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WESTINGHOUSE TRITON11™ BWR FUEL DESIGN

Uffe C. Bergmann
Westinghouse Electric Sweden, Nuclear Fuel Engineering,
Västerås, Sweden, SE-721 63
bergmauc@westinghourse.com

Jeremy King
Westinghouse Electric Company LLC, BWR Product Management, Global Product Management and Strategy,
5801 Bluff Road, Hopkins SC, USA, 290161
kingjs@westinghouse.com

ABSTRACT

This short paper describes the main characteristics of the **TRITON11** fuel design, a new 11×11 BWR fuel design developed by Westinghouse. The current status of development is discussed.

1 INTRODUCTION

The Westinghouse product line includes two fuel products currently delivered to boiling water reactors (BWRs); SVEA-96 Optima2 and SVEA-96 Optima3. Reload quantities of these products have been delivered since 2002 and 2011, respectively.

As a next step in the BWR product line, Westinghouse has developed an 11×11 BWR fuel design named **TRITON11**. Given the current economic pressure on the utilities, the key development objective was to significantly reduce the fuel cycle costs, while maintaining and further improving safety margins. Careful considerations were made to meet the varying requirements between the different BWR utilities. In particular, the fuel was optimized for both short and long cycle operation, as well as for the uprated cores and higher burnups. In addition to these advances, careful considerations were given to the overall reliability of the new design to further reduce the risk of fuel failures.

2 TRITON11 FUEL DESIGN

Further improved fuel economy requires improved thermal margins since both SVEA-96 Optima2 and Optima3 are already highly optimized for reactivity performance at the fuel lattice level. It was realized that better thermal margins must come from adding more fuel rods, thereby reducing the linear heat generation rate and surface heat flux. This requires going beyond the 10×10 fuel lattice and abandoning the SVEA water cross. An 11×11 fuel design was chosen as optimum, considering benefits versus manufacturing cost and added complexity.

The numbers, dimensions and positioning of fuel rods and internal water channels passing non-boiling water were analyzed intensively. The resulting **TRITON11** fuel lattice (lateral view) and fuel bundle (axial view) are shown in Figure 1.

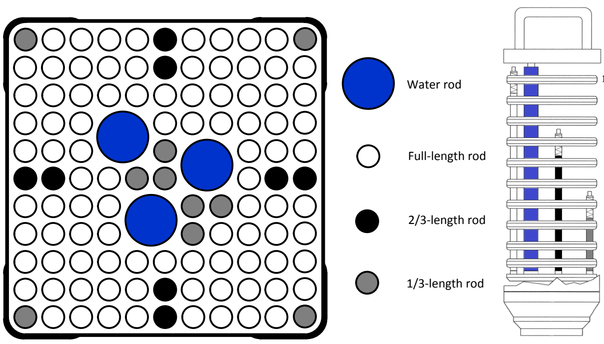

Figure 1: **TRITON11** fuel lattice cross-section geometry (left). **TRITON11** fuel bundle geometry (right).

In total, the fuel bundle contains 109 fuel rods, among them 18 part-length rods (PLRs) of two lengths. The heated rod length (sum of all rods) is increased by 10% as compared to SVEA-96 Optima3. Hence, for the same bundle power, the average LHGR is reduced by 10%. Three cylindrical water channels, denoted *water rods*, have been uniquely adapted to the 11×11 rod lattice which allows an optimum size (when displacing 2×2 rods) and positions with center of gravity close to the center of the fuel lattice. The dispersion of the moderator away from the center gives a more homogenous and more efficient moderation of the fuel rods. The resulting rod power distribution becomes inherently more uniform, even flatter than for SVEA-96 Optima3 which is already highly optimized thanks to the water wings.

The uranium weight is significantly increased as compared to SVEA-96 Optima3. The negative impacts that this would normally have on core stability (due to increased friction pressure drop and stronger void feedback) and shutdown margin (SDM) are more than compensated by the PLRs.

Taking benefit of the extraordinary mechanical strength of the SVEA-96 Optima3 spacer concept where thin flexible cell walls provide line contact with the rods, the **TRITON11** spacer has been made significantly lighter than spacers based on the traditional dimple-spring concept. This provides important enrichment savings (~0.04 wt% U-235) as well as a reduction in pressure drop which is traded into more uranium. The design is aiming for a significant improvement in dryout margin in term of the critical power ratio (CPR), thanks to the increased surface heat transfer area and further optimization of the spacer mixing vane features.

Direct comparisons with Westinghouse's latest product, SVEA-96 Optima3, show typical enrichment savings of 0.10-0.15 wt% U-235; at the same time as significantly reducing the reload size as a result of increasing the uranium weight. Loading fewer fresh bundles means fewer assemblies to the back-end.

Although the **TRITON11** fuel geometry differs quite significantly from SVEA fuels, most of the assembly components are already proven in previous products and are simply adapted to the new geometry: the fuel rod, the spacer grid, the debris filter, the handle, the inlet nozzle, materials, burnable absorber (BA) and UO2 pellets, etc. The important reliability benefits from SVEA-96 Optima3 are maintained: enhanced debris failure resistance and structural strength of spacer grids based on a unique cell-type technology, elimination of potential cladding bending stresses by having fuel rods resting on top of bottom tie plate and extending through top spacer, excellent debris trapping efficiency of **TripleWave+™** filter, robust Inconel X-750 spacer material, excellent dimensional stability and low hydrogen pickup of **Low Tin ZIRLO™** material used for fuel channel and water rods (similarity to SVEA water wings), successful ZrSn-liner, and high-density **ADOPT™** pellet. New data from 2015 confirm low growth and insignificant bow of **Low Tin ZIRLO** channels when operated under very demanding conditions.

The **TRITON11** fuel incorporates a robust mechanical design concept based on lifting via the three water rods. Further improvements in fuel reliability are enabled by: increased thermal margins, **HiFi™** cladding material with reduced hydrogen pickup, spacer frame with improved debris resistance, and redundant bundle lift and spacer capture functions provided by the three (non-U bearing) water rods.

3 TRITON11 DEVELOPMENT STATUS

The **TRITON11** fuel product is in the final stage of development prior to insertion of Lead Test Assemblies (LTAs) in a commercial reactor. The detailed fuel design has been completed, with the exception of the spacer grid thermal-hydraulic features which are still being optimized for dryout performance. Extensive testing and analyses are ongoing to ensure that all design requirements are fulfilled. Various tests are being performed in the Västerås fuel fabrication facility to verify manufacturability and prepare for LTA production. Concepts for fuel service, inspection and repair are being developed. Transport qualification is considered. A rigorous development process is being followed per Westinghouse procedures, with regular Design Reviews involving expertise throughout the company as well as representatives from utility customers. This makes sure that all important aspects are considered.