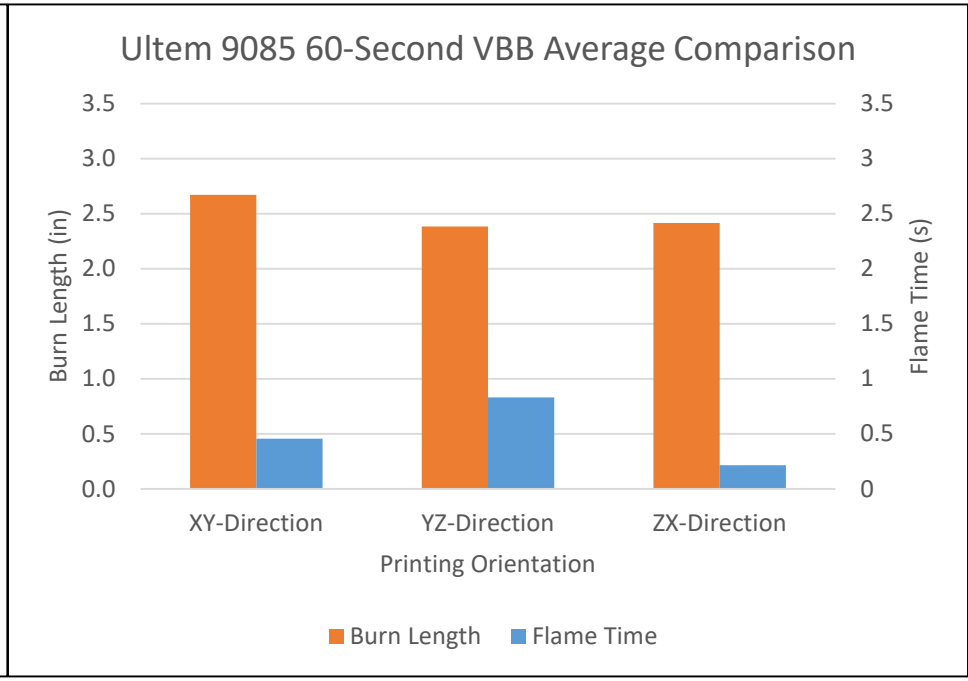
Ultem 9085

- On some 60-second tests, material would melt down to the burner
- Never any flame time when this happened, charred plastic blocked most of the flame
- Flame time seemed to depend on the shape of the material as it melted and where it pushed the Bunsen burner flame

Ultem 9085

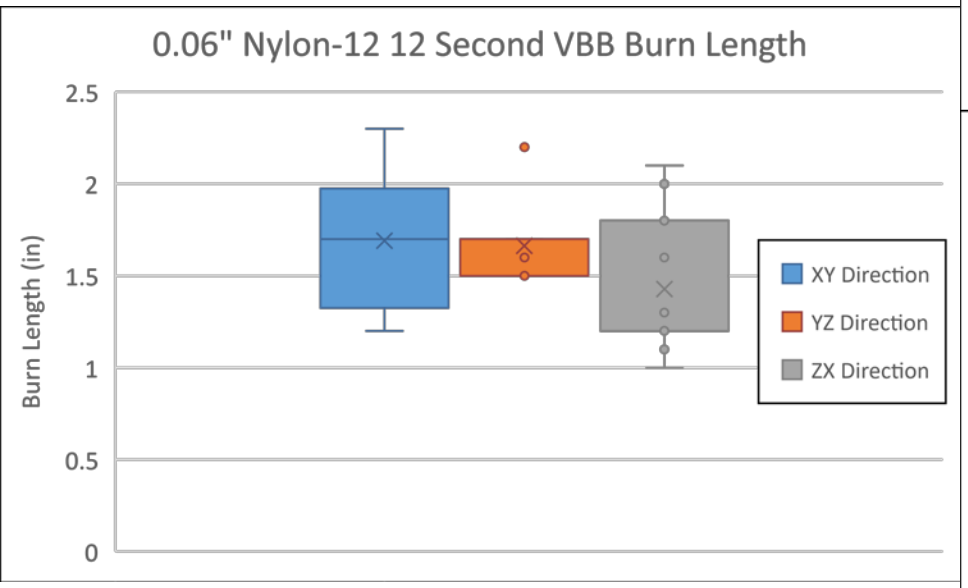
- YZ direction had the lowest flame time in 12-seond test, most in 60-second test
- Overall very little burning on any sample
- Minimal differences in orientations overall

