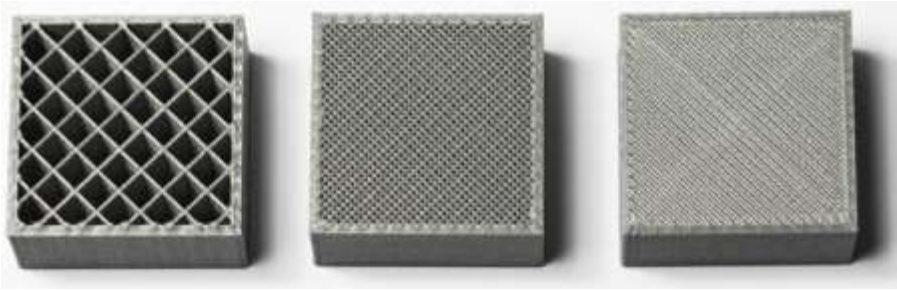
Relationship Between 3-D Printed Materials and Flammability

Presented to: International Aircraft Materials Fire Test Forum
By: Steve Rehn
Date: 6/11/2020

Introduction

- **3D printing introduces all new variables in material construction**
- **Variables include:**
  - Printing orientation
  - Infill percentage
  - Raster angle
  - Layer thickness
  - Raster width

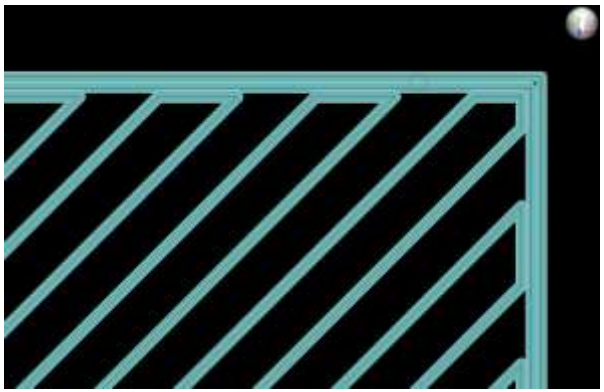


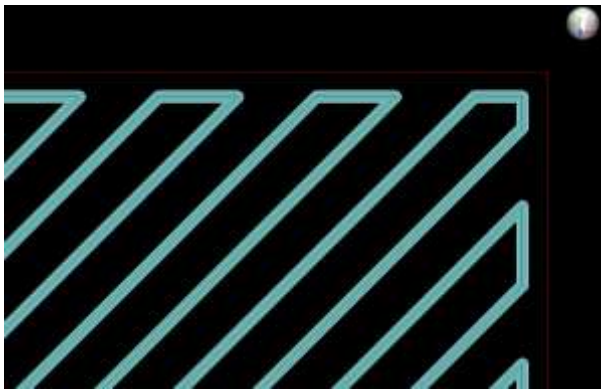
Test Plan

- **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**

Calculating Infill Percentage

- **Infill percentage calculated from Insight program material estimate**
- **Create toolpath of single layer**
- **Delete outer contours to only calculate infill**
- **Divide material used by material used in solid sample to get infill %**





Sparse: 0.100 in^3 material

Solid: 0.435 in^3 material

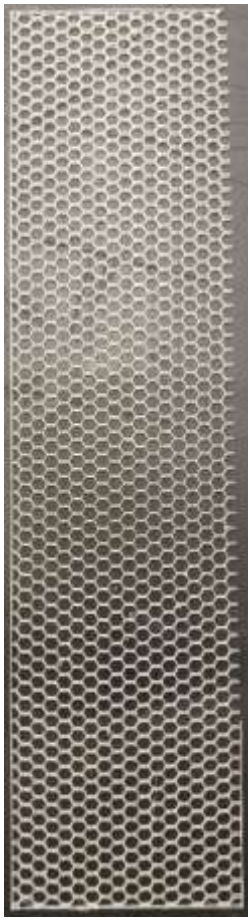
$$^{0.100}/_{0.435} = 23.0\%$$

Print Infill Patterns

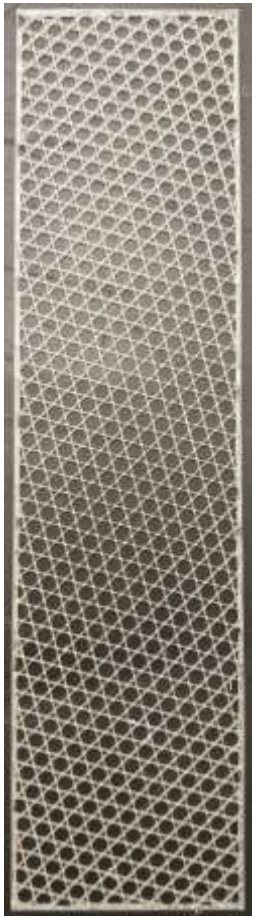
- **Tested with Ultem Support (PES) and Ultem 9085 (PEI) materials**
- **Several infill patterns and percentages**
- **Tested infill by itself and with solid outer layers**

Print Infill Patterns

Sparse
(23.0%)



Hexagonal
(29.7%)



Hexagram
(32.4%)

Permeable
Triangular (32.4%)

Sparse DD
(44.8%)

Infill Only

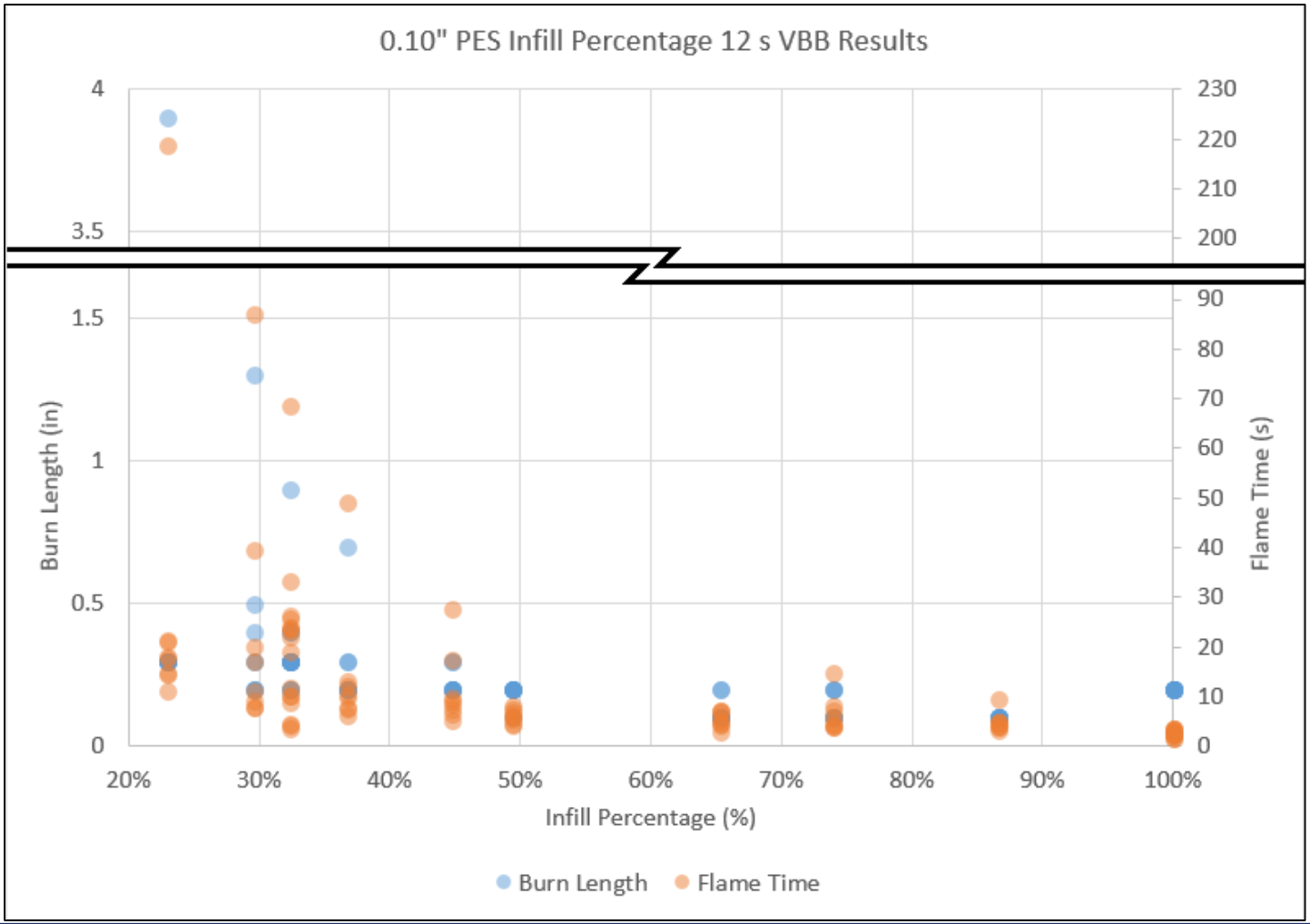
- **PES Material**
- **0.060” sample thickness**
- **Every sample tested burned until chamber filled with smoke and put out fire**

