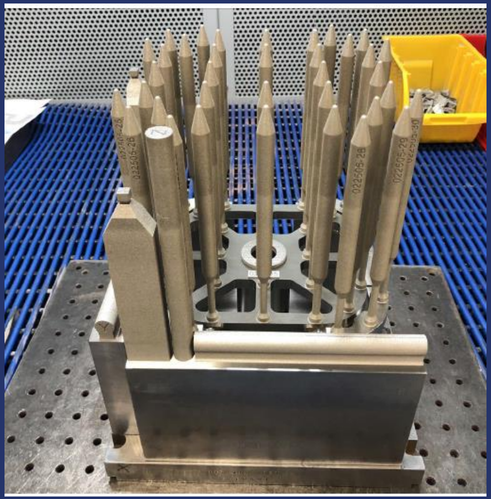
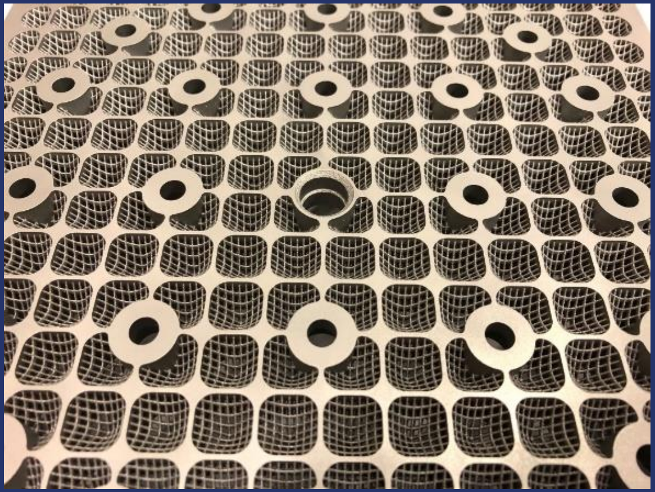
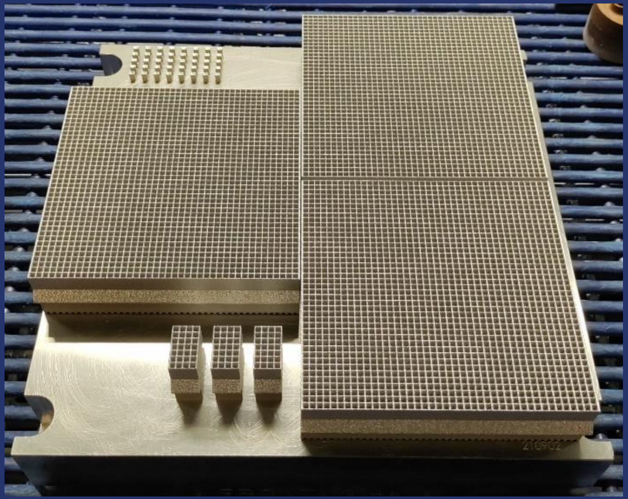
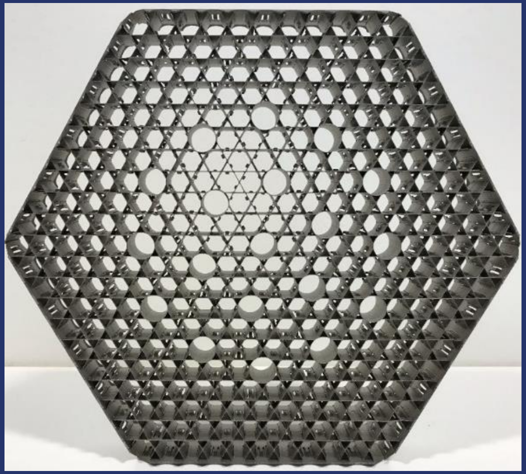




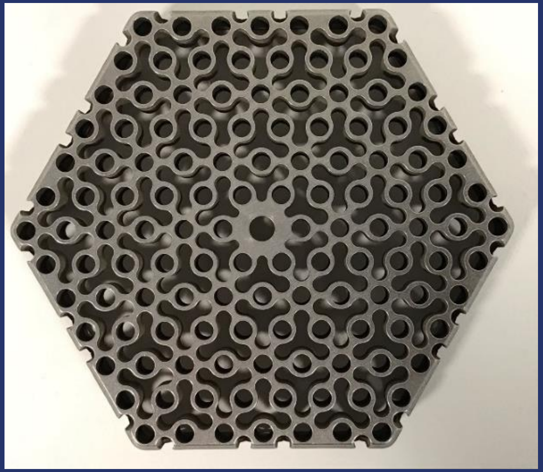


Additive Manufacturing Design and Process



August 2022

Uffe Bergmann & William Cleary



Outline

- Introduction to Additive Manufacturing (AM)
  - Powder Bed Fusion
- Current AM Projects for Westinghouse Fuel
- AM Process Development

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Introduction to Additive Manufacturing

What is Additive Manufacturing?