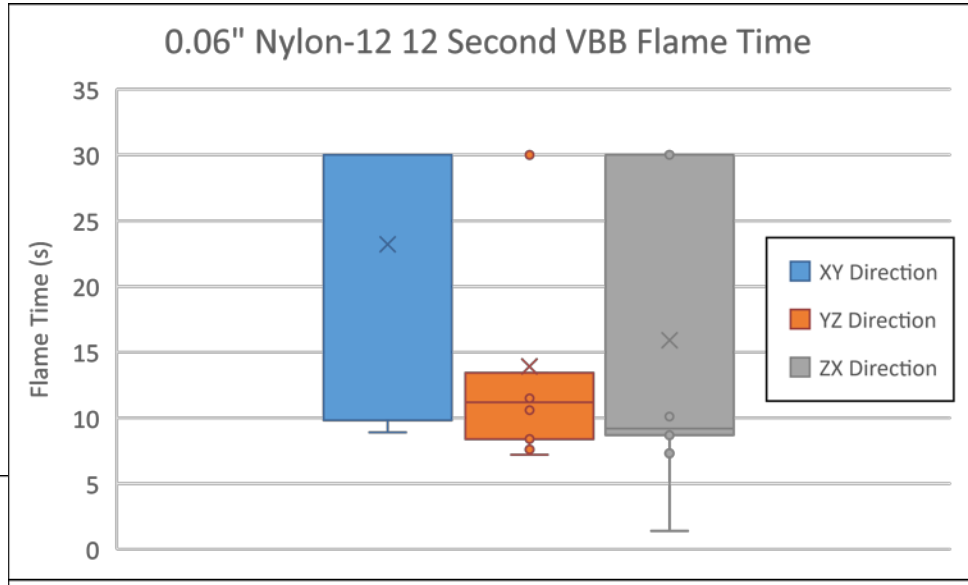


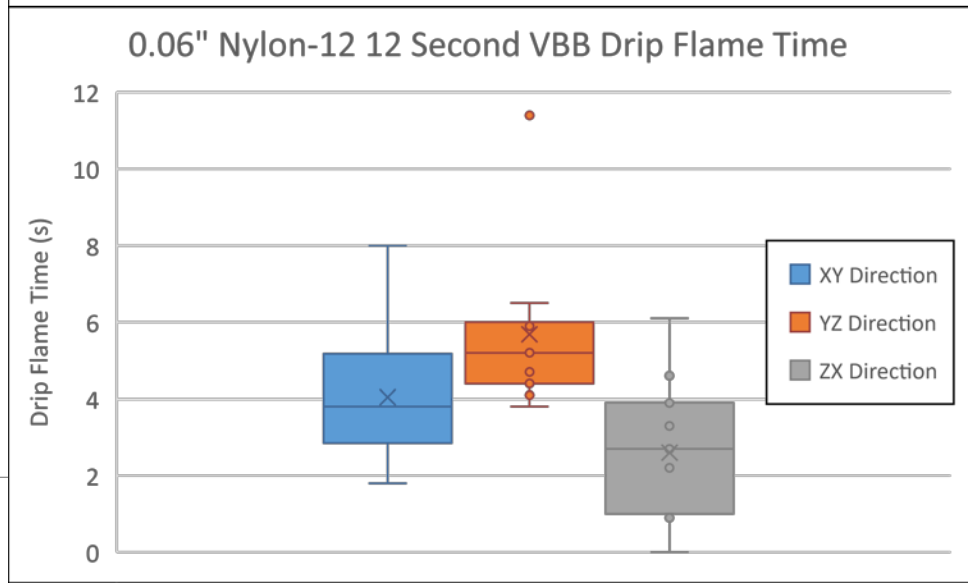


Nylon-12

- 12-Second Vertical Bunsen Burner
- 0.060 inch thick material
- 12 samples per orientation
- *Manually Extinguished after 30 seconds

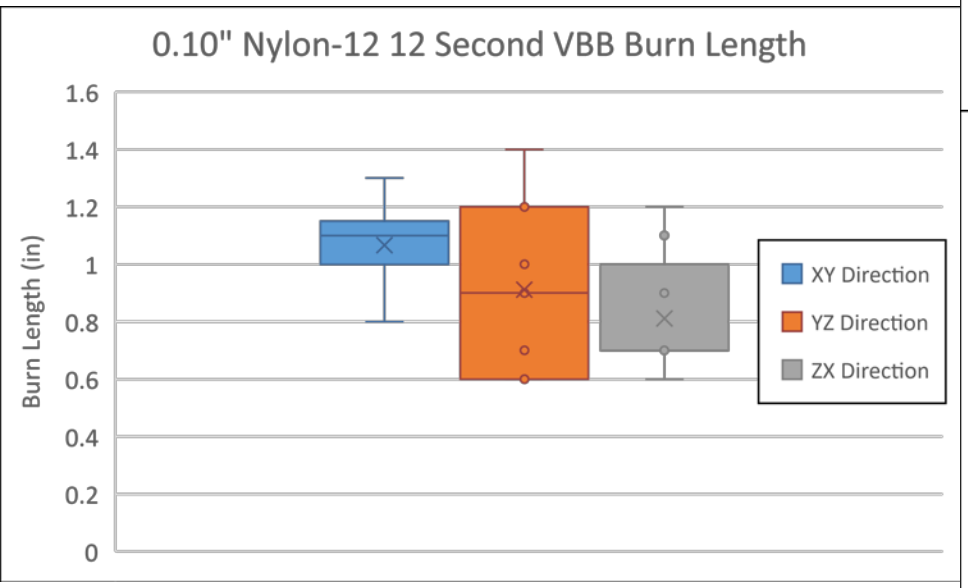


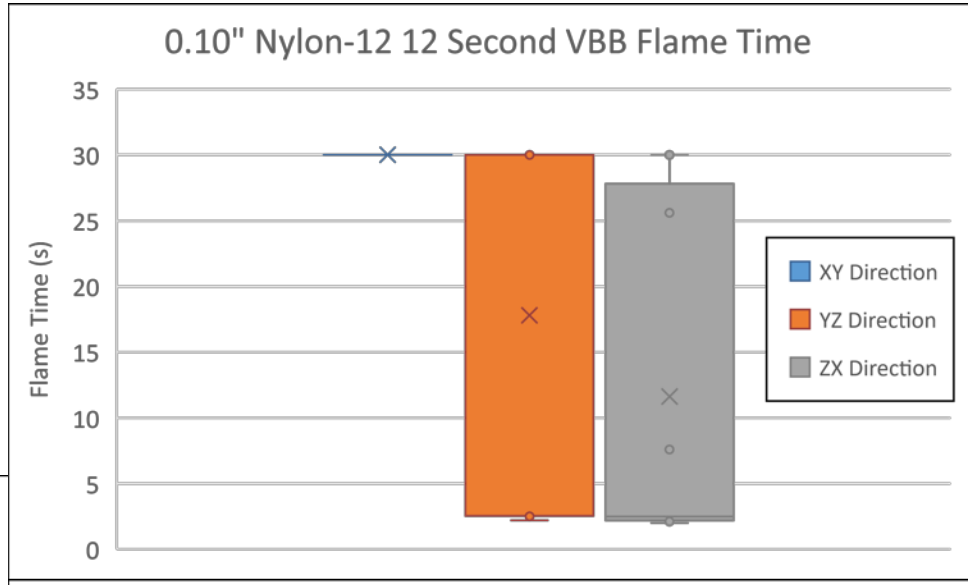


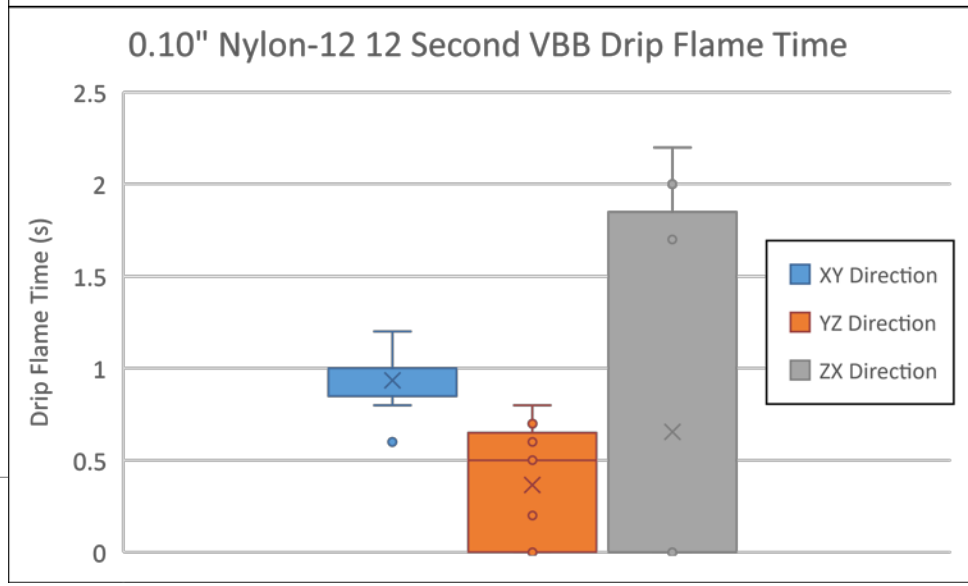


Nylon-12

- 12-Second Vertical Bunsen Burner
- 0.10 inch thick material
- 9 samples per orientation
- *Manually Extinguished after 30 seconds