Varying Infill with Solid Outer Layers

- **Tested 0.10” thickness**
- **2 solid outer layers, rest is hollow infill**
  - On 0.10”, 2 solid layers, 6 infill, 2 solid layers
- **Two materials – Ultem Support (PES) and Ultem 9085 (PEI)**
- **12-second vertical Bunsen burner for both materials, 60s VBB for Ultem 9085**

Varying Infill – Ultem Support

- 8 samples per infill pattern



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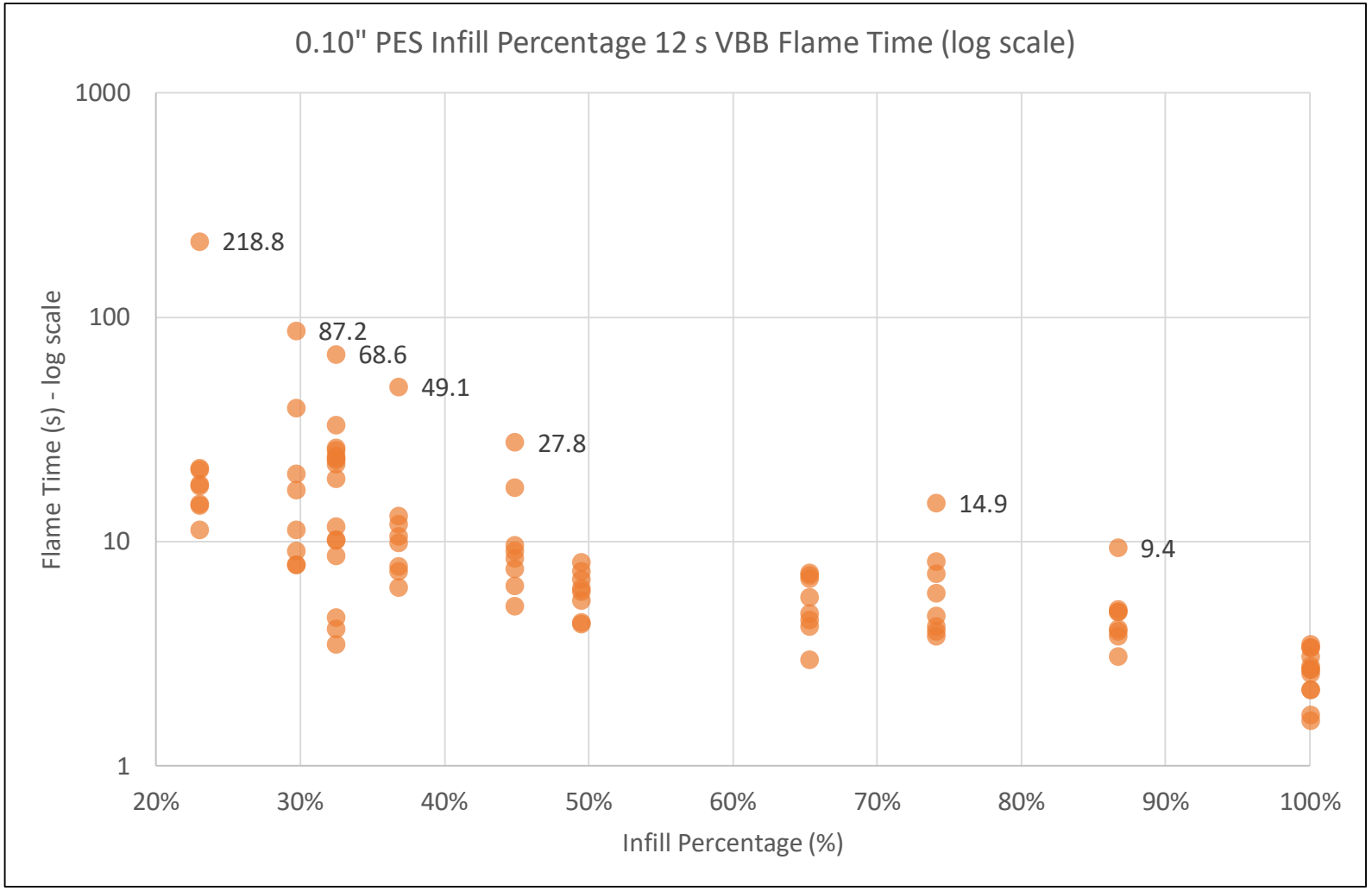
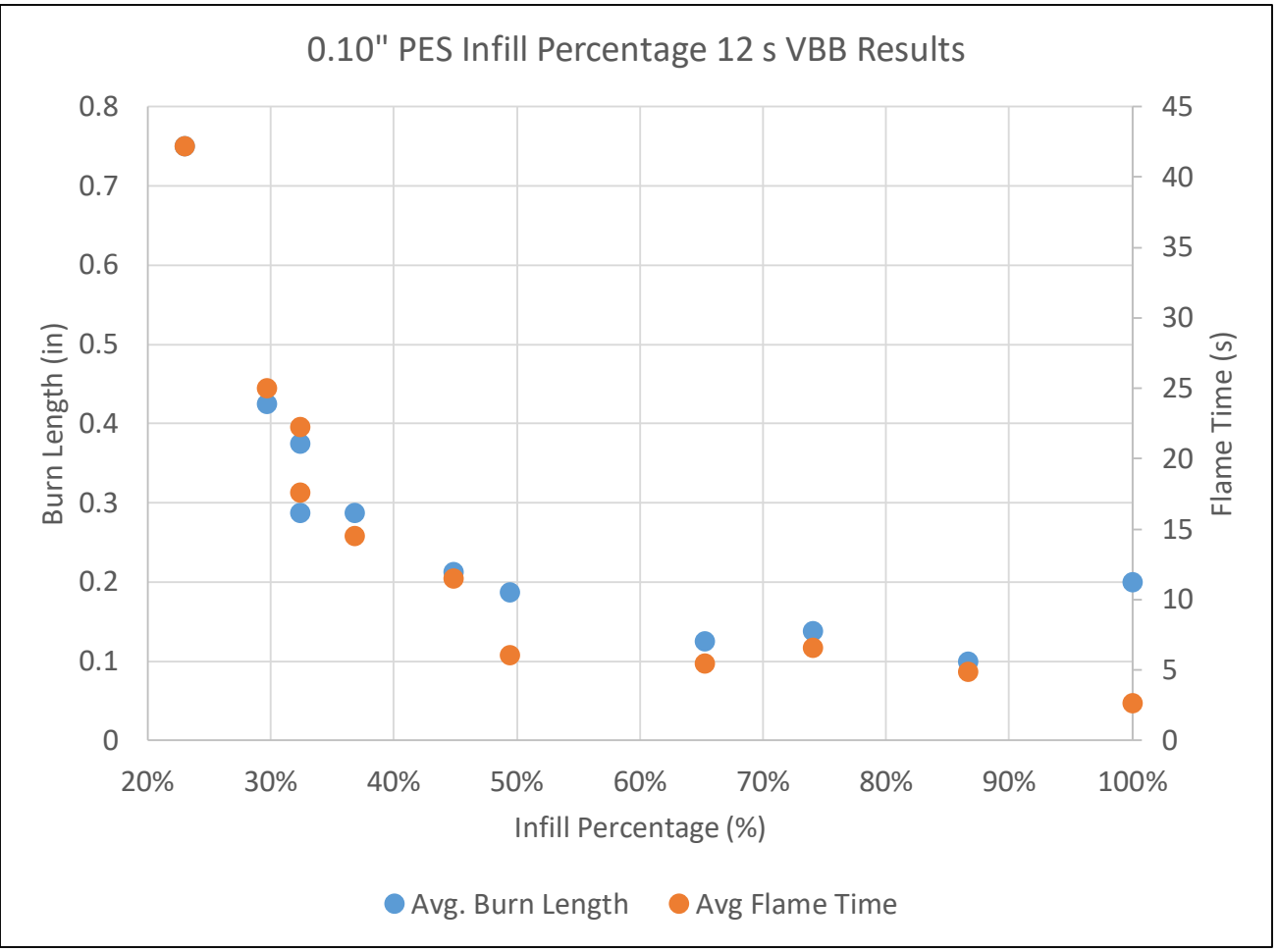


