



PIE of AM 316SS Thimble Plugging Device After Three Cycles of Operation in Byron Unit 1

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ABSTRACT:

Additive manufacturing methods can enable improved fabrication of components with innovative features and enable diverse supply chains for the current and future light water reactor fleet. Early applications for additively-manufactured (AM) nuclear components include austenitic stainless steels due to feedstock availability and initial codification work for material properties and design within the ASME Boiler & Pressure Vessel Code.

Westinghouse fabricated a thimble plugging device (TPD) using laser powder bed fusion (LPBF) by printing Type 316L Stainless Steel (316L-SS) rodlets on top of a wrought Type 304SS base plate. This TPD was inserted in Byron Unit 1 in 2020 and was removed in Fall 2024, becoming the first AM component with significant thermal neutron dose (~1.8 dpa estimate) in a commercial pressurized water reactor (PWR) available to the industry for evaluation.

The objective of this proposal is to perform advanced microstructural analysis of the non-irradiated and irradiated AM rodlets and the conventional base plate. The analytical Scanning/Transmission Electron Microscopy coupled with X-ray Energy Dispersive Spectroscopy S/TEM-XEDS characterization will focus on identification of radiation-induced defects, cavities and nanoscale segregation, as well as the formation of any secondary phases. TEM samples will be prepared by twin-jet electropolishing of 3 mm discs. These specimens will be obtained from three regions: AM-TPD rodlet tip (closest to the fuel) and base (further away), and the conventional base plate adjacent to the rodlet base. The electropolished specimens will be supplemented with a smaller number of TEM lift-out samples prepared using focused ion beam (FIB) from the same regions to provide a microstructural comparison between specimens that only have neutron damage (TEM foils) and those prepared using a Ga+ FIB (FIB lift-out specimens), which contain both neutron and ion damage (due to FIB milling process). The purpose of this technique comparison is to provide data showing similarities and differences between the resultant microstructures so that other researchers who do not have the facilities to make TEM foils from highly irradiated components but have access to FIB can use these data to better separate the effects of ion damage from neutron damage in AM components. Scanning Electron Microscopy (SEM) micrographs of polished cross-sections of the AM rodlet and rodlet/base plate region will also be provided. All TEM specimen preparation and SEM characterization will be performed at the Westinghouse Hot Cell Facility. All STEM-XEDS characterization will be conducted at INL-IMCL.

This project has two deliverables:

- 1) An interim report that summarizes the results of sample preparation activities and cursory evaluation of non-irradiated TPD samples, and SEM, provided in Q1 of FY2026
- 2) Final, formal report containing detailed S/TEM and XEDS evaluation of the irradiated and non-irradiated specimens, provided in Q4 of FY2026

Understanding how the post-irradiated microstructure relates to mechanical properties will immensely help industry's acceptance of AM components for irradiation applications in the commercial nuclear market as well as providing critical PWR irradiation data on AM 316L-SS.