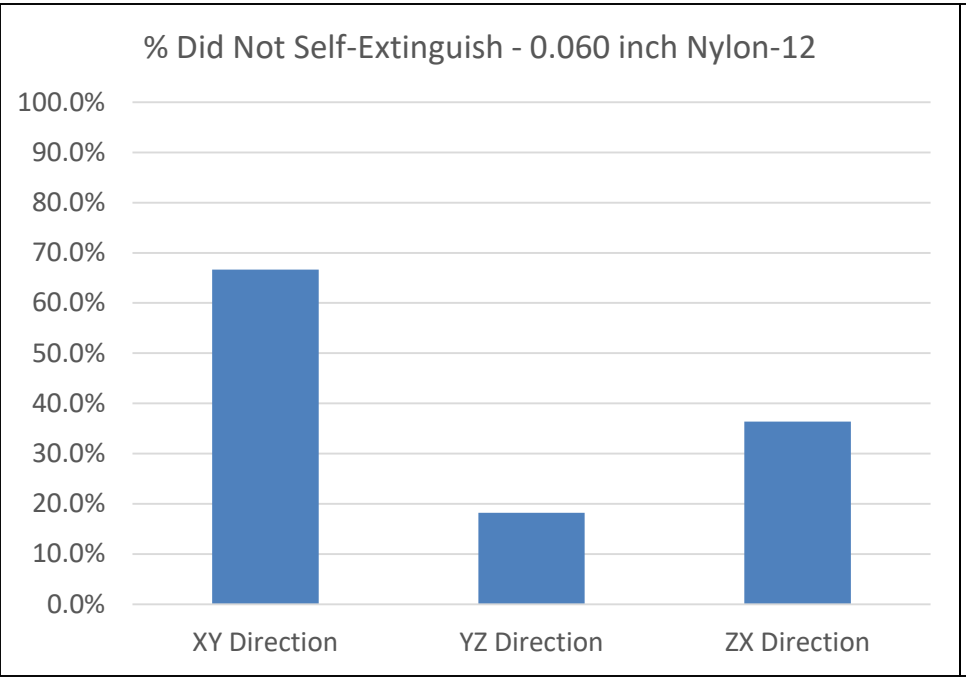


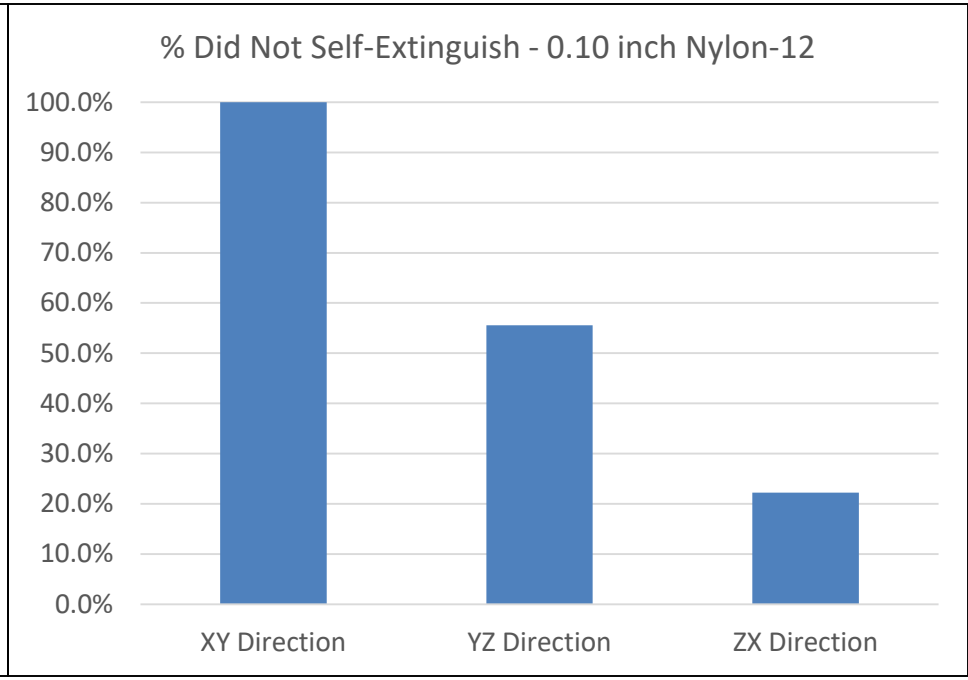




Nylon-12

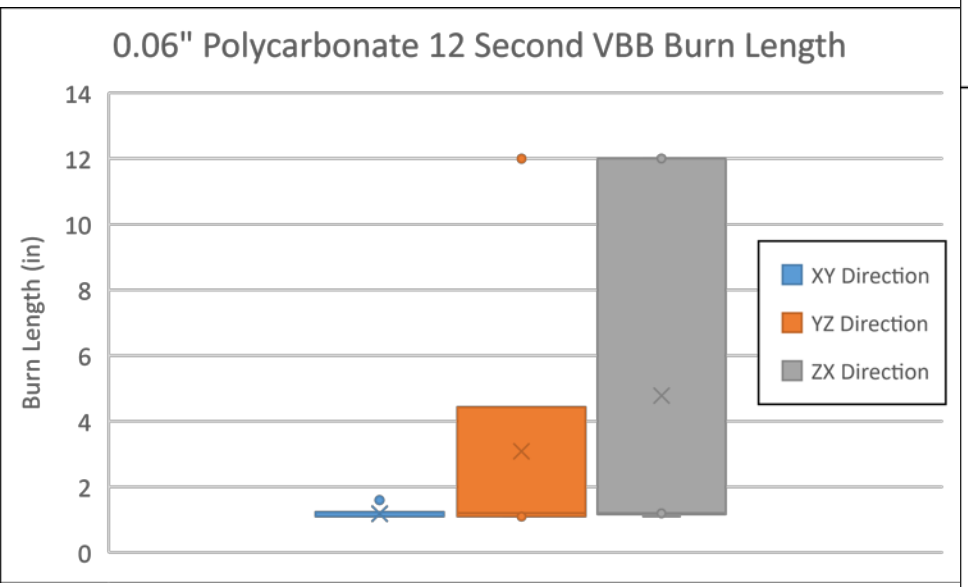
- Graphs show percentage of samples that were manually extinguished
- XY Direction performed worst for both thicknesses