According to ASME:

Any process that creates objects by adding material instead of removing it

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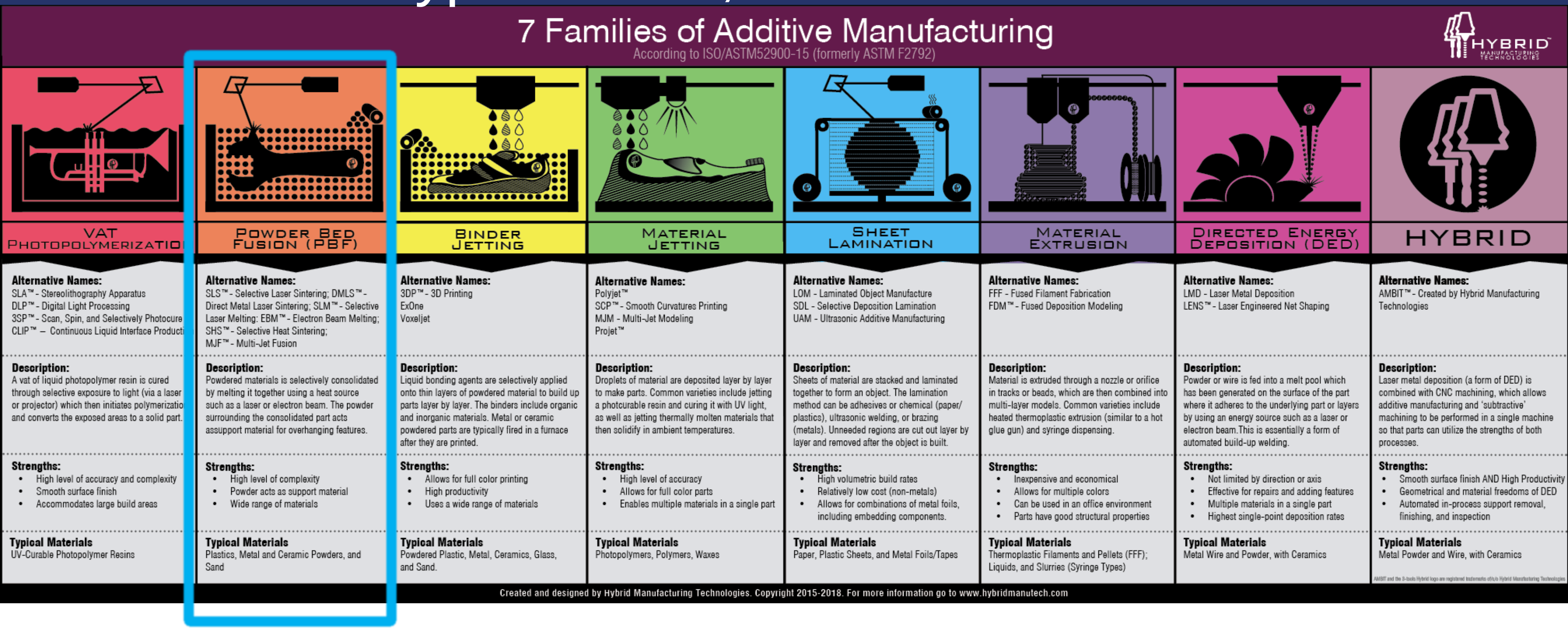
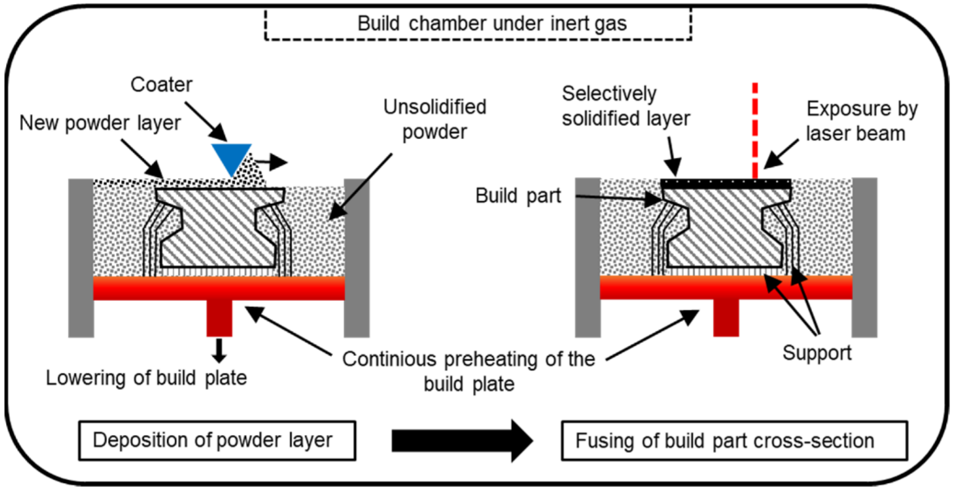
There are 7 types of AM, we focus on one of them

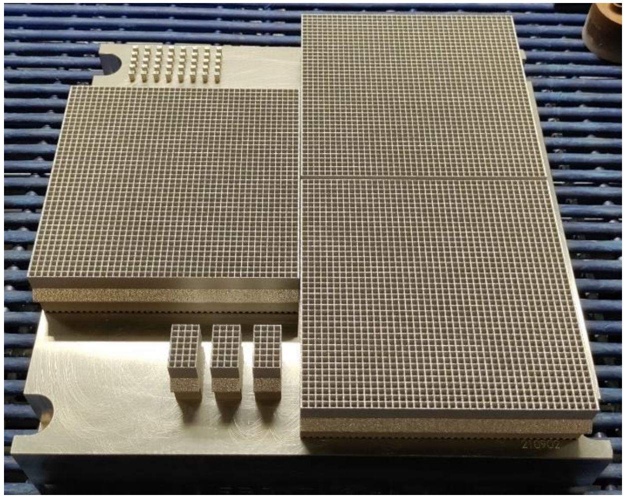


Powder Bed Fusion

Overview of Powder Bed Fusion

1. A layer of powdered material between 20-80μm is spread across a build platform
2. Laser fuses 1st layer cross-section geometry to build platform
3. New layer of powder is spread on top of the previous layer using the recoater blade
4. Further layers/cross sections are fused and added
5. The process repeats until the entire model is created
6. Unmelted powder remains in position until printing ends and is removed and recovered during post processing