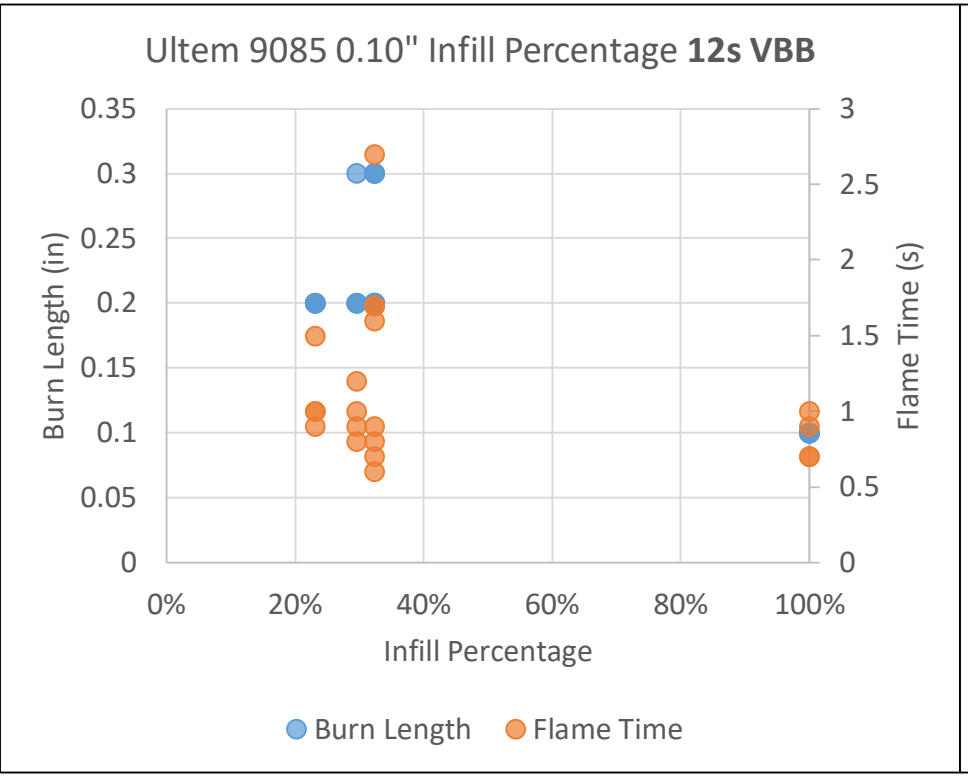
Varying Infill – Ultem Support

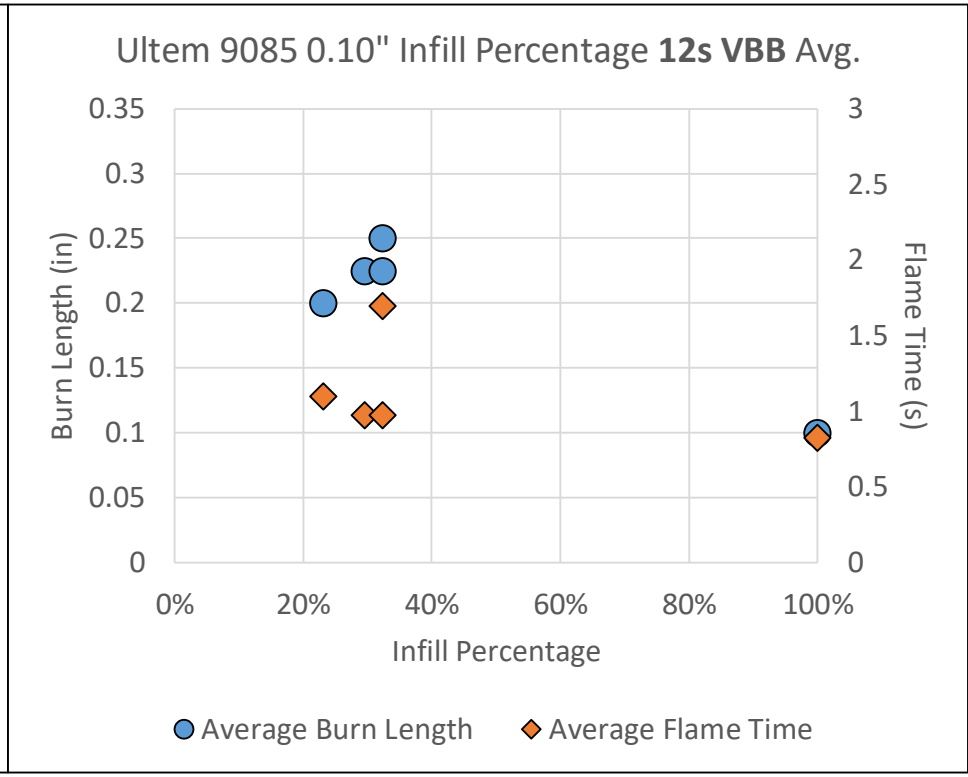


- Good correlation between infill percentage and test results
- Less infill % causes more burning

Varying Infill – Ultem 9085 (PEI)