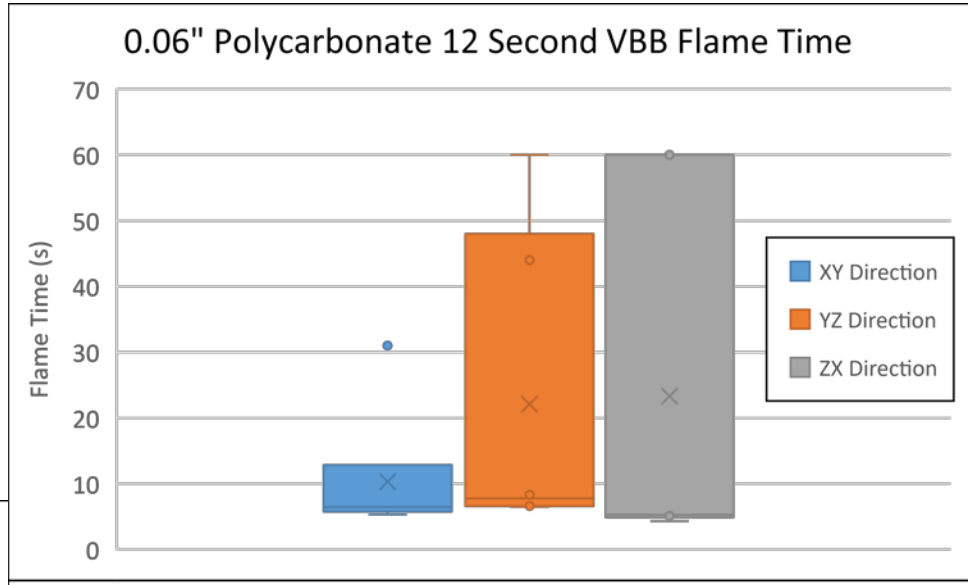


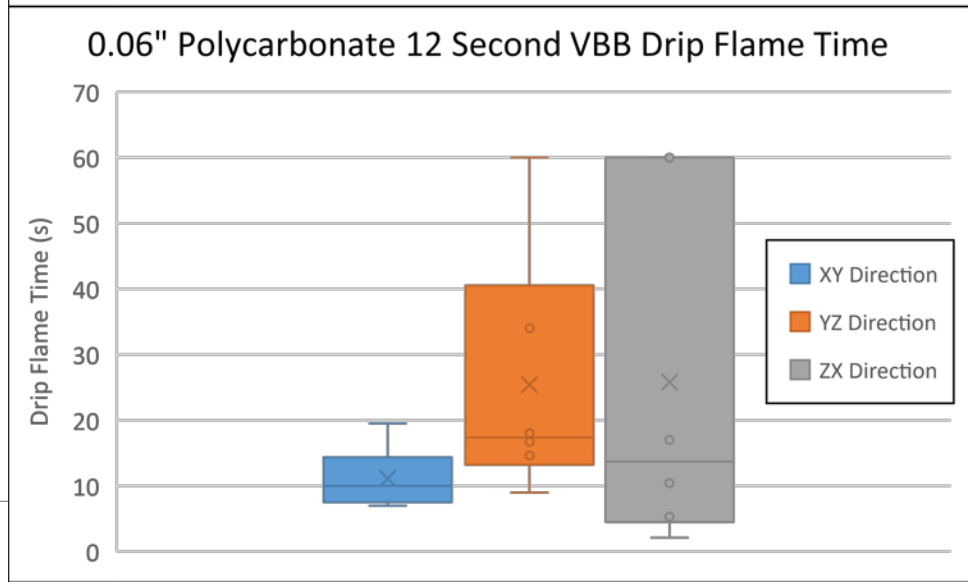


Polycarbonate

- 12-Second Vertical Bunsen Burner
- 0.060 inch thick material
- 6 samples per orientation
- *Manually Extinguished after 60 seconds
- 17 out of 18 samples failed