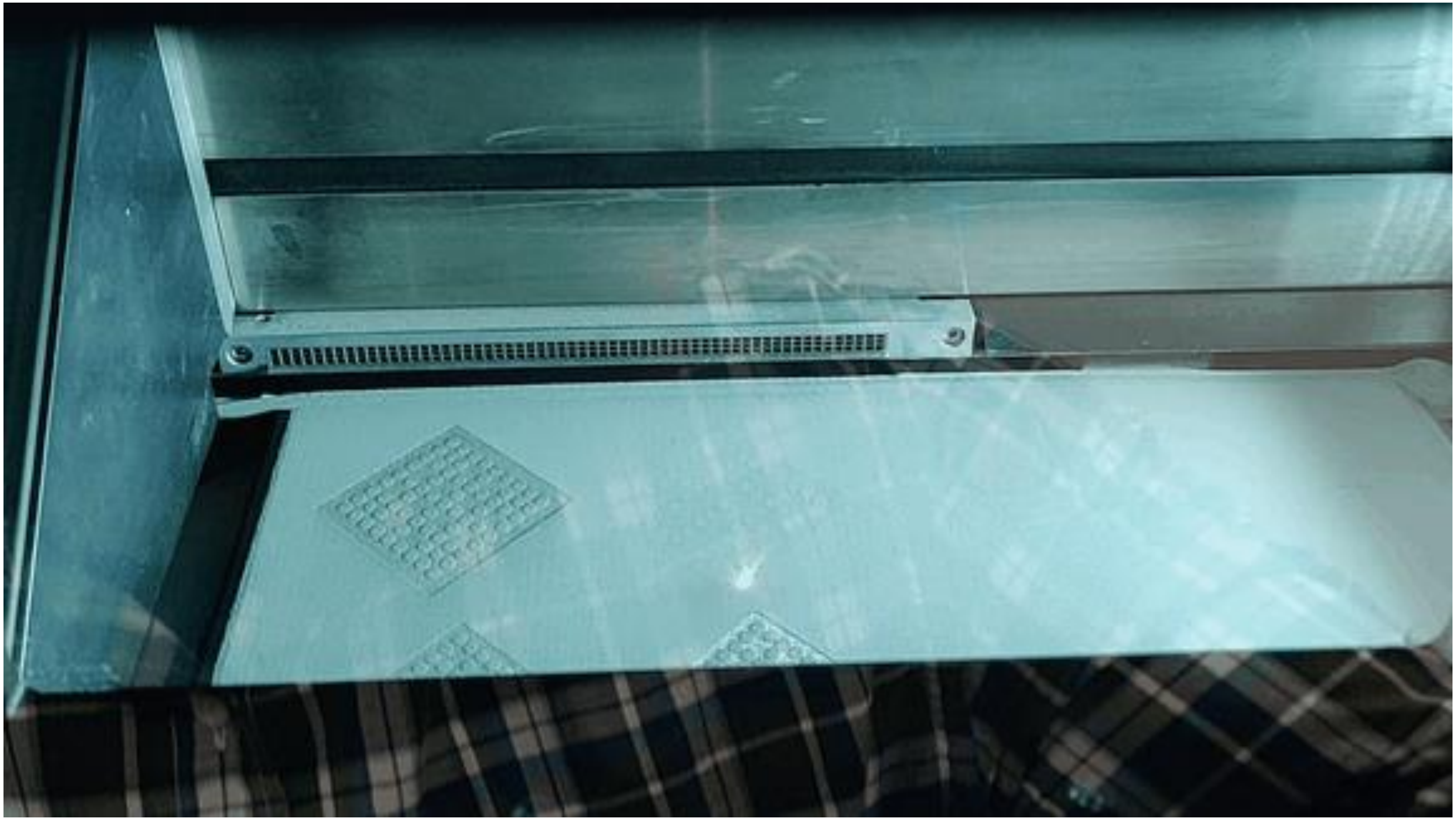
Westinghouse Machine

- EOS M290
- Year purchased: 2018
- Location: Penn United, Cabot, PA
- 250 x 250 x 325 mm
- 400W Yb fibre laser

Penn United - AM Facility

- Operates three EOS M290s and one EOS M400-4
- EOS M290s are process development machines
- EOS M440-4 is for larger production volumes
  - Large building volume of 400 x 400 x 400 mm with four 400 W lasers operating independently

Powder Bed Fusion
- EOS M290 in Operation



Powder Material Availabilities

- Currently Printing
  - Stainless Steels
    - 304
    - 316L
  - Nickel Alloys
    - A625
    - A718
  - Tool Steels
    - MS-1
    - H230
    - 17-4 PH
- Low cobalt powder available
- Investigating zircaloy development
- Multiple suppliers
  - Promotes security of supply

Example Commercial Powder Suppliers

https://www.oerlikon.com/am/en/offerings/metal-powders/

http://www.praxairsurfacetechnologies.com/en/components-materials-and-equipment/materials/additive-manufacturing-powders/?tab=cobalt-iron-and-nickel-powders

https://www.additive.sandvik/en/products-services-am/metal-powder/

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Opportunities for AM

- Better performance
  - Printing complex shapes
  - Enabling geometry that cannot be machined or cast
- Cheaper manufacturing of components
  - Printing near net shapes
- Faster lead time (considering manufacturing & material)
  - Printing in hours or days
- Combining assemblies into single part

Current AM Projects for Westinghouse Fuel

Current AM Projects for Westinghouse Fuel

- PWR Thimble Plugging Device (WEC)
- PWR Additively Manufactured Bottom Nozzle (WEC)
- BWR **StrongHold**® Debris Filter (WSE)
- VVER-1000 Prototype Grids (WSE)
- VVER-440 Top and Bottom Flow Plates (WSE)