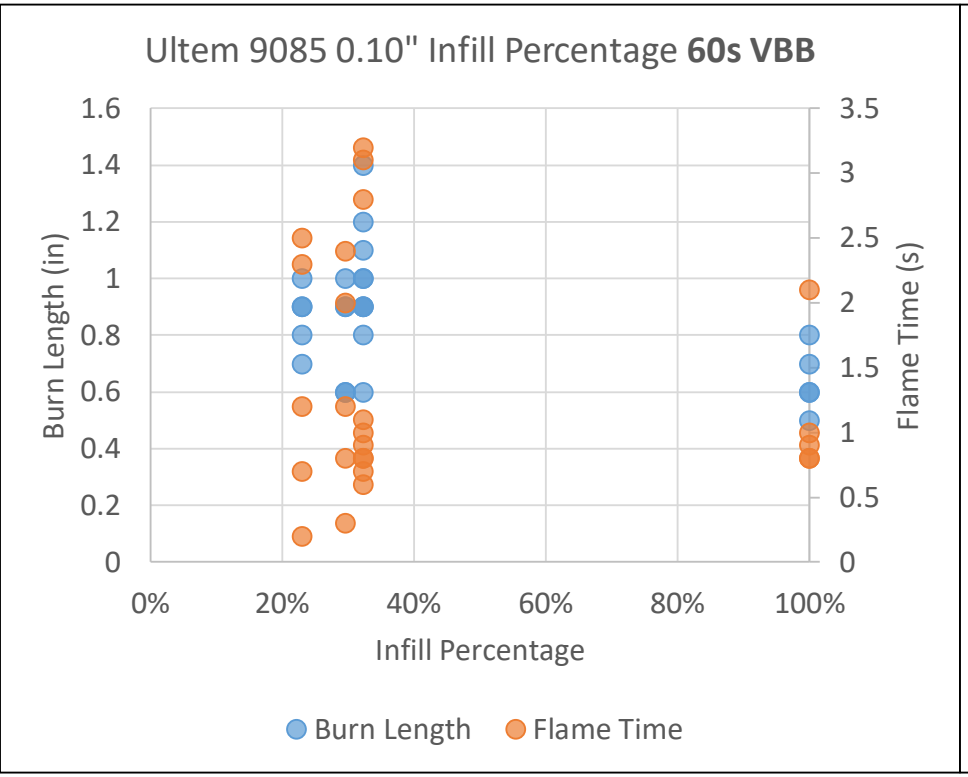
- **Same layer configuration – 2 solid outer layers, 6 inner infill layers (0.10 inch thickness)**
  - 12-second test, 4 samples per infill pattern

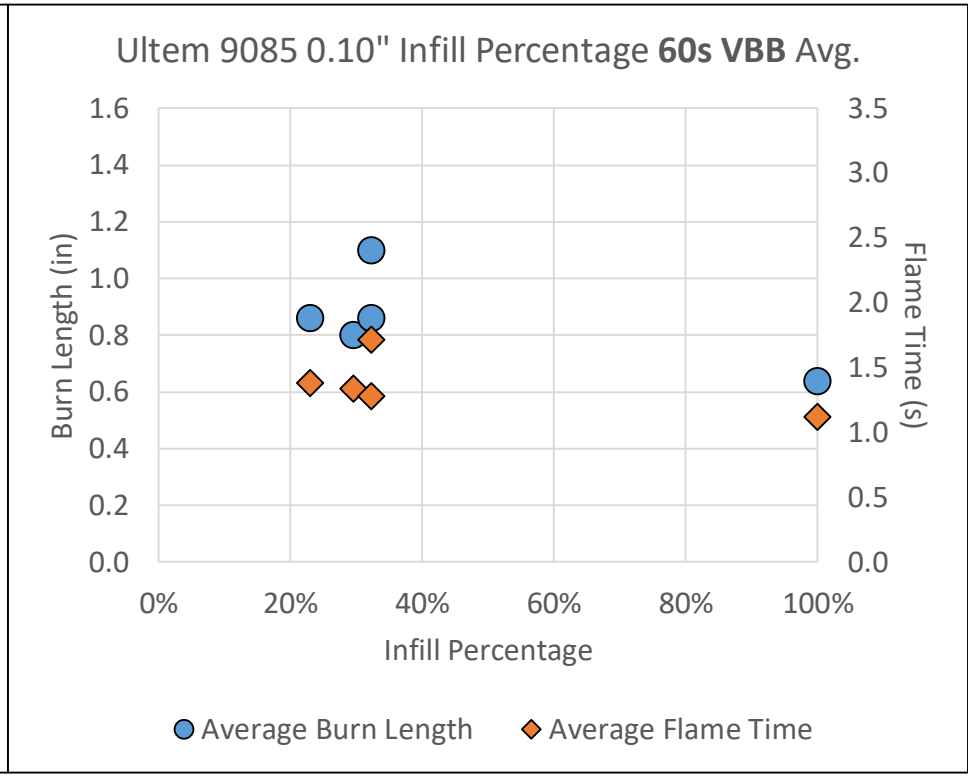




Varying Infill – Ultem 9085

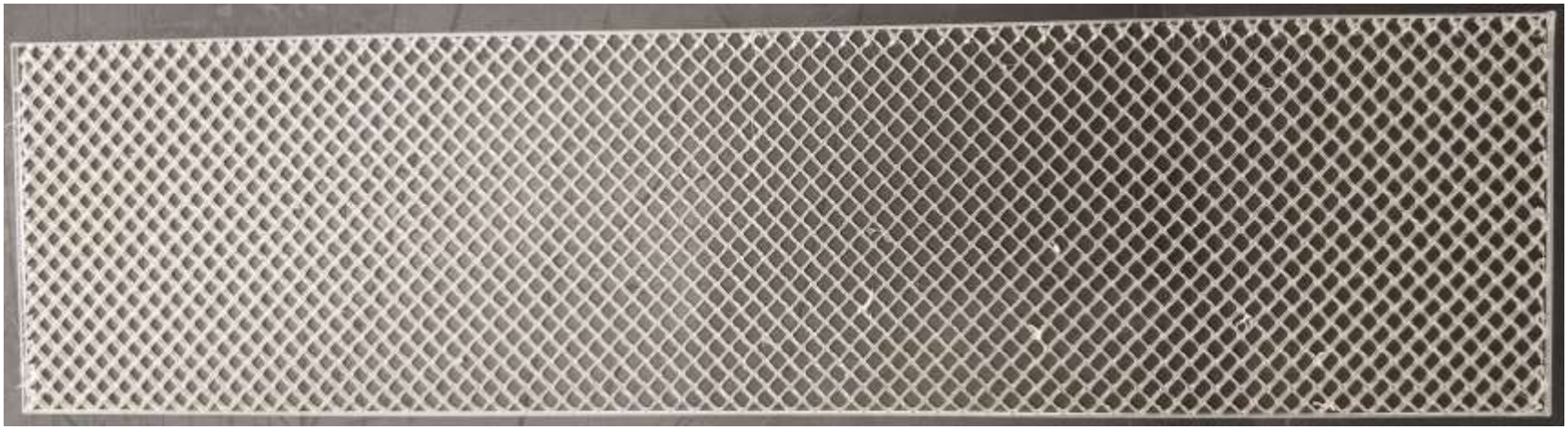
- **Same layer configuration – 2 solid outer layers, 6 inner infill layers (0.10 inch thickness)**
  - 60-second test, 5 samples per infill pattern





Varying Infill – Ultem 9085

- **Infill only – 0.06 inch thickness**
- **Same tests as completed by Airbus**
  - Have not reconciled infill % calculation yet