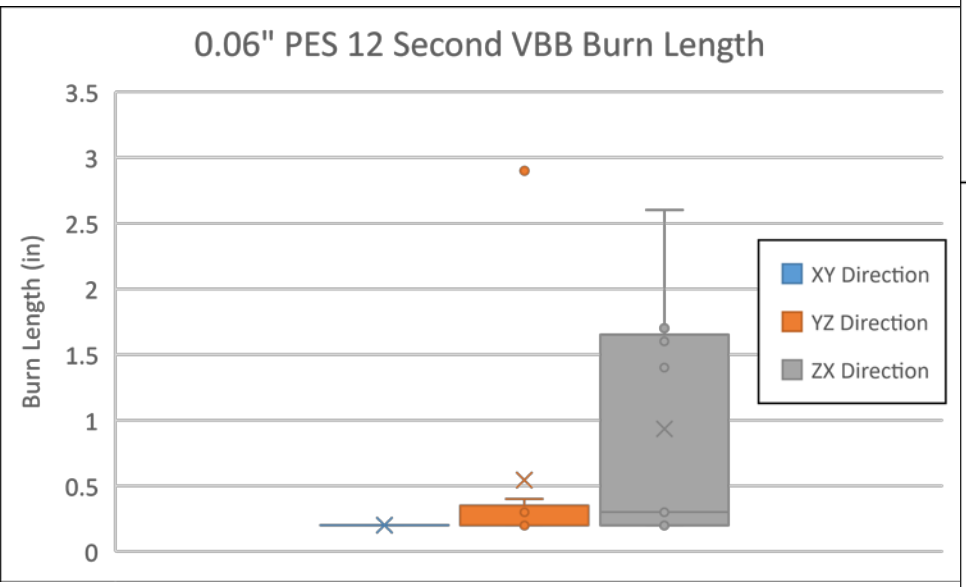


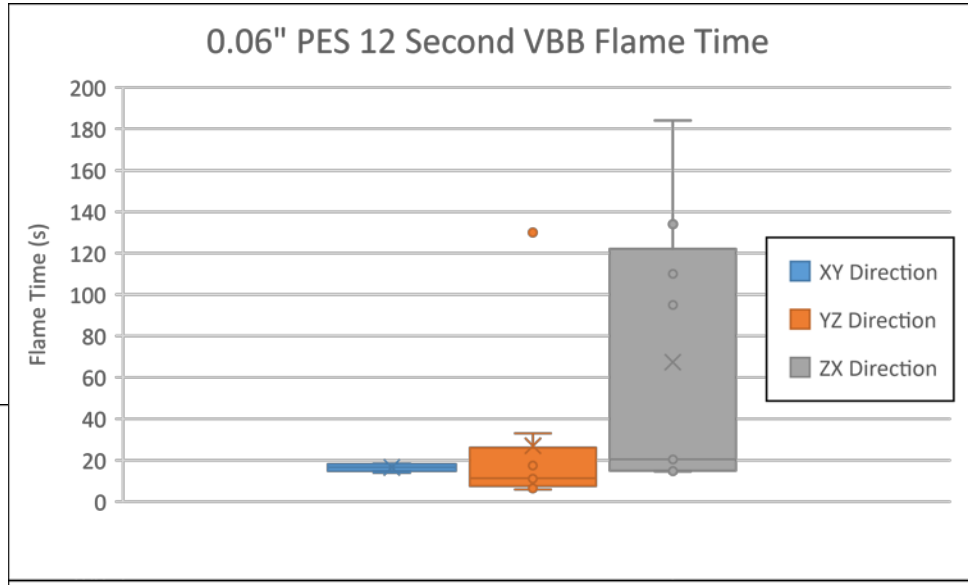
PC-ABS

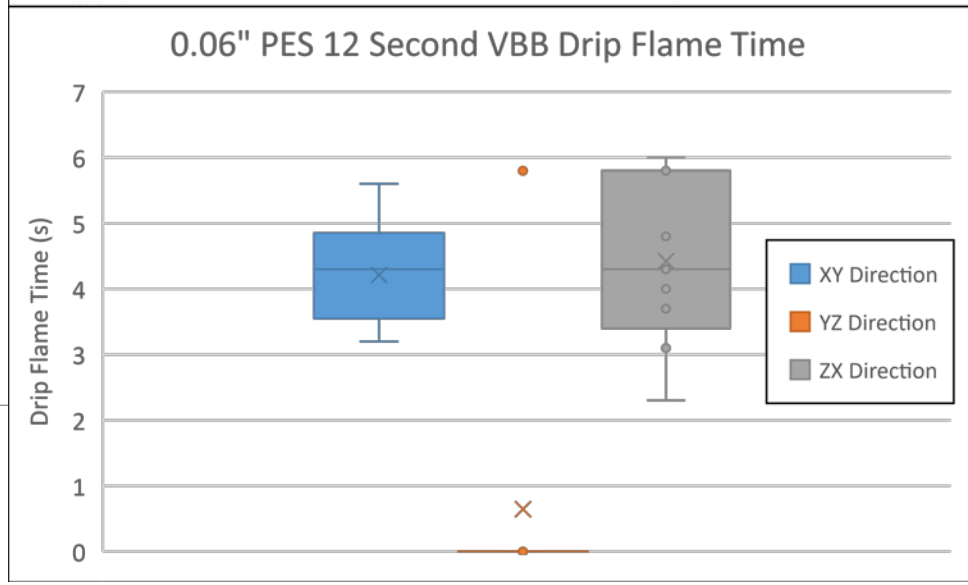
- **XY direction had 118s flame time, 8.2 in. burn length, lots of drip flame time**
- **Tested YZ and ZX directions and had to extinguish the flames**
- **Not a good candidate for further testing**

Ultem Support

- 12-Second Vertical Bunsen Burner
- 0.060 inch thick material
- 9 samples per orientation

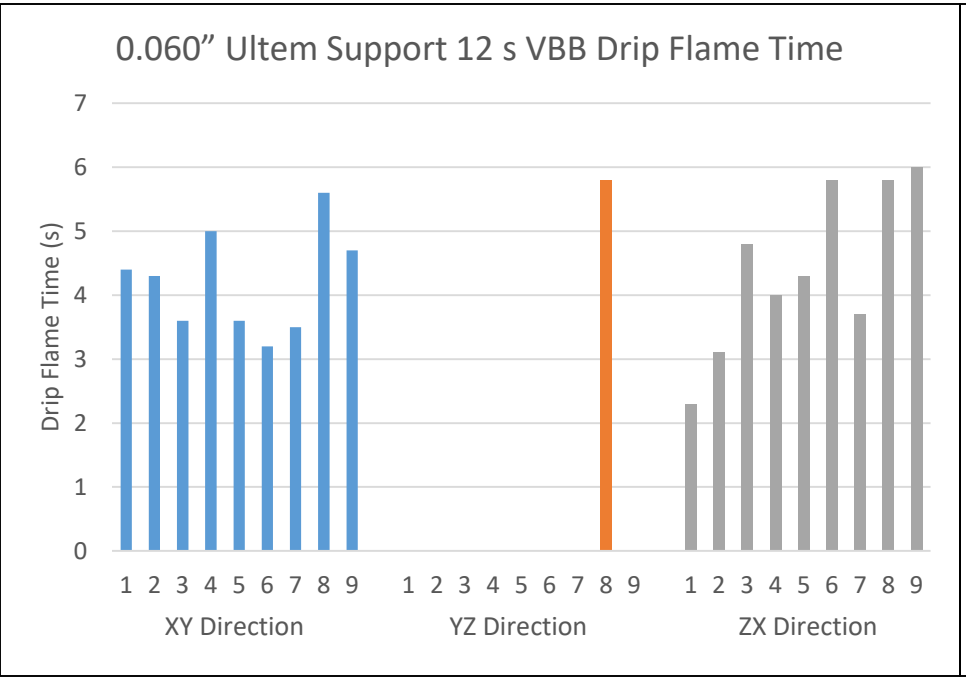


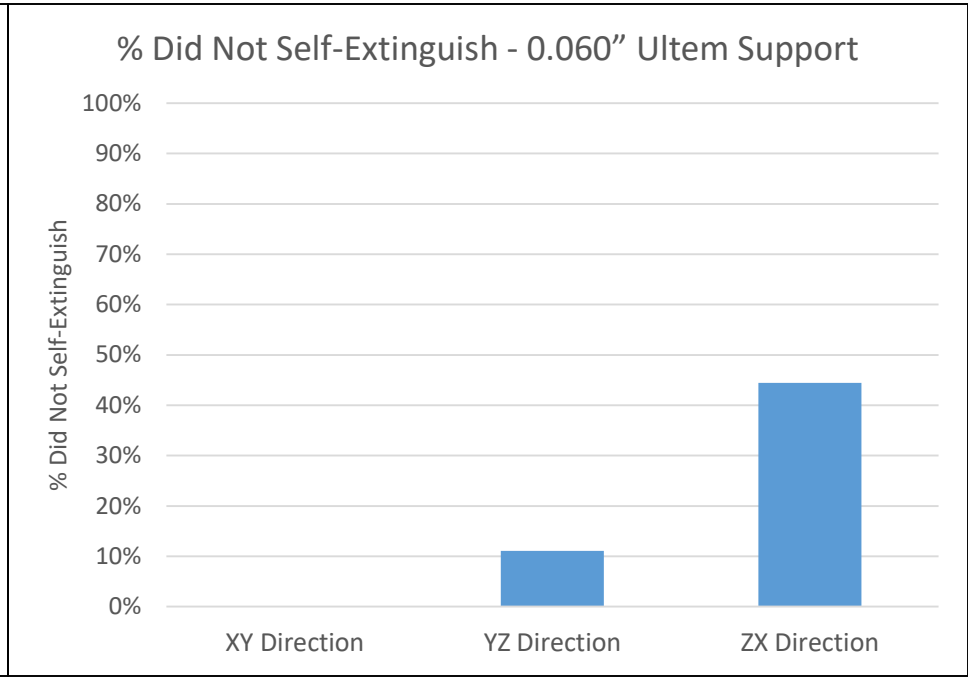




Ultem Support (PES)

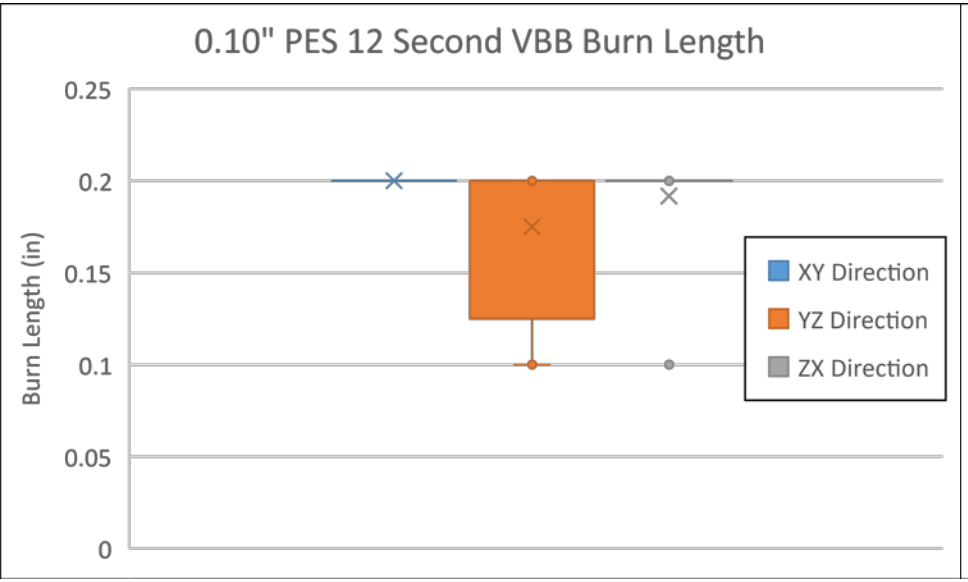
- YZ Direction had much less drip flame time than other orientations
- % Did not self extinguish means flame times greater than ~30 seconds
- ZX direction had greatest number of samples with long flame times