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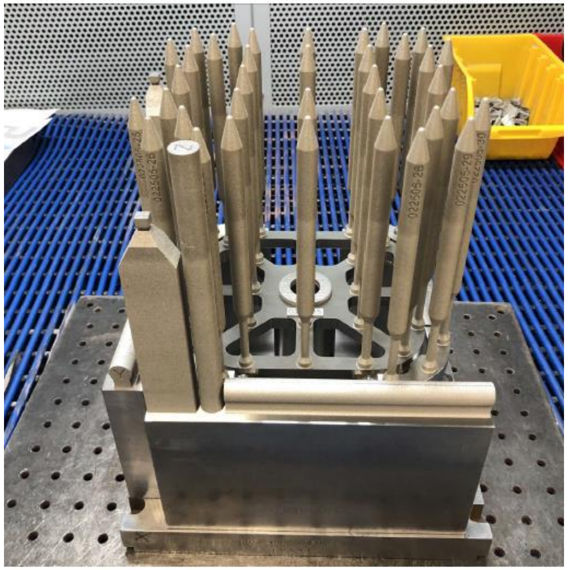
PWR Thimble Plugging Device - 316L Material

- Selected as first AM demonstration component in commercial reactor
  - Low risk component, moderate complexity
  - **Inserted in U.S. PWR in Spring 2020**



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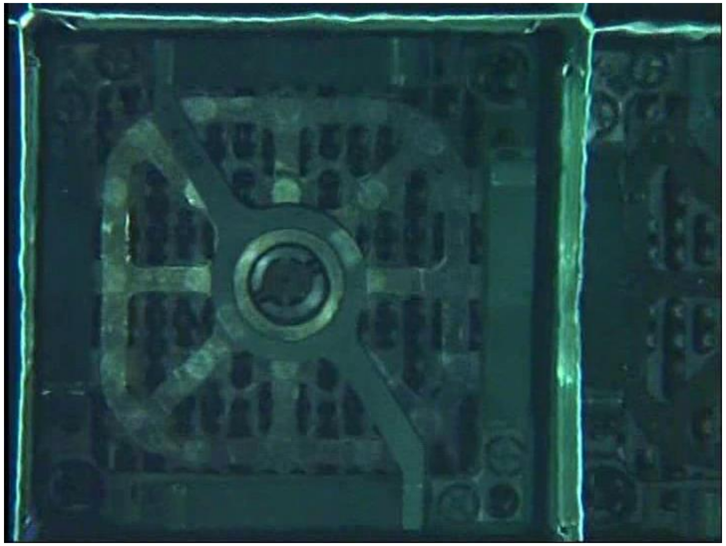
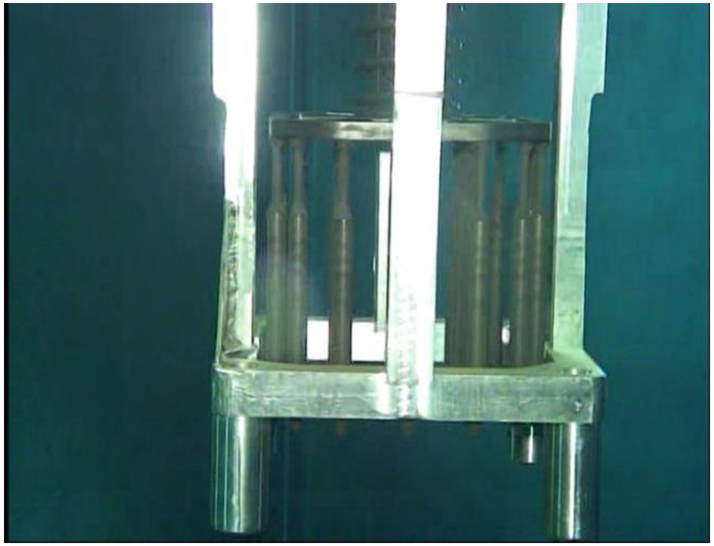
PWR Thimble Plugging Device - 316L Material

- First inspection (after one 18-month cycle) in Sept 2021
  - No visual distortion
  - Normal drag forces during removal and reinsertion
- Component placed back in core for further irradiation



