

Z4B – BQ Fuel Channels

Advanced Alloy for High Burnup Operations

Framatome's Z4B alloy coupled with a beta-quench (BQ) heat treatment reduces fuel channel corrosion and hydrogen uptake and resolves dimensional stability challenges to assure control blades can always be promptly repositioned. Z4B-BQ fuel channels also provide margin for extended burnup without increasing activated metal at the reactor site.

Challenge

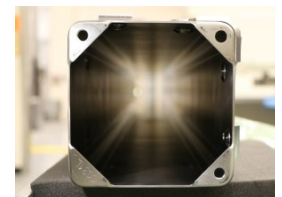
Power uprates and extended intervals between control blade sequence exchanges are important for flexible and efficient BWR operations. However, these operations can be challenging for standard zirconium alloys with only conventional annealing. Many BWRs have experienced channel bow in high burnup fuel sufficient to result in slow-to-settle and even failure-to-settle control blade interference. Hydrogen uptake, particularly when asymmetric between opposing faces, and as-rolled microstructure were identified in extensive root cause investigations as the key factors driving late-life accelerated bow.

Solution

Framatome used its unrivaled experience with zirconium alloys and heat treatments to address the key factors of excessive channel bow. Candidate solutions were validated through extensive laboratory and in-reactor qualification testing to identify the optimal solution: combining a proprietary alloy, the Z4B Alloy, with a beta-quench heat treatment in the final thickness to erase rolling artifacts in the finished sheet. This approach successfully resolves the dimensional stability challenges without increasing the inventory of activated metals at the reactor site.

The Z4B Alloy is a proprietary variant of Zircaloy-4 using the same alloying elements, but with beneficial increases in chromium and iron. This yields more protective precipitates in the finished sheet, reducing corrosion and hydrogen uptake, even under shadowing from control blades.

A beta-quench heat treatment after the sheet is rolled to final thickness precedes conventional annealing to allow crystals to reform in random orientation. By controlling the quench from the beta-phase temperature, the size and distribution of precipitates is optimized for corrosion resistance.



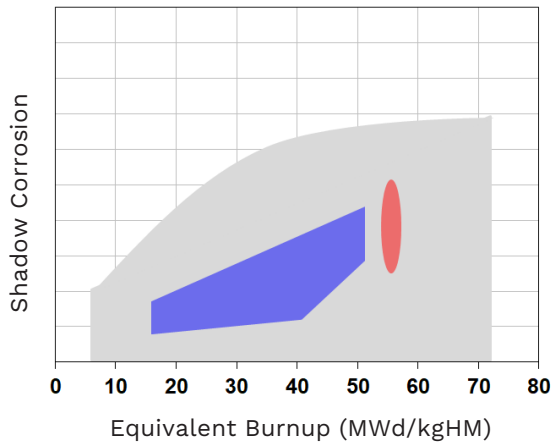
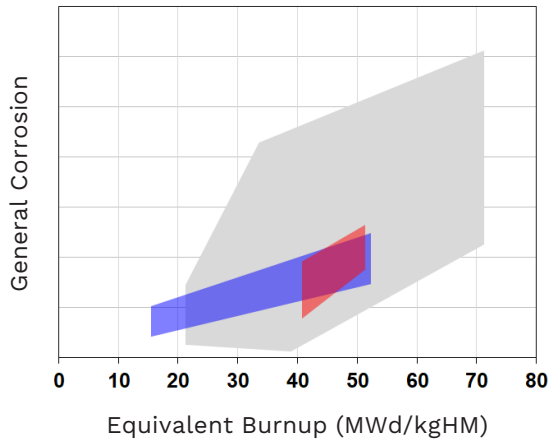
Z4B-BQ fuel channels are fabricated with established rolling and forming processes

Customer benefits

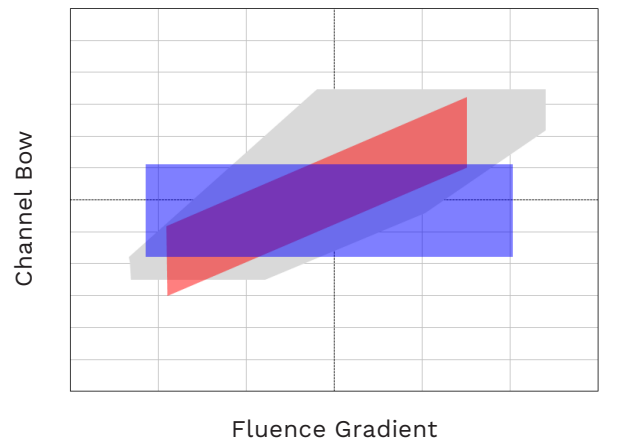
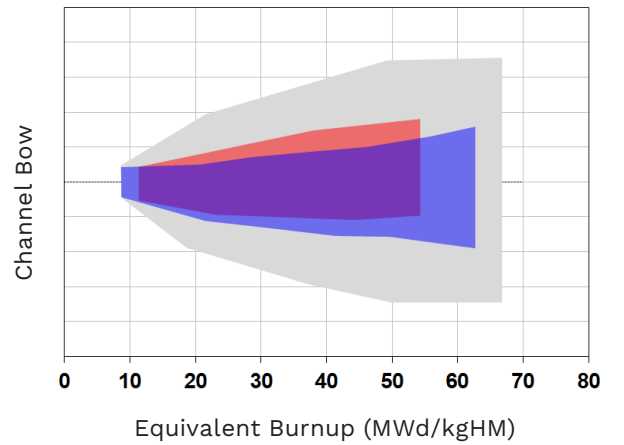