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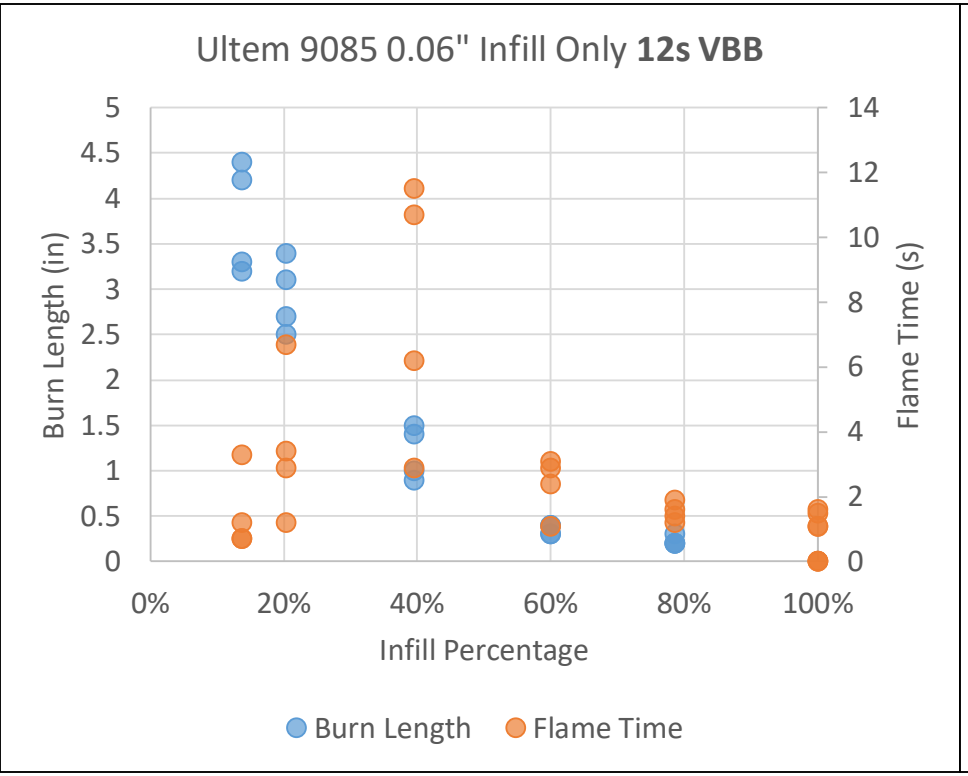