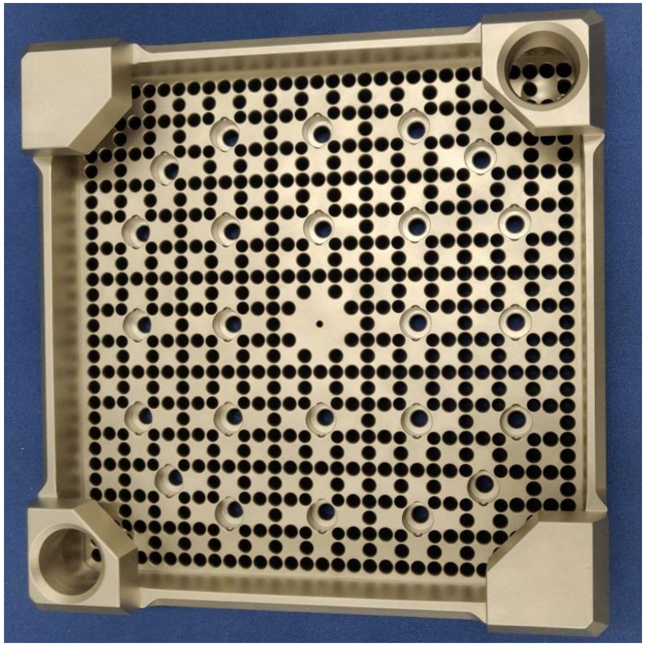


Expected appearance

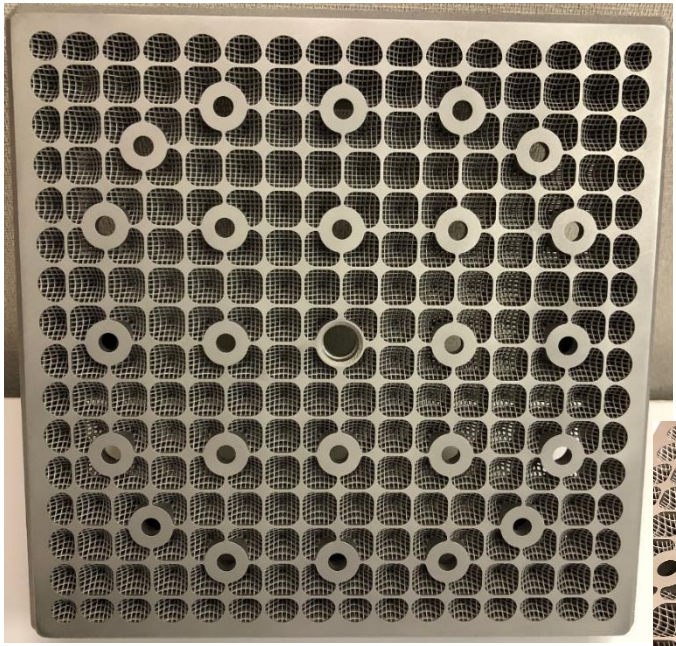
PWR Additively Manufactured Bottom Nozzle - A718 Material

- Improved debris filtration with same pressure drop
- Larger flow holes enabled by utilizing strength of A718 material
- Double spire with several mesh thicknesses evaluated

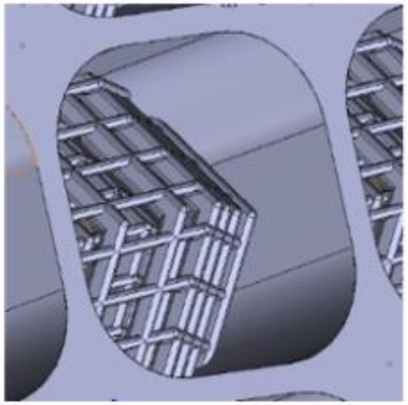
Conventional Design

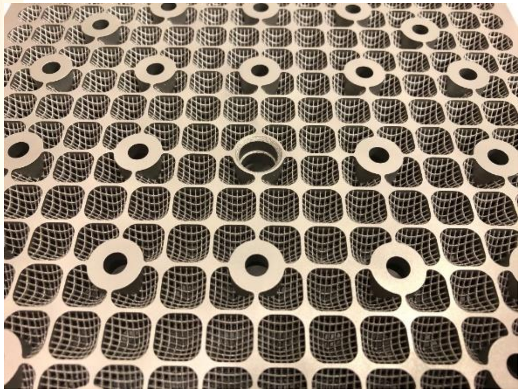


AM Design



Double spire mesh





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To be inserted as Lead Test component in 2024

BWR StrongHold® Debris Filter - 316L Material

- Outstanding debris capture performance thanks to internal design features only possible with AM
- First AM component to be inserted in reactor core for improved performance (intended for final use)

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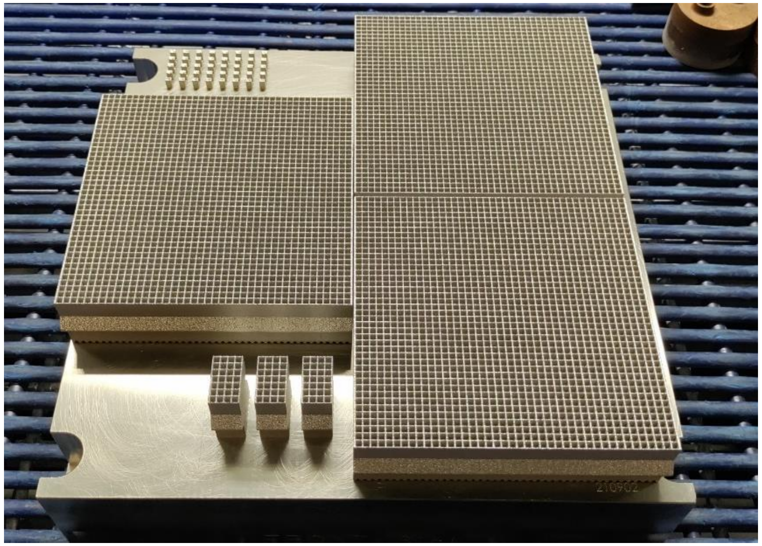
First use of 3D-printed nuclear fuel debris filters

14 June 2022

Share

Nuclear fuel debris filters manufactured by Westinghouse Electric Sweden AB using 3D printing technology have been installed at unit 2 of the Olkiluoto nuclear power plant in Finland and unit 3 of the Oskarshamn plant in Sweden.