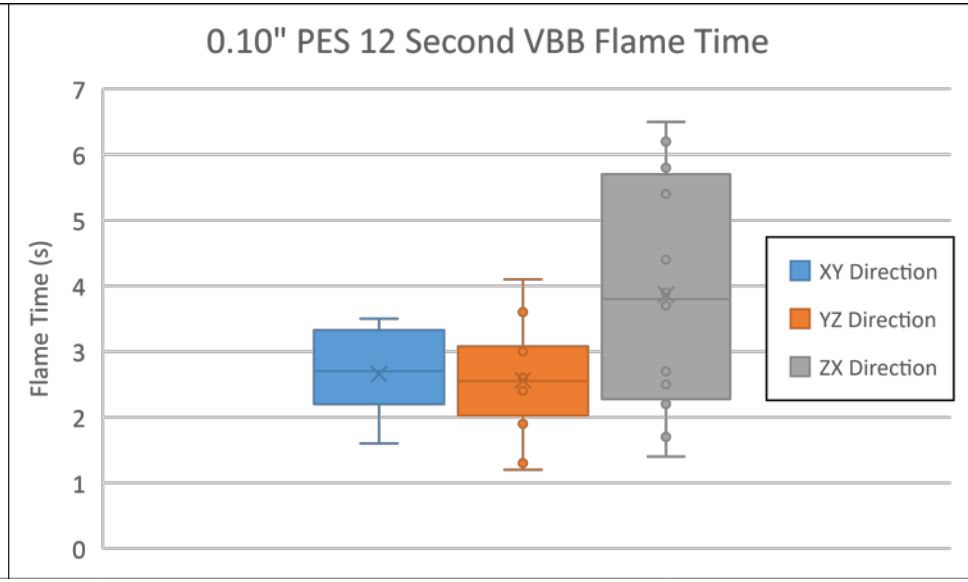




Ultem Support (PES)

- 12-Second Vertical Bunsen Burner
- 0.10 inch thick material
- 12 samples per orientation





Print Orientation Summary

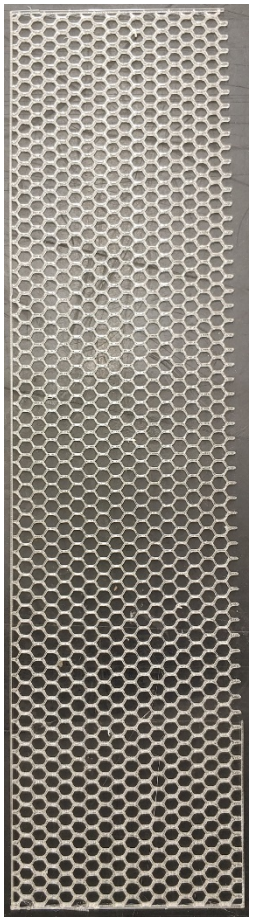
- **Differences in Ultem 9085 were minimal**
- **XY Direction was worst case for Nylon-12**
- **ZX Direction was worst case for Ultem Support**

Print Infill Patterns

- **Tested with Ultem Support (PES) material**
- **5 infill patterns**
- **Tested infill by itself and with solid outer layers**

Print Infill Patterns

Sparse
(31.5%)



Hexagonal
(36.1%)

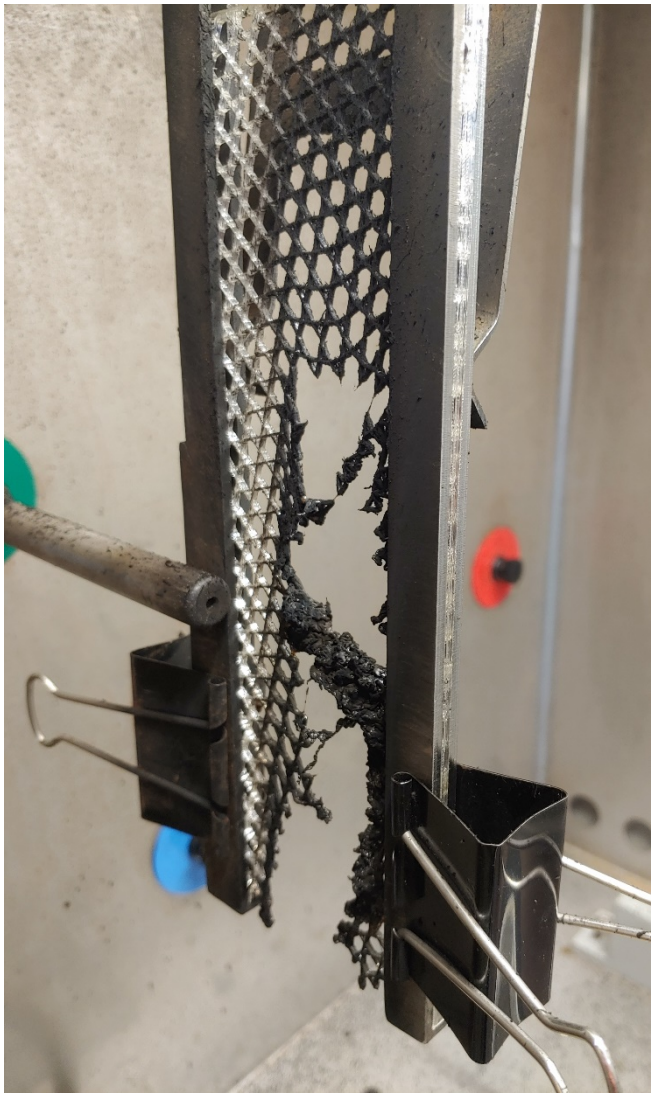
Hexagram
(38.6%)

Permeable
Triangular (38.6%)

Sparse DD
(51.0%)

Infill Only

- **0.060” sample thickness**
- **Every sample tested burned until chamber filled with smoke and put out fire**

