Delivering the Nuclear Promise
Top Innovative Practice

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Deployment of a Full Lead Test Assembly of Accident Tolerant Fuel at Calvert Cliffs-2

2022 Top Innovative Practice Winner

Summary

In recent years the nuclear industry has been challenged to produce innovative fuel products and engineering solutions that both lower costs and improve safety and operating margin to ensure long-term success of the industry. To meet this industry need, Framatome has spent the last several years developing an Accident Tolerant Fuel (ATF) product. Constellation and Framatome are partnering to bring batch ATF fuel into commercial reactors.

Constellation deployed the Framatome PROtect™ Lead Test Assembly (LTA) at Calvert Cliffs-2. This is unique, first of a kind LTA utilizes accident tolerant chromia doped uranium dioxide fuel pellets and chromium coated fuel rod cladding. This is the first LTA to demonstrate technological improvements in both cladding and fuel pellet design.

The Framatome PROtect™ LTA (Figure 1) was developed and deployed in response to the U.S. DOE ATF initiative and will improve reactor safety and economics when deployed in reload quantities. The accident tolerant attributes of this LTA improve reactor safety during normal operation, transients, design basis accidents, and beyond design basis accidents. This more robust fuel type will also help support burnup limit extension, which will enable the use of higher U-235 enrichment. This new fuel assembly type will be transferable across the entire Framatome-fueled PWR fleet, and much of what has been learned in developing advanced manufacturing technology will be applicable to Framatome's development of BWR ATF fuel as well.

Innovation

The Framatome PROtect™ LTA project has demonstrated several firsts for the U.S. industry: First deployment of a full fuel assembly with full-length chromium-coated rods – The processes necessary to coat an assembly's worth of full-length fuel rods were scaled and refined to support this initiative. The manufacturing and tooling necessary are all first-of-a-kind (FOAK) and required innovative solutions to comply with stringent coating quality requirements in the timeframe needed for loading in the Calvert Cliffs Unit 2 core.

Safety

The Framatome PROtect™ LTA contains features that will improve reactor safety for the nuclear industry:

- Fretting resistance – The material characteristics of the chromium coating provide significant additional

margin to fretting-type failures, including debris fretting which remains one of the primary causes of fuel leaks in the nuclear industry.

- Potential coping time increase – The time for operators to restore emergency power, cooling, and achieve safe shutdown in the event of a beyond design basis accident is increased in coated rods due to oxidation rate reduction on the rods at high temperatures.

- Corrosion resistance – Chromium-coated cladding exhibits a substantial improvement in corrosion, even when compared to advanced zirconium alloys currently in use. This has the potential to result in a decrease in hydrogen generation in the event of a beyond design basis accident. Further, it could also result in a lower propensity for Crud Induced Localized Corrosion (CILC) and Crud Induced Power Shift (CIPS).

- Reduced Dose Rate Due to Fission Gas Retention – Dose rates in the event of fuel failures may be reduced due to improved fission gas retention and washout characteristics in chromia-doped fuel pellets. This allows plant personnel to receive lower doses for needed work and helps ensure the health and safety of the public.

Cost Savings

Anticipated costs savings from the features of the Framatome PROtect™ fuel assemblies could be substantial and can be used as one of the means to ensure the viability of nuclear plants well into the future. The following features will provide cost savings:

- Reduction or elimination of fuel cleaning – Given the corrosion resistance of the chromium-coated rods, fuel cleanings can either be eliminated or reduced. This would be a substantial O&M savings over the life of the plant. It is estimated that a savings of $1M per reload can be realized if fuel cleaning is eliminated. Additional savings could be realized by considering ALARA, critical path savings, and personnel allocation to other critical tasks.

- Compatible with Higher Burnups – With the corrosion resistance of chromium-coated fuel rods and the improved fission gas retention and stability of chromia-doped fuel pellets, higher overall burnups may be supported. This allows for better fuel utilization and smaller batch sizes, which helps to reduce fuel costs.

- Ramp rate relaxation – The stability of the chromia-doped fuel pellets due to their larger grain size allows for ramp rates which can be faster than current fuel technology allows. This could result in significant savings each cycle.

- Fuel Failure reduction or elimination – The significant additional margin to fretting-type failures could result in cost savings of up to $5M in one cycle assuming a fuel failure was prevented. This value considers higher dose rates, core redesign costs, field exams, sipping, ultrasonic testing, and other costs that are incurred in the event of a fuel failure.

Productivity/Efficiency

There are multiple increases in efficiency and productivity resulting from the use of the Framatome PROtect™ LTA that could reduce activities by many man-months:

- Elimination of Fuel Cleaning – The elimination of fuel cleaning results in at least two man-months of productivity savings. This is quantified by assessing the time involved from procurement, equipment mobilization, fuel cleaning time itself, and demobilization activities. Efficiencies are gained as well when utility employees can focus the time savings on other activities.

- Fuel Failure Prevention/Elimination – If a fuel failure is prevented, this results in at least 6 man-months of productivity savings for activities including root cause analyses, core redesigns, procurement of sipping and testing equipment, and cycle monitoring activities.

- Ramp Rate Relaxation – The ability to relax ramp rates can result in long term efficiency gains over the course of plant life. Further efficiency gains can be obtained if a plant experiences mid-cycle trips through the course of a given cycle.

- This more robust fuel type will support burnup limit extension, which will in turn permit the use of higher U-235 enrichment. These efficiency gains in the nuclear fuel cycle could support longer fuel cycles, resulting in reduced outage time.

Transferability

The chromium coated rods and chromia-doped fuel pellets are the primary features of the Framatome PROtect™ LTA design. These features will be interchangeable among many fuel assembly designs for the PWR fleet, providing immediate benefit to the nuclear industry with minimal impact to processes and procedures.

Team Members

- William Gassmann, Senior Staff Fuels Engineer (Constellation)
- Tim Schearer, Senior Staff Fuels Engineer (Constellation)
- Tom Morello, Principal Fuels Engineer (Constellation)
- Ken Connor, Reactor Engineering Manager (Constellation)
- Rachel Love (Framatome)

Figure 1 - Framatome_PROtectTM_LTA

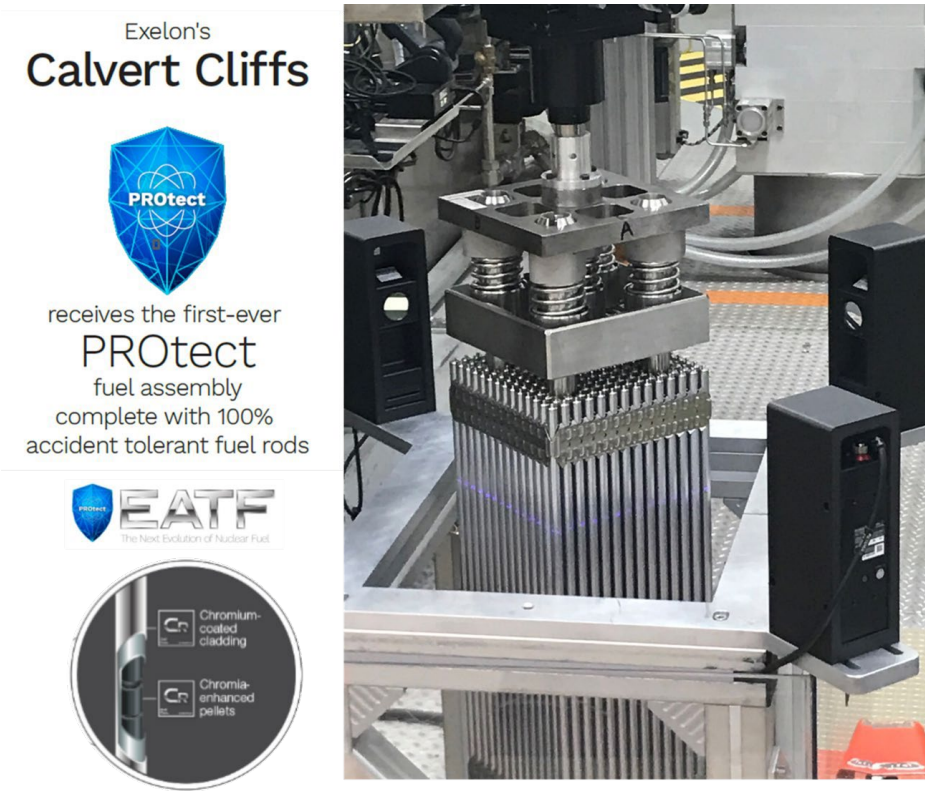

Figure 2 – Physical Vapor Deposition (PVD) Method

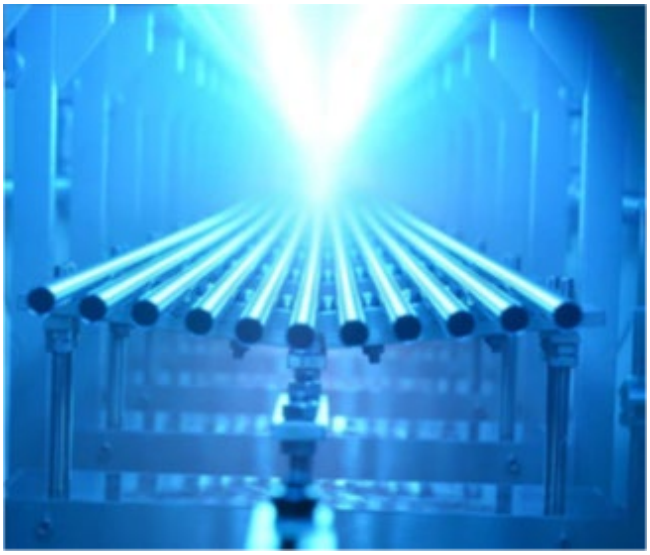

Figure 3 – Delivery of ATF Assembly at Calvert Cliffs