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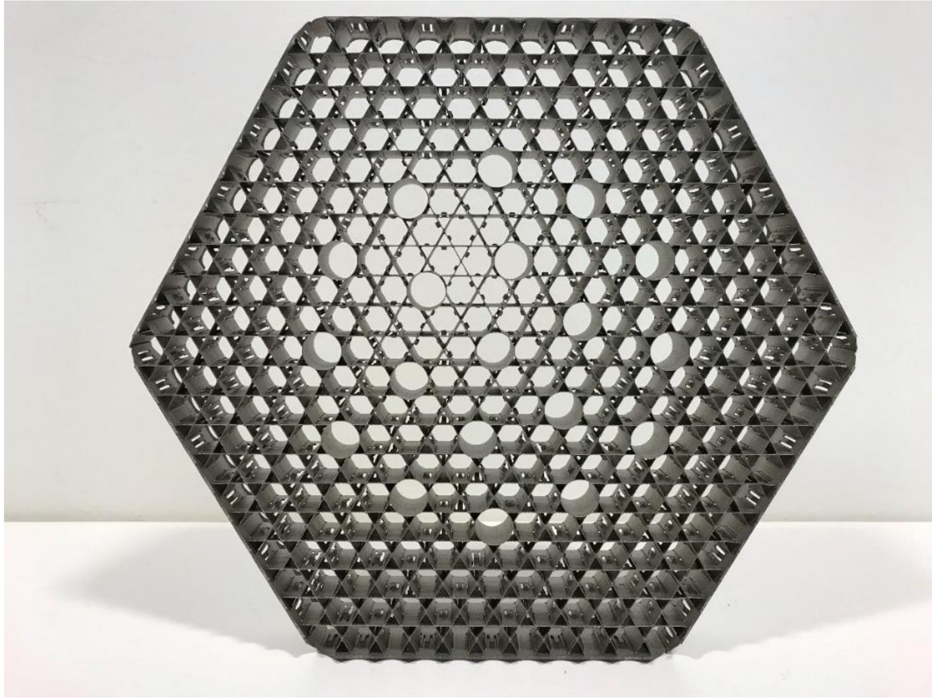
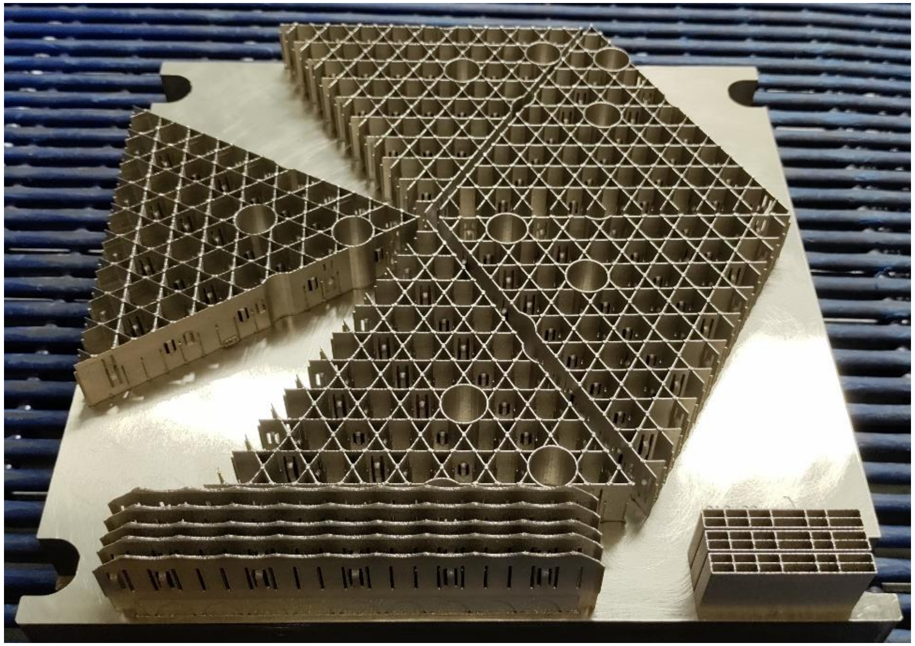
Lead Test StrongHold filters operating in Oskarshamn 3 and Olkiluoto 2 BWR units since May 2022

VVER-1000 Prototype Grids - A718 Material

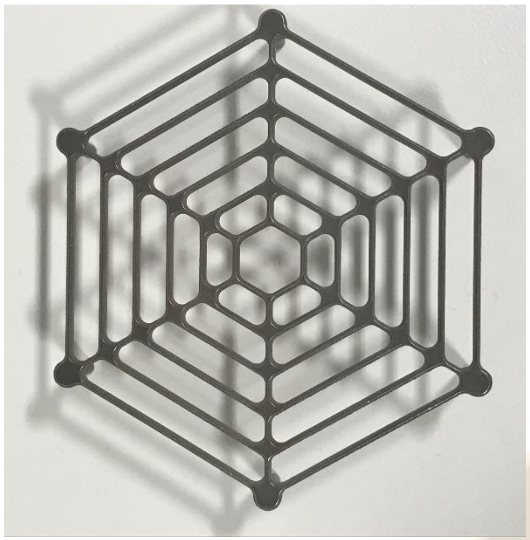
- Full-size grids in A718 material made for scoping tests of new grid design concepts and existing RWFA grid as reference

