Delivering the Nuclear Promise
Top Innovative Practice

December 11, 2023

DNP-TIP-2023–02

Implementation of Advanced PRIME™ Fuel Features
2023 Top Innovative Practice Winner[1]
Westinghouse Vendor Award Winner

Summary

At Southern Nuclear Company (SNC), the PWR Fuel Engineering team worked with Westinghouse to implement the PRIME™ fuel features, that offer safety and economic improvements due to a more robust fuel design. Implementing PRIME™ fuel ensures that operator burden from fuel performance is minimized while keeping the reactor in a safe operating condition.

PRIME™ fuel features[2] consist of three enhancements to the 17x17 Optimized Fuel Assembly (OFA) fuel design: Low Tin ZIRLO™ grid strap material, reinforced dashpot for the guide thimble tubes, and a lower pressure drop bottom nozzle (PRIME™ BN).

Innovation

With an eye toward innovative approaches, SNC PWR Fuel Engineering achieved gains in PWR fuel performance margins by leveraging improvements in nuclear materials (Low Tin ZIRLO™) and research and development on bottom nozzle flow and debris capture.

The PRIME™ fuel Low Tin ZIRLO™ grid strap implementation at the Plant Farley and Plant Vogtle units represents the first reload quantities of this grid material design in a Westinghouse NSSS fuel design (17x17 OFA). Implementation of this change leveraged data and evaluations from previous lead test assembly (LTA) programs and successful reload implementation in other reactor designs (KWU[3] and CE plants).

The PRIME™ BN implements the debris resistance and debris capture features of Westinghouse's Advanced Debris Filter Bottom Nozzle (ADFBN) to prevent inter-fuel assembly debris migration. The PRIME™ BN also uses an updated flow hole design implemented in 17NGF[4] assemblies to improve pressure drop and increase flow through the assembly. Thus, this bottom nozzle design combines the benefits of two previous bottom nozzle improvements for a more robust bottom nozzle design.

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[1] Winning entries of from NEI's Top Innovative Practices (TIP) awards are republished as DNP Efficiency Opportunities to ensure the broadest possible dissemination of these operating plant innovations.
[2] For more information, see https://www.westinghousenuclear.com/Portals/0/flysheets/NFCM-0008%20PRIME.pdf
[3] Kraftwerk Union
[4] Westinghouse 17x17 Next Generation Fuel

The reinforced dashpot in the guide thimble tubes has successfully operated in other Westinghouse fuel designs. However, the implementation at Plant Farley and Plant Vogtle is the first use of this variation in the 17x17 OFA fuel design.

Background

Operating costs for nuclear units have grown significantly since the start of the commercial nuclear power industry. For nuclear power generation to remain competitive in the future, process efficiencies and innovations are needed. The challenge for any change in the nuclear industry is that it must be safe as well as innovative. An area of opportunity to reduce operating costs while improving operational safety is through improved fuel design and manufacturing.

Safety

The design functions of the fuel assemblies are to serve as the primary fission product barrier, to allow full control rod insertion within the credited rod drop time, and to maintain a coolable geometry.

The fuel rod matrix and cladding provide the primary fission product barrier. The PRIME™ mid and IFM[5] grids use Low Tin ZIRLO™ material, which has a lower tin content than the previously used ZIRLO™ material. The lower tin content results in less growth at high burnup and improves corrosion resistance and grid-to-rod fretting margin. The PRIME™ BN fuel design feature also enhances debris resistance performance. This change provides a more robust barrier to fuel failure.

The fuel assembly skeleton is primarily responsible for maintaining a coolable geometry. The bottom nozzle serves as the bottom structural element of the fuel assembly and directs the coolant flow to the fuel assembly bundle region. The PRIME™ BN decreases flow resistance which allows increased flow through the fuel assembly. This increased flow has a positive impact on the margin to Departure from Nucleate Boiling (DNB[6]). DNB analysis is one of the key safety analyses performed each cycle. Maintaining sufficient DNB margin prevents excessive clad temperature during safety transient analyses, specifically Condition II faults.

The top nozzle and guide tubes allow for control rod insertion. The reinforced dashpot design is a more robust guide tube design which improves dimensional stability at higher burnup. This more robust design is less prone to guide tube and fuel assembly bowing with increased burnup, thus improving margin to incomplete control rod insertion. This change also benefits fuel handling at higher burnup.

Cost Savings

The industry is developing various initiatives to increase cycle lengths and increase fuel average burnups. Increased cycle lengths have the potential to reduce outage lengths and/or frequency which reduces overall outage costs including replacement power cost. Increased fuel average burnups allow for better fuel utilization and optimization. This can lead to reduced upfront fuel purchase costs as well as savings in dry cask storage.

The improvement in fuel performance margins gained using PRIME™ fuel features can be leveraged as part of these cost-saving initiatives. In addition, the PRIME™ fuel features provide improvements to fuel performance by reducing risk of grid-to-rod fretting failures, debris fretting failures, and assembly damage due to assembly bow and distortion. Fuel failure and fuel damage often require core redesign during the outage which results in a less optimized core loading pattern and less optimized use of the fuel, thus impacting fuel costs. In addition, preventing fuel failures results in $4-6 million dollars in inspection and root cause analysis costs that are saved

[5] Intermediate flow mixing grids, as described at https://www.westinghousenuclear.com/Portals/0/flysheets/NFCM-0009%20RFA-2%20Design.pdf
[6] The point at which the heat transfer from a fuel rod rapidly decreases due to the insulating effect of a steam blanket that forms on the rod surface when the temperature continues to increase.

for every fuel cycle that operates defect-free. The PRIME™ fuel features reduce the likelihood of incurring such costs.

Productivity/Efficiency

The PRIME™ fuel features provide improvements to fuel performance by reducing risk of grid-to-rod fretting failures, debris fretting failures, and assembly damage due to assembly bow and distortion. Fuel failure and fuel damage can significantly impact engineer workload and productivity during the cycle as well as additional fuel management and handling during outages to perform fuel inspections. Also failed or damaged fuel can often require core redesign during the outage which requires significant employee time and outage hours. The PRIME™ fuel features reduce the risk of these failures.

Transferability

The PRIME™ fuel features have been implemented on the 17 OFA design at the Plant Farley and Plant Vogtle units. The successful implementation at SNC is fully transferable to all units using the 17 OFA fuel design and is expected to become the new standard for this fuel design. These changes are also transferable to other Westinghouse NSSS designs such as the 17 RFA fuel design.

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Additional Information

None