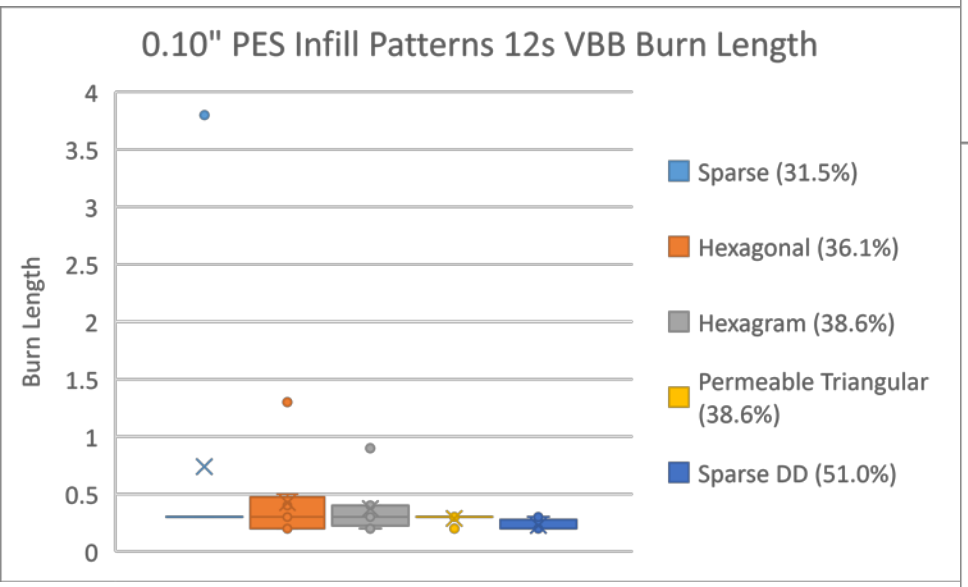


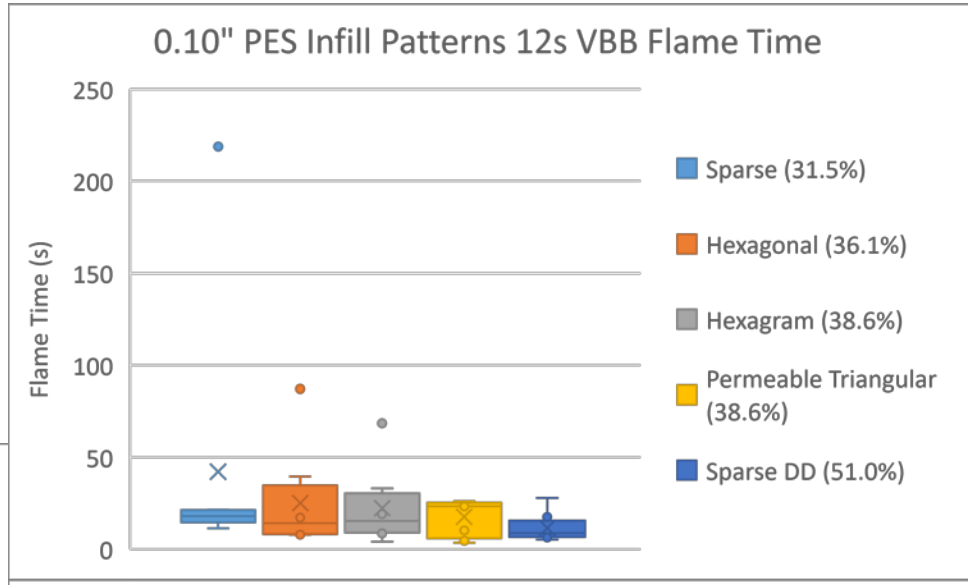
Varying Infill with Solid Outer Layers

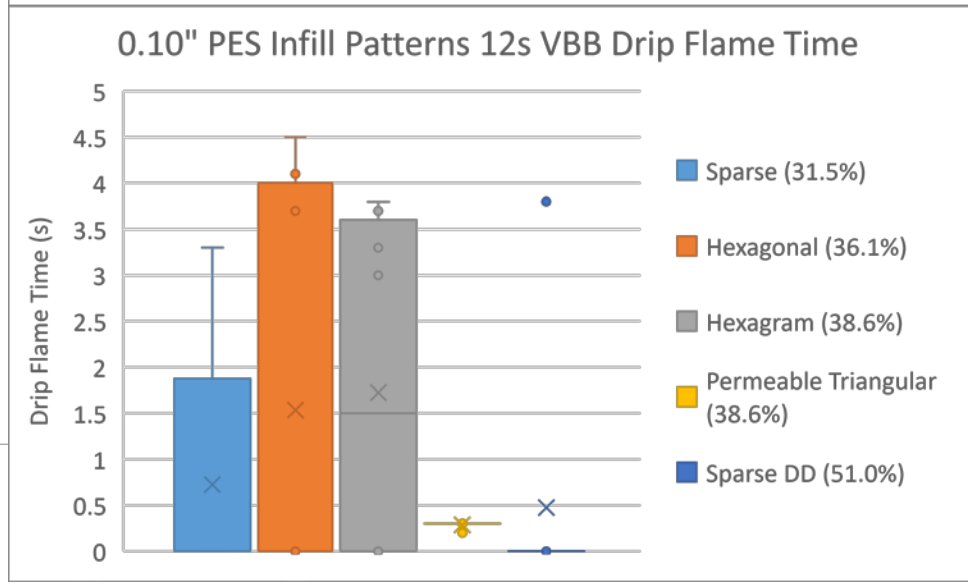
- **Tested 0.10” and 0.25” thicknesses**
- **2 solid outer layers, rest is hollow infill**
  - On 0.10”, 2 solid layers, 6 infill, 2 solid layers
  - On 0.25”, 2 solid layers, 21 infill, 2 solid layers