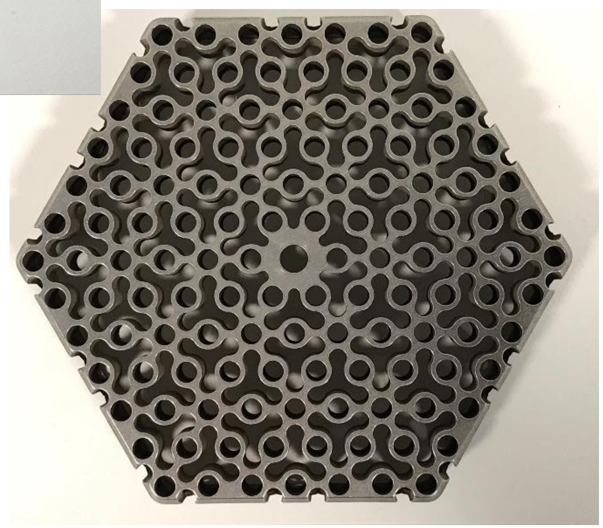


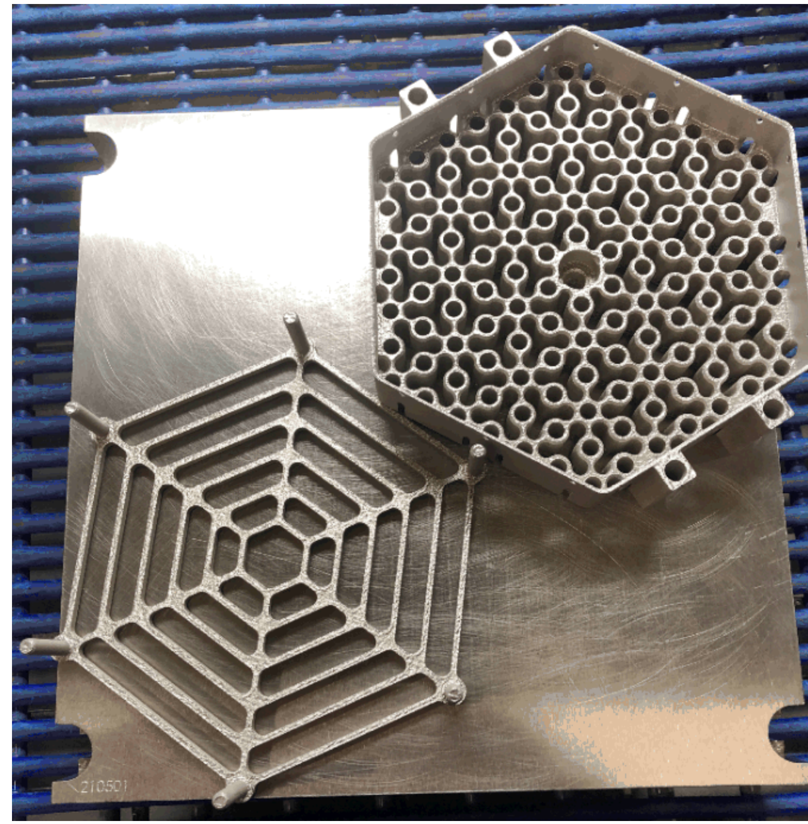


VVER-440 Flow Plates
- 316L Material

- AM process used for top and bottom flow plates







AM Process Development

AM Process Development Steps

- Design for AM (CAD to as-printed model)
- Optimize machine parameters for geometry, mechanical properties and surface finish
- Build part
- Cleaning / powder removal
- Heat treatment (on build plate)
- Post machining
- Surface treatment
- Dimensional inspection
- Mechanical / material testing

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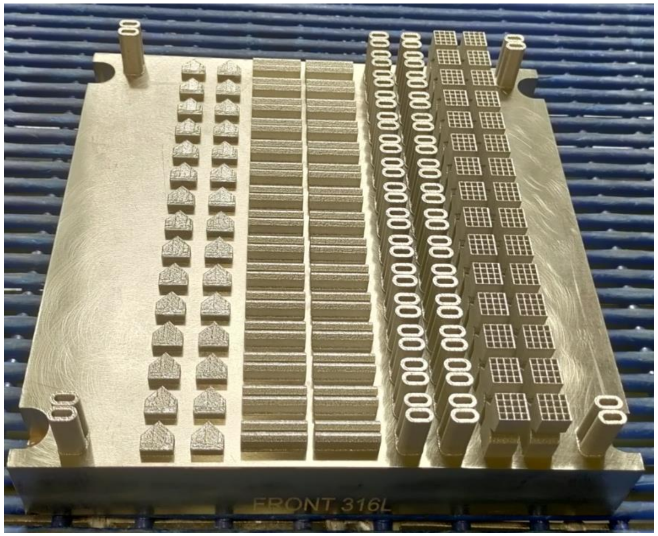
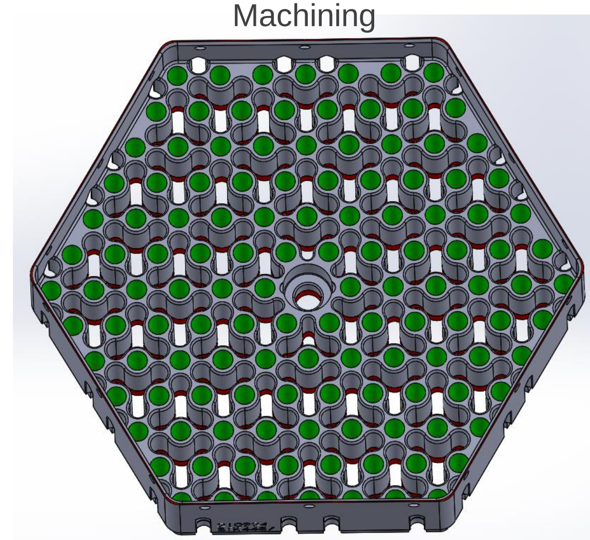
AM Process Development Steps