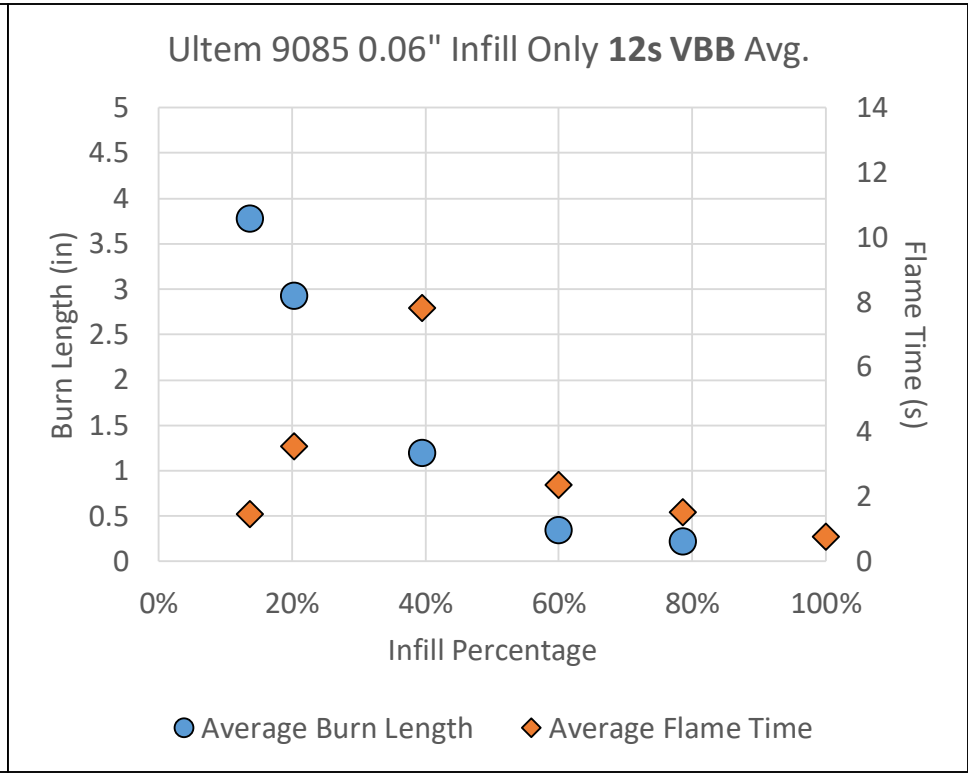

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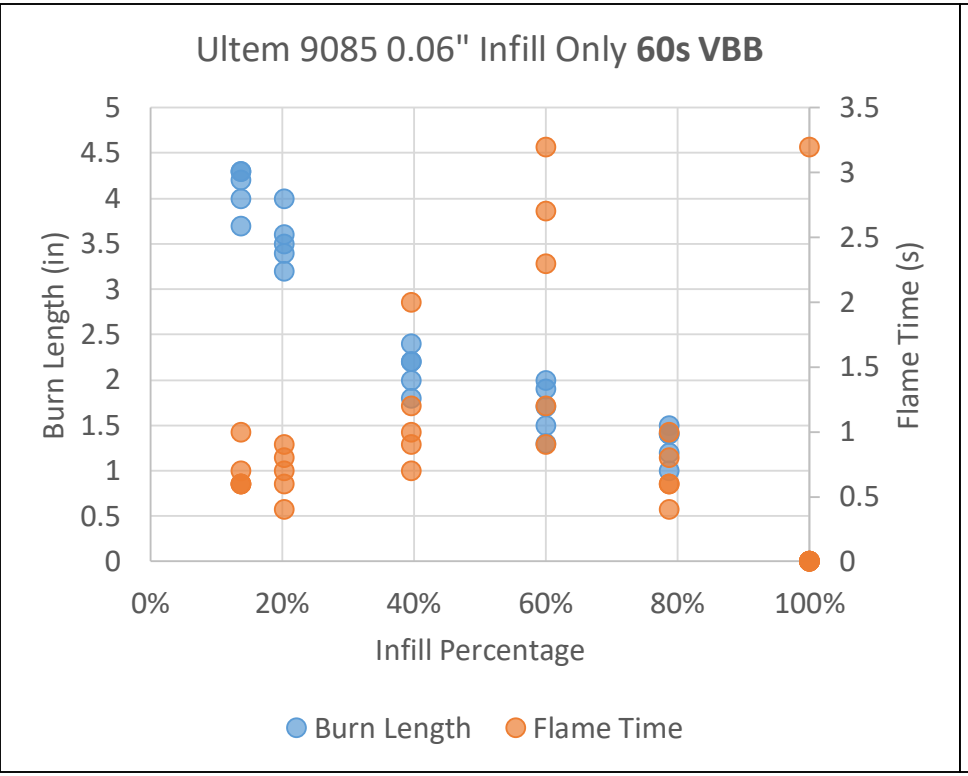
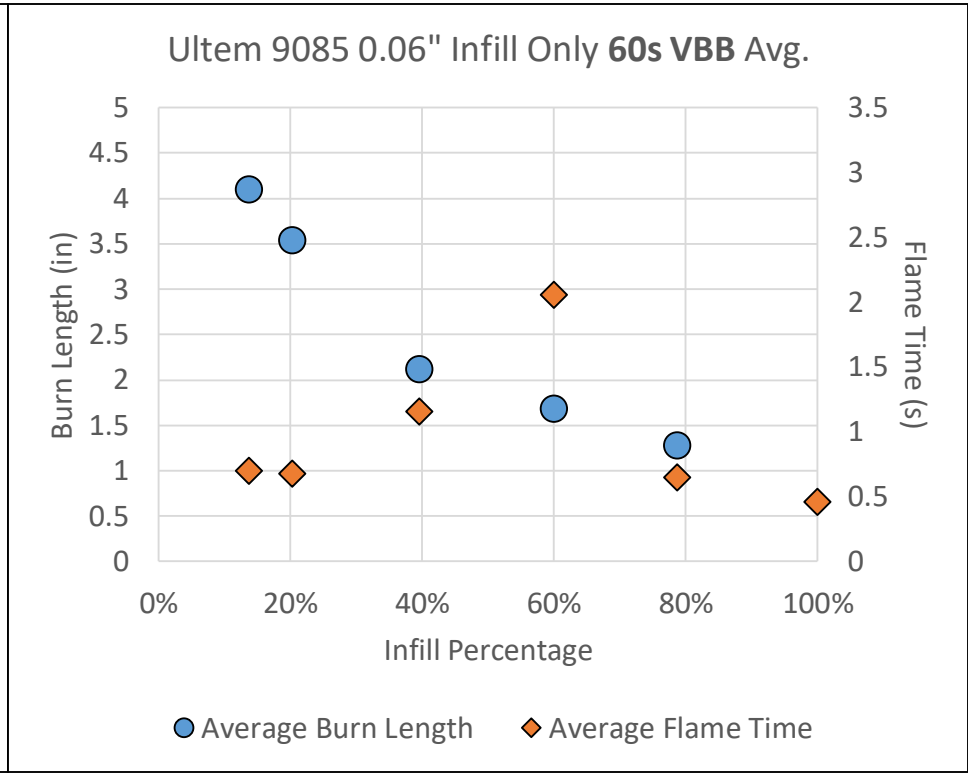
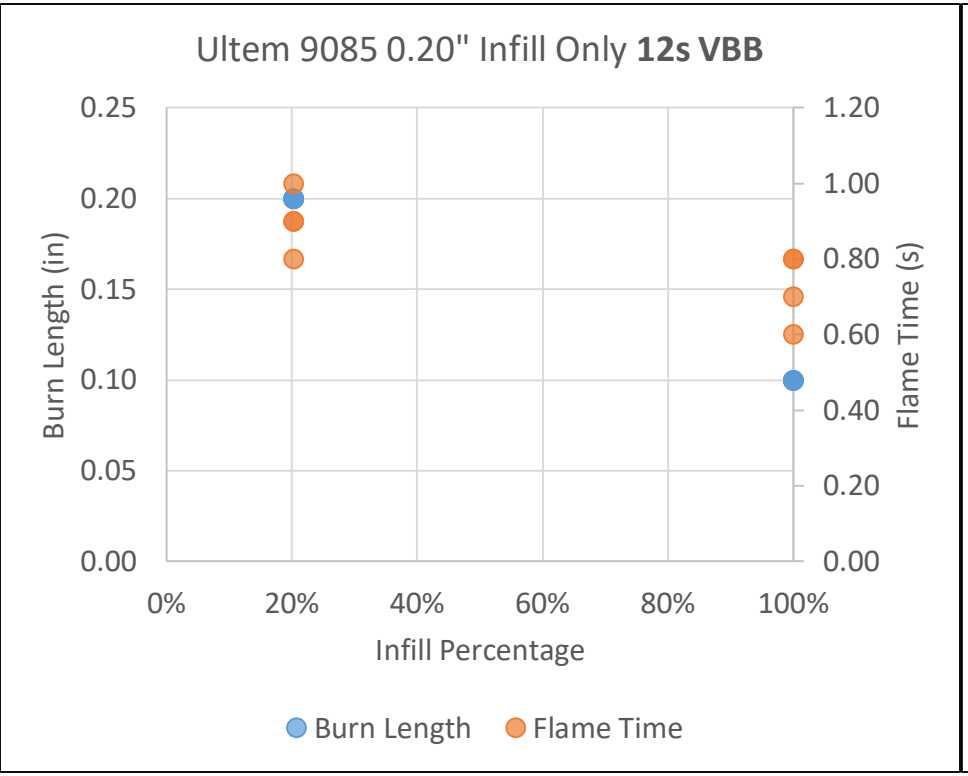
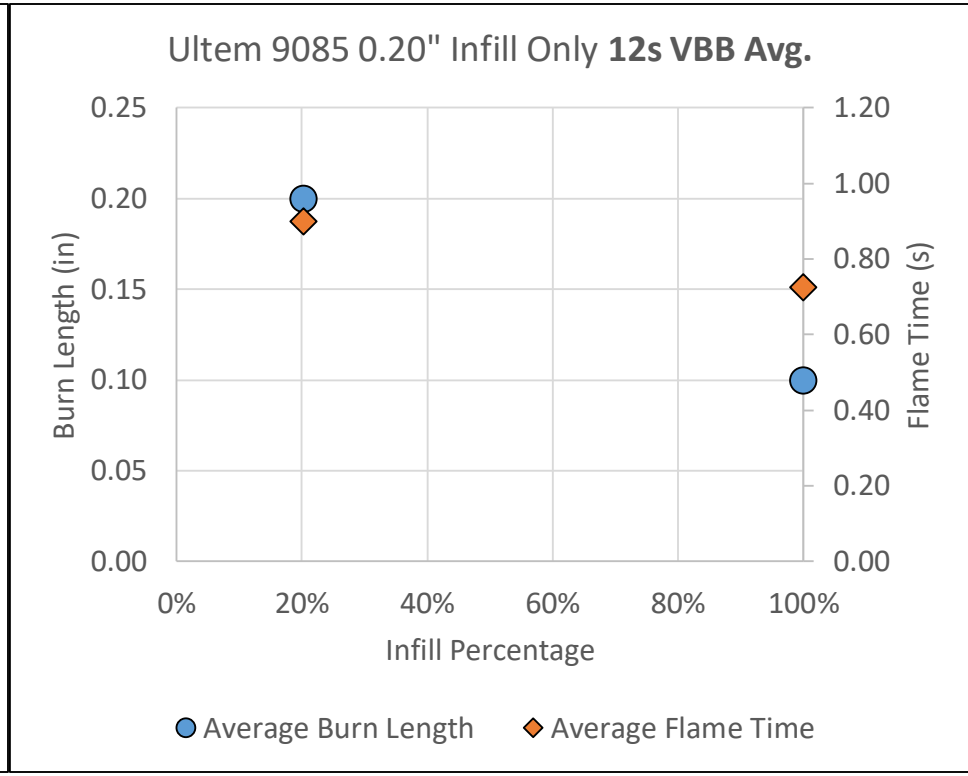




Varying Infill – Ultem 9085

- **Infill only, 0.20 inch thickness**
  - 12-second test, 4 samples per infill pattern





