Delivering the Nuclear Promise
Top Innovative Practice

December 11, 2023

DNP-TIP-2023–01

Lost Parts Penalty Removal for Peripheral Core Locations
2023 Top Innovative Practice Winner[1]
GE Hitachi Vendor Award Winner

Summary

Nuclear plants strive to prevent the intrusion of foreign materials into the reactor coolant system (RCS). When these foreign material controls reveal that a foreign object might be lost in the RCS, plant personnel take exhaustive measures to locate and remove the lost object. When that fails, the plant resorts to evaluating the potential effects of the lost object on critical components, including fuel. This evaluation could lead to setting lower operating limits for the most susceptible fuel bundles in a boiling water reactor (BWR) core. A cross-disciplinary team at Constellation Nuclear Fuels developed advanced analytics to determine whether certain operating limit penalties for BWR fuel bundles in the periphery of the core could be eliminated in this scenario. The penalties are applied to ensure that a potential flow blockage due to lost parts assumed to be in the reactor coolant system would not threaten the integrity of fuel rods in peripheral bundles. The analytics substantiated that the penalties could be removed, and the approach was piloted successfully at the Limerick plant. Constellation is now applying this approach to other BWRs in the Constellation fleet.

Innovation

Nuclear fuel operating limits include conservatisms ("penalties") based on assumptions about potential blockage of coolant flow through each fuel bundle. Constellation Nuclear Fuels developed an innovative approach that eliminated the need for applying operating limit penalties for fuel bundle flow blockage considerations for lost parts (see Figure 1) in the vessel.[2] This approach was developed specifically for peripheral fuel bundles as these bundles have a smaller inlet orifice, resulting in more severe blockage potential. Inlet flow blockage of this magnitude would severely reduce the available flow, and hence impair cooling of the fuel bundle, potentially resulting in dryout conditions and fuel failure. This straightforward, easy to implement approach is predicated on approved regulatory bases and industry operating experience. By eliminating the need for operating limit penalties, this new approach reduces the scope and resource requirements for evaluating the impact of lost parts, which arise most often during a refueling outage. Hence, this reduces the risk of extending outage time. Eliminating the need for applying thermal limit penalties also reduces the fuel cycle impact.

[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] As noted previously, the plant follows a rigorous process to find and remove foreign materials determined to be lost in the reactor coolant system. The advanced analytics discussed here are not an alternative to that process, but a compliment to it.

The first pilot application of the new approach was implemented at the Limerick Generating Station and resulted in removing the operating penalty imposed upon peripheral bundles (a more than 60% operating limit improvement for these bundles). The same approach was extended to the Quad Cities Nuclear Power Plant. Due to the generic nature of the developed approach, this approach can be applied to any other BWR.

Background

After identifying the need for an industry-wide standardized approach to reduce operating limit penalties, a proposal was submitted to the Constellation Innovation Team. The project was launched and the core development team identified that improved analytics could help reduce rework, operator burden, and costs associated with operating with the peripheral bundle penalties imposed by previous approaches. After these initial steps, the core team worked to find an effective solution for the question of, "How might we respond to lost parts in a manner that is less burdensome, minimizes operating limit penalties (and fuel cycle cost impact), and reduces downstream impacts?" The team identified a success path through an analytical approach.

Safety

By eliminating the need for extensive operating limit penalties and considering the applied region of the core (i.e., peripheral fuel bundles), this approach reduces the need for control blade maneuvers in the high burnup region of the core. This reduces the risk of High Residence Time (HRT) and associated fuel integrity issues, further improving safety.

Cost Savings

There are two direct cost savings areas:

1) Avoiding fuel cycle impacts (due to elimination of the thermal limit penalties)

2) Reducing the risk of outage extension by removing lost parts evaluations from the outage critical path

There are indirect cost savings, as well. The approach eliminates the need for control blade maneuvers near HRT bundles, reduces the risk of HRT Pellet Clad Interaction[3] fuel failures, and averts the impacts of BWR fuel failures (e.g., reducing radioactivity in the coolant, contamination in the plant, radiation exposure to workers).

Productivity/Efficiency

This approach was developed in collaboration with Constellation Safety Analysis, Fuel Reliability, Regulatory Assurance, and Reactor Engineering groups. The applied approach reduces the scope and resource requirements for lost parts evaluations, which are typically required during refuel outages, when most available plant resources are already being fully utilized to support standard outage efforts. Furthermore, eliminating the need for thermal limit penalties on peripheral fuel bundles eliminates the need for additional resources in the control room for manual operating limit monitoring of these otherwise non-limiting bundles.

Transferability

The developed approach is generic and can easily be applied to any other BWR. Constellation is in the process of implementing this solution for its entire BWR fleet. Additionally, this innovative concept was adopted as the industry best practice guidance by the Boiling Water Reactor Owner's Group – Reload Analysis and Core Management Committee (TP23-SEQ-205, Reload Analysis and Core Management Committee, Best Practice Guidelines – Lost Parts Penalty Removal Guidance – Peripheral Bundles, October 2023).

[3] Background on Pellet-Cladding Interaction is available at https://www.nrc.gov/docs/ML0935/ML093500677.pdf.

Team Members

- Baris Sarikaya, Sr. Staff Fuels Engineer, Constellation
- James Fogarty, Sr. Staff Fuels Engineer, Constellation
- Chad Burns, Project Manager, Nuclear Fuels, Constellation
- Eric Bruch, Sr. Engineer, Constellation
- James Tusar, Sr. Manager, Nuclear Fuels, Constellation

Additional Information

Figure 1 – Lost Parts Found in Reactor Vessel