30/60µm parameter optimization build

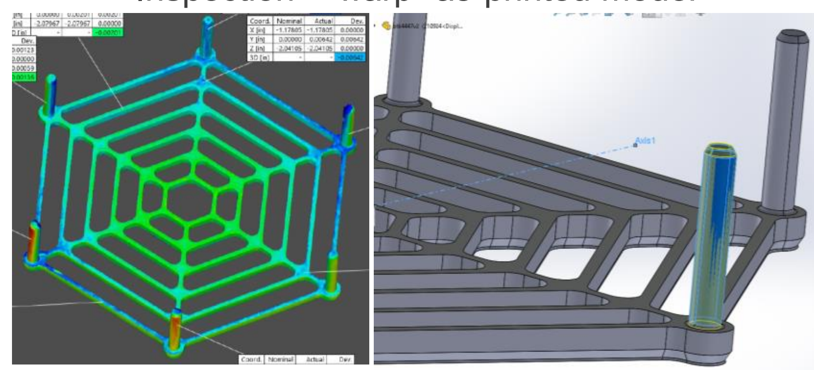


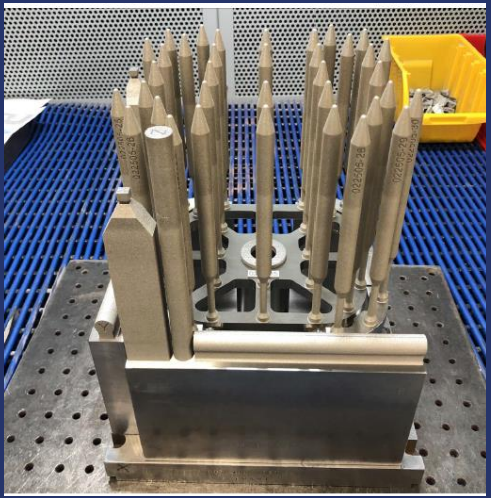
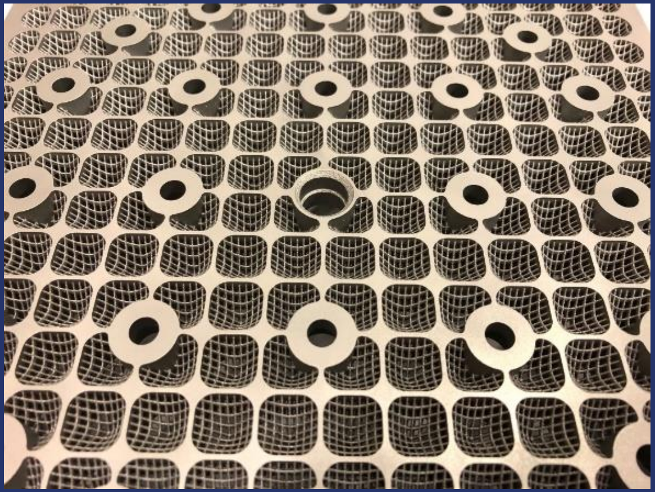
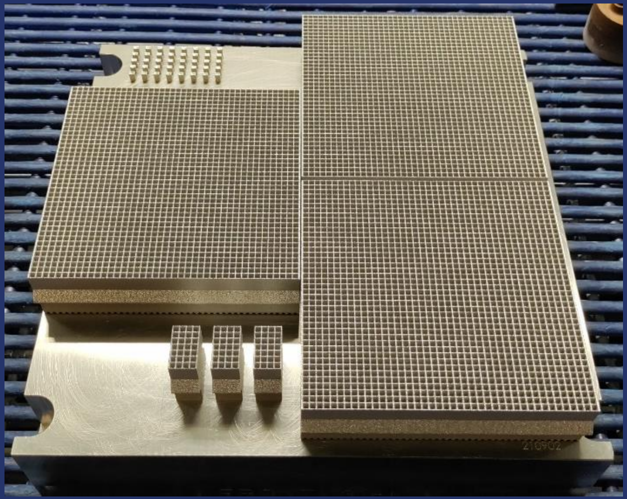
Machining



Mechanical Testing

Inspection - “warp” as-printed model



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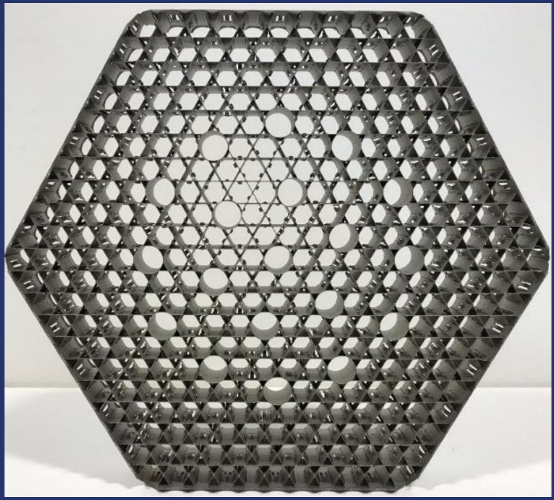
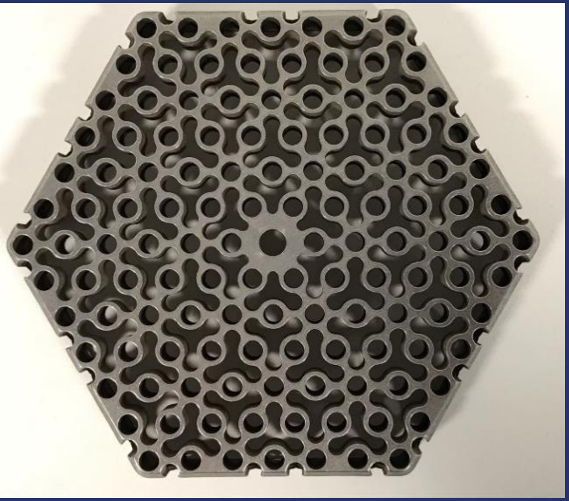
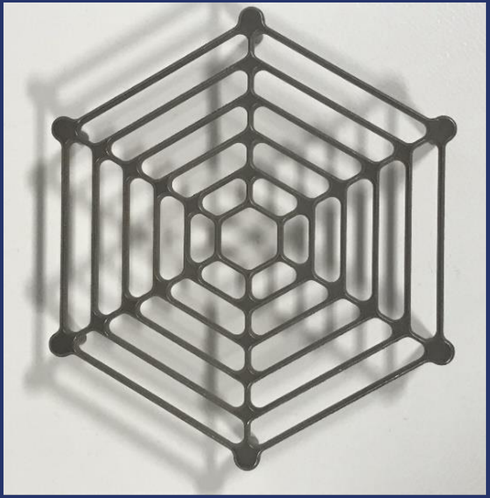

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