Varying Infill

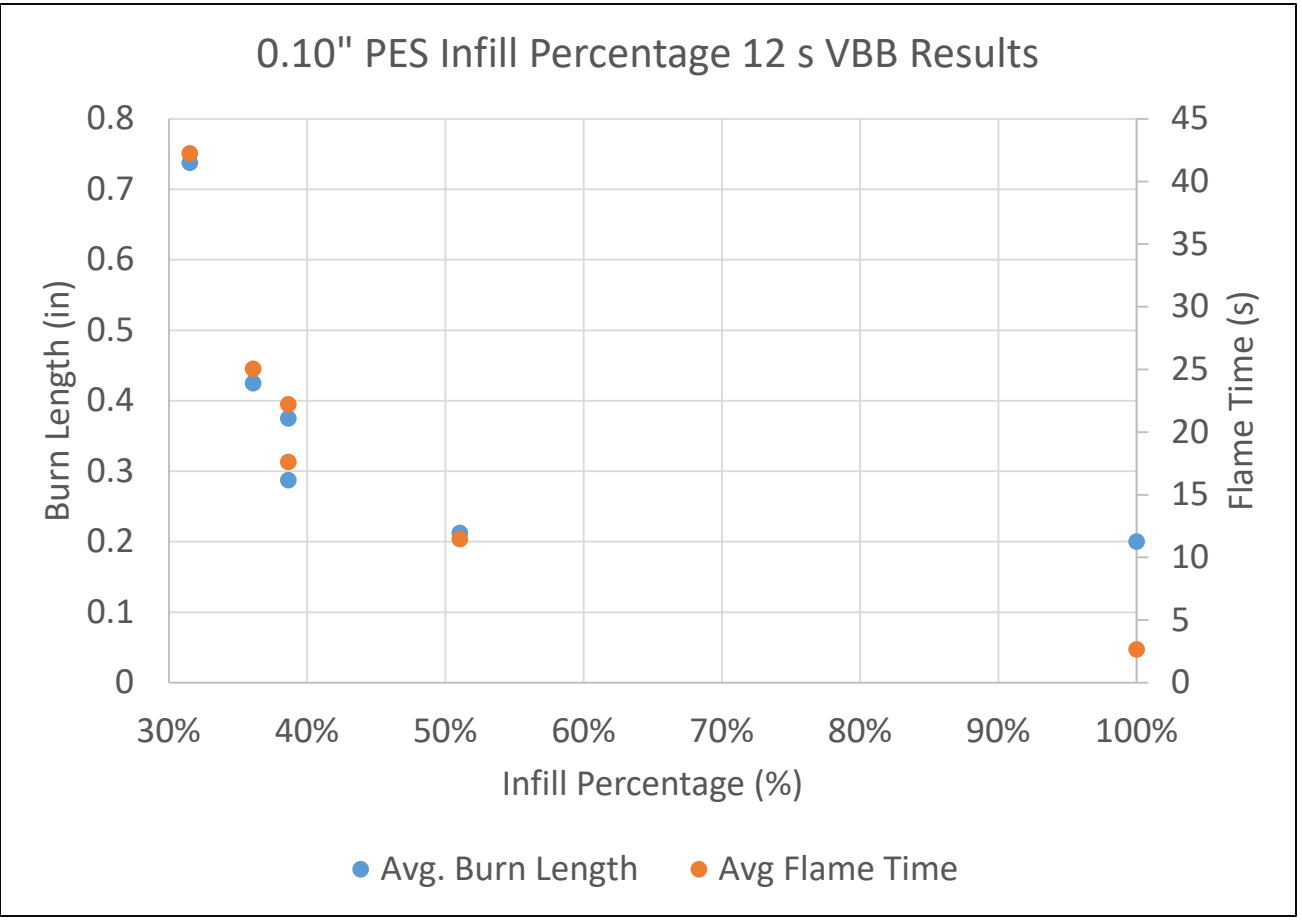
- 12-Second Vertical Bunsen Burner
- 0.10 inch thick material
- 8 samples per infill pattern







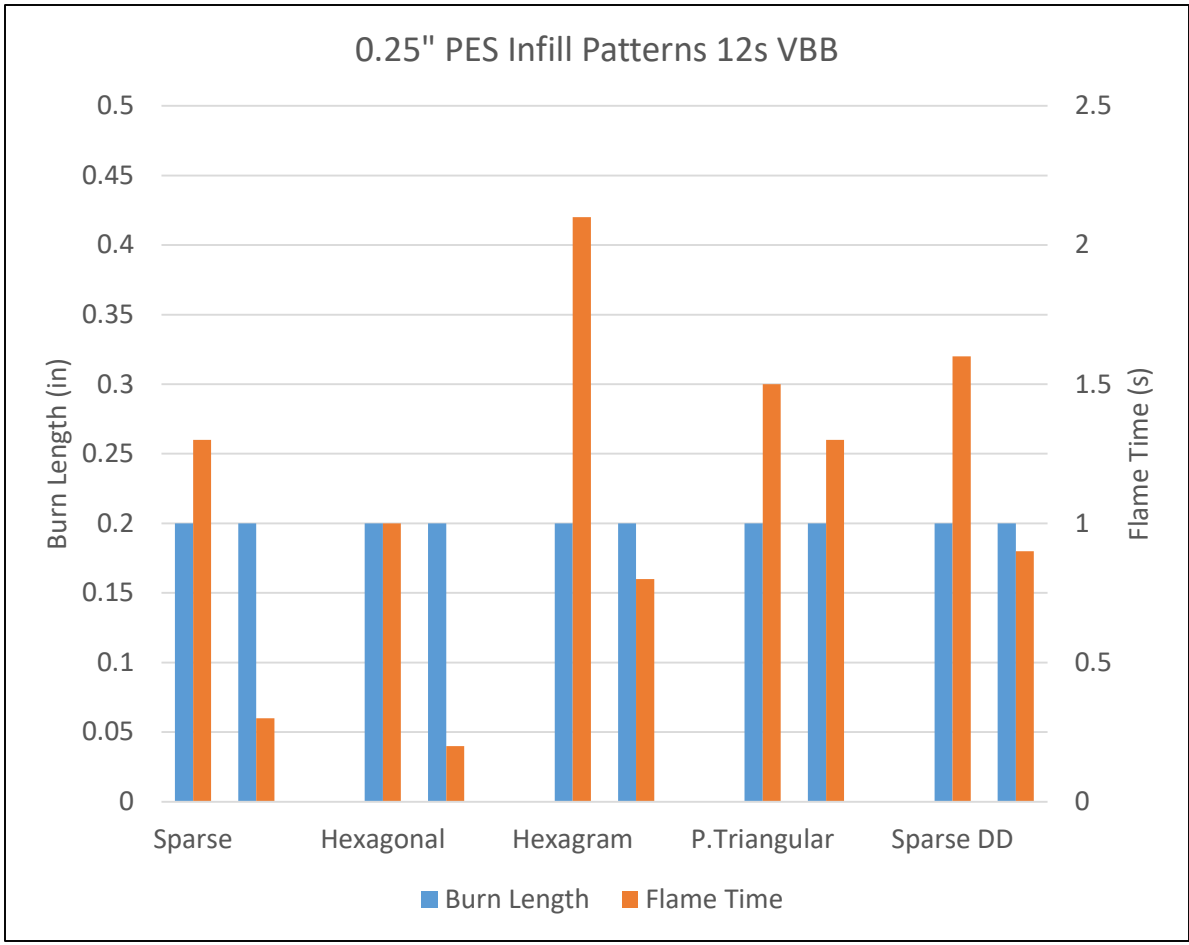
Varying Infill



- Good correlation between infill percentage and test results
- Less infill % causes more burning which agrees with Airbus' results with Ultem 9085

Varying Infill

- 12-Second Vertical Bunsen Burner
- 0.25 inch thick material
- 2 samples per infill pattern
- Tested to determine if more infill layers could cause more burning
- Very little burning from all samples



Conclusion

- **Printing Orientation**
  - Minimal difference with Ultem 9085
  - Ultem Support 0.60”: YZ-direction only dripped on one sample vs every sample for the other print orientations
  - ZX-direction was most severe case for Ultem Support
  - XY-direction was most severe case for Nylon-12
- **Infill Percentage**
  - Less infill percentage is more severe case than more infill
  - Agrees with other results using Ultem 9085

Questions?

Contact:
Steven Rehn
Federal Aviation Administration
William J. Hughes Technical Center
Fire Safety Branch, Bldg. 203
Atlantic City Int'l Airport, NJ 08405
(609) 485-5587
steven.rehn@faa.gov