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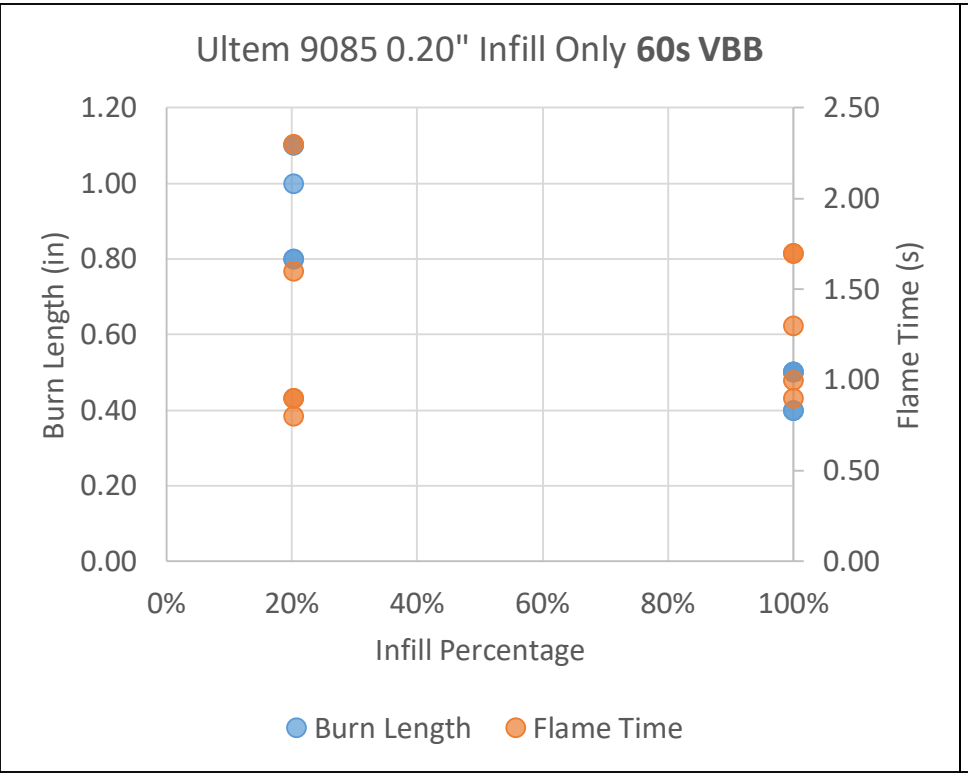
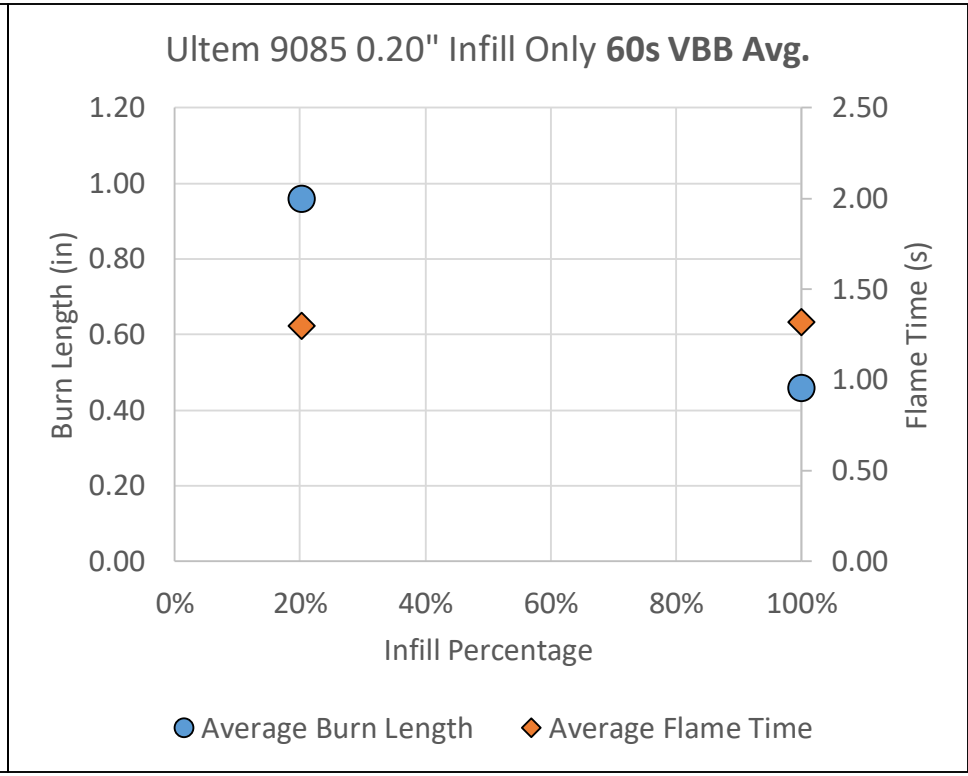
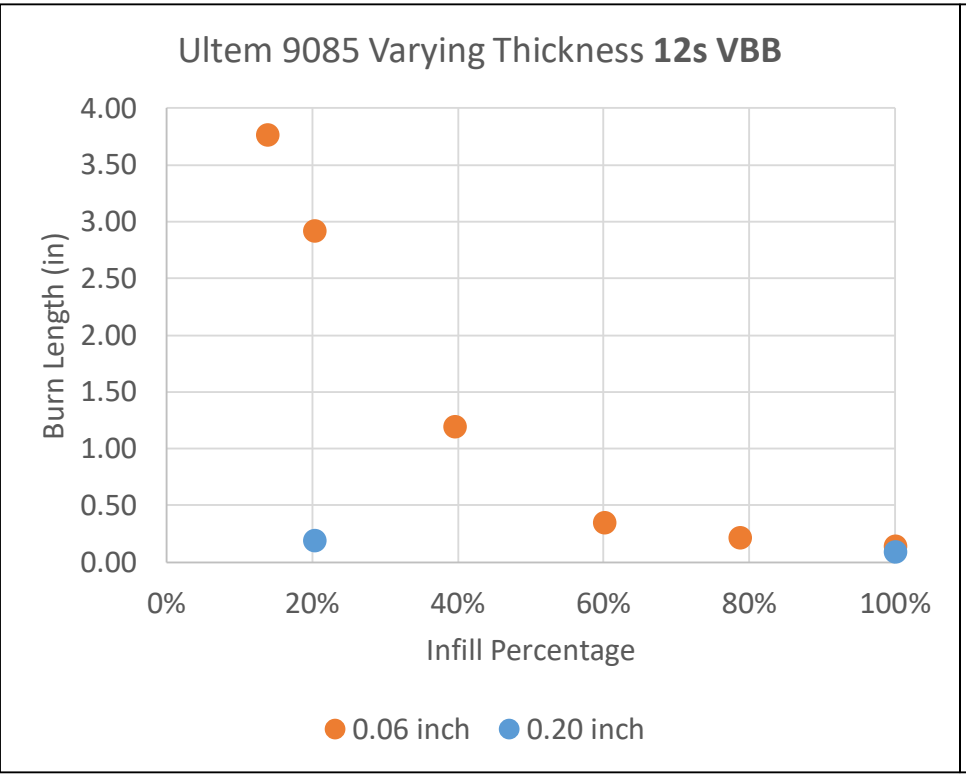
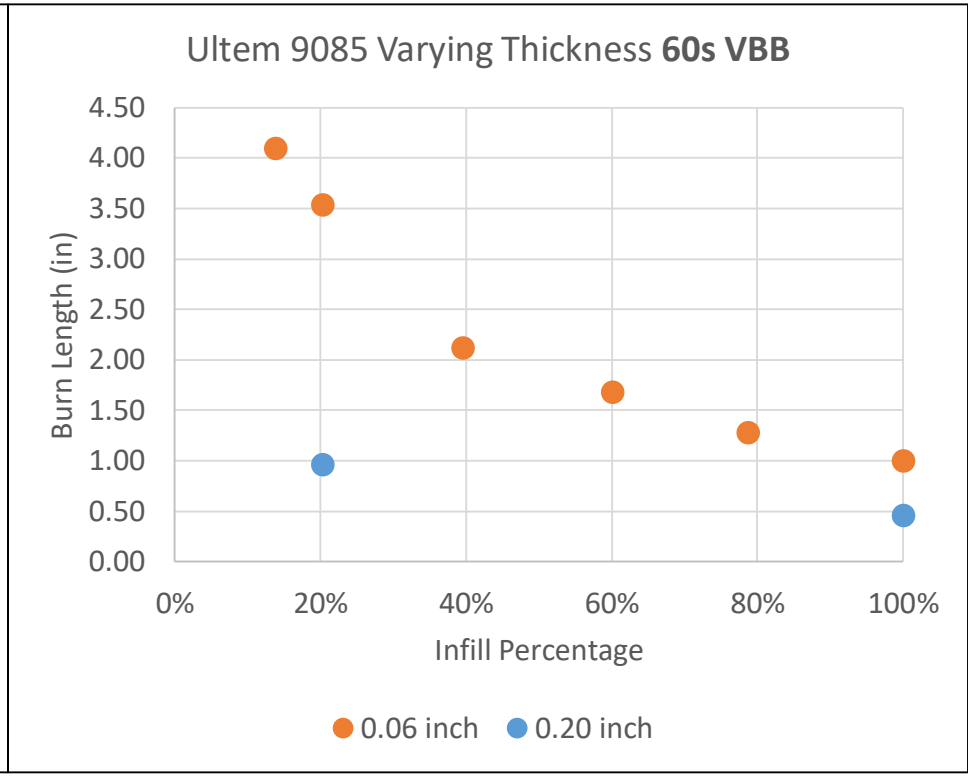




Varying Infill – Ultem 9085

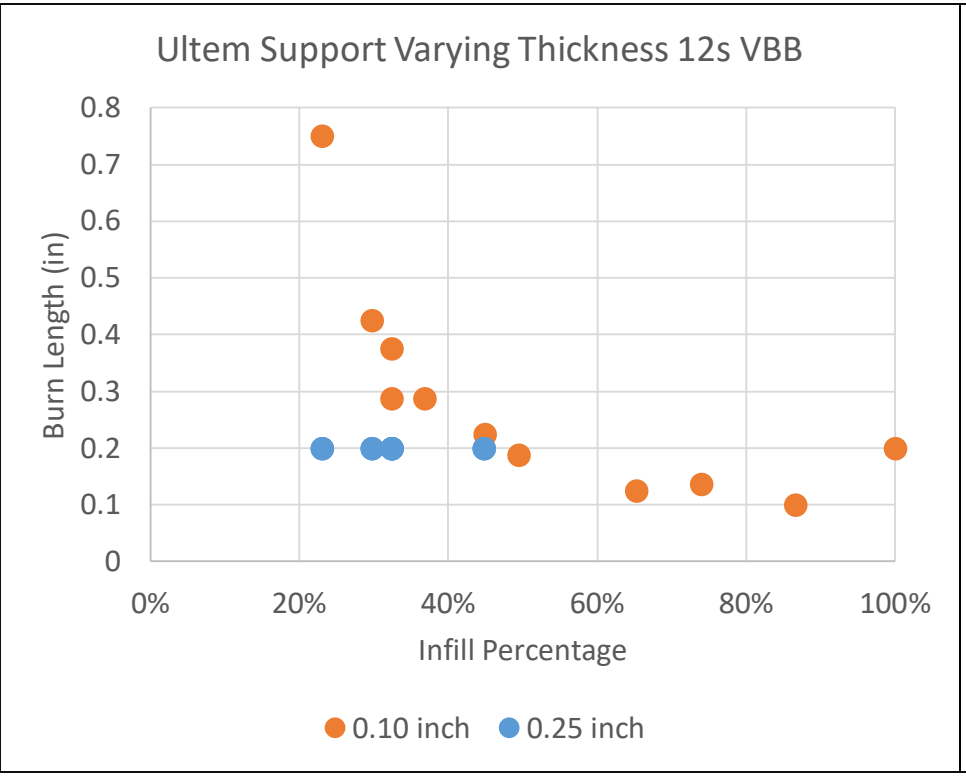
- **Infill only, 0.06 inch vs. 0.20 inch thickness**

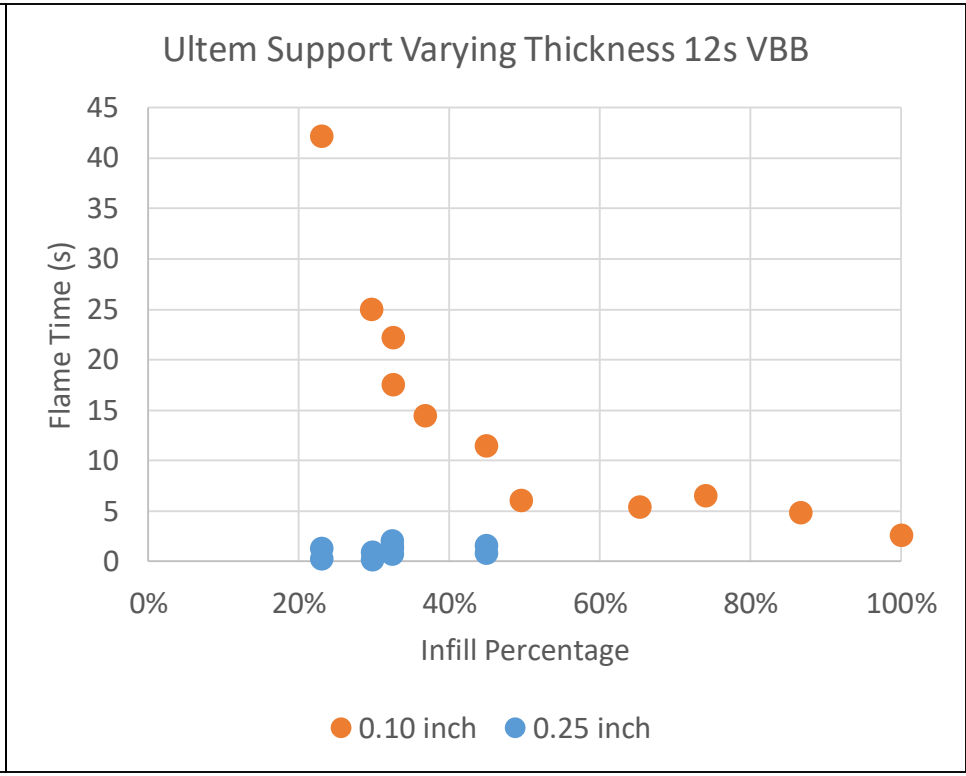




Varying Infill – Ultem Support

- **Infill w/ solid outer layers, 0.10 inch vs. 0.25 inch thickness**
  - 12-second VBB





Additive Manufacturing VBB AC

- **Began writing advisory circular for vertical Bunsen burner testing of 3D printed materials**
  - Details most severe case for each variable in order to reduce/simplify testing
  - For example, lower infill % is more severe than higher infill %, therefore testing lower infill substantiates higher infill.
  - Will have separate section for PEI-based materials
  - Can discuss further in task group meeting

Conclusion

- **Less infill percentage is more severe case than more infill**
- **Agrees with Airbus test results using Ultem 9085**
  - Have not made direct comparison yet because of infill percentage calculation
- **Thinner samples is more severe than thicker**
- **Next parameter to test**
  - Raster angle?
  - Raster width?

Questions?

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