Nuclear Fuel/Fuel Engineering

Westinghouse RFA-2 Design

**Background**

The Westinghouse nuclear fuel business has more than 30 years of experience in the design of nuclear fuel assemblies that help utilities achieve exceptional fuel reliability and performance in today’s operating and commercial environment.

Building on that experience, the 17x17 robust fuel assembly (RFA-2) has been employed with excellent fuel performance throughout the United States and worldwide.

**Description**

The RFA-2 fuel assembly can provide the lower cycle costs needed in today’s competitive market. With advanced features like fretting margin, heat transfer improvements, the Westinghouse integral nozzle and enhanced debris mitigation, customers can feel confident about fuel performance.

**Fretting Margin**

RFA-2’s increased contact area with the rod is its primary method to significantly improve grid-to-rod fretting performance. In addition, the springs have less stiffness to reduce static and dynamic loads, and the edge geometry of the springs and dimples has been improved to reduce edge hardness. Endurance testing has shown the RFA-2 mid grid to improve grid-to-rod fretting performance four times more than previous designs.

**Heat Transfer Improvements**

The RFA-2 mid grid incorporates a high-performance mixing vane to optimize coolant mixing. This enhanced mixing improves departure from nucleate boiling (DNB) performance and reduces fuel rod hot spots, which are known to contribute to crud buildup on fuel rods and power shifts in the core. This heat transfer is further enhanced by using high-performance intermediate flow mixers (IFMs). The use of three IFMs provides additional coolant mixing, improves thermal margin and reduces fuel rod surface temperatures for reduced oxidation and crud disposition.

**Westinghouse Integral Nozzle**

The Westinghouse integral nozzle (WIN) is an industry-leading design with proven performance. Spring reactive loads are restrained completely by the nozzle castings, and there are no screws, thereby providing trouble-free operation. The WIN meets all Westinghouse and industry requirements and is directly interchangeable with the former design.

**ZrB₂ Integral Fuel Burnable Absorber**

Fuel cycle economics are important to any utility, and Westinghouse’s zirconium diboride (ZrB₂) integral fuel burnable absorber (IFBA) is a key element in achieving superior fuel cycle costs (FCCs). ZrB₂ was specifically designed to allow utilities to achieve optimum uranium utilization over a multitude of loading patterns and operating schemes. IFBA rods enhance power distribution with no residual poison penalty. The benefits are increased neutron economy and flexibility, increased margins-to-peaking-factor limits, and lower FCCs and spent fuel costs. No burnable absorber worldwide offers the superior predictability and economics of the Westinghouse ZrB₂ IFBA.
**Optimized ZIRLO**

As the nuclear industry pursues longer operating cycles with increased fuel discharge burnup and more aggressive fuel management, the corrosion performance requirements for the nuclear fuel cladding become more demanding. The cladding material for the 17x17 RFA-2 is the newer optimized ZIRLO material design, which has been demonstrated to have improved corrosion resistance compared with prior fuel cladding materials. The optimum tin level provides a reduced corrosion rate while maintaining the benefits of mechanical strength and resistance to accelerated corrosion from abnormal chemistry conditions. Reducing the associated corrosion buildup, and thus minimizing temperature feedback effects, provides additional margin to fuel rod internal pressure design criteria.

**Enhanced Debris Mitigation**

No one surpasses Westinghouse’s proven multi-layer debris protection. RFA-2 uses three layers of protection, including a standardized debris filter bottom nozzle (SDFBN) protective grid and long solid-fuel-rod-bottom end plug, and optional fuel rod oxide coating.

The SDFBN provides the first level of defense against debris. Designed to mitigate debris-induced fuel rod fretting failures, the SDFBN has proven effective in enhancing reliability and reducing costs that could result from repair and replacement.

Located atop the SDFBN is the robust protective grid (RPG). The RPG provides an additional debris barrier, resulting in increased fuel reliability. Any debris that passes through the SDFBN will tend to be trapped in the RPG against the elongated solid-fuel-rod-bottom end plug.

The final level of debris protection is provided by applying an oxide coating that shields the bottom six inches of each fuel rod, thus increasing wear resistance over uncoated cladding.

Added together, this provides a level of debris mitigation that is unsurpassed.

**Axial Blankets**

Axial blankets provide improved fuel cycle economics by reducing neutron leakage from the core. The enhanced neutron economy of the blankets means that more neutrons are available to support longer cycle lengths (18 to 24 months). The use of 6- to 8-inch axial blankets at the top and bottom of the fuel stack provides an optimum uranium resource benefit that satisfies a broad range of operating conditions.
Field Proven Performance
RFA/RFA-2 17x17 fuel has operated in 55 plants in the United States, Spain, Belgium, France, Sweden and South Africa. The first RFA reload regions began operation in 1998 and the first RFA-2 reloads began in 2003. All plants that had initially implemented RFA have now transitioned to the RFA-2 fuel product with its improved grid-to-rod fretting margin. The following observations can be made on the experience of RFA/RFA-2 fuel shipments through the end of 2012:

- RFA fuel has been used in 20 plants with 103 reload regions and 7,084 assemblies
- RFA-2 fuel has been used in 54 plants with 232 reload regions and 10,958 assemblies
- Either RFA or RFA-2 fuel has been used in 55 plants with 335 reload regions and 18,042 assemblies with 4.76 million fuel rods
- RFA/RFA-2 fuel has been used in both three-loop and four-loop 17x17 plants with 12-foot fuel designs with and without IFM grids and 14-foot fuel designs without IFM grids over a range of coolant temperatures, flow rates and inlet flow distributions.

The RFA/RFA-2 design has effectively eliminated grid-to-rod fretting of the mid-grid as a leakage mechanism. This includes several assemblies that have operated for four 18-month cycles with residence times of about six years. Fretting wear exams that have been performed on discharged RFA or RFA-2 fuel have shown low wear, less than 10 percent generally.

The overall performance of this fuel has been very good for fuel using the protective grid that provides additional stability and sufficient margin to prevent bottom grid fretting. The last deliveries of the RFA fuel design without a P-grid were made in 2008.

There have been zero leakers in the more than 6,700 assemblies that used oxide coated cladding and a P-grid through the end of 2012.

Benefits
The RFA-2 fuel design is built on the proven experience and world-class leadership of Westinghouse in the design and manufacture of nuclear fuel. It provides the following benefits:

- Stiff structure for margin-against-fuel-assembly distortion
- High-contact-area mid grids for significantly increased margins-to-fuel-rod fretting
- IFM grids that provide significant DNB margin
- High-performance mixing vane grids
- High-burnup advanced materials – ZIRLO, and optimized ZIRLO
- Multiple layers of defense against debris
- Industry’s best IFBA
- Axial blankets for optimum fuel cycle economics

Westinghouse’s priority is to develop, design and deliver products and services that meet utilities’ needs for reduced FCCs and excellent reliability in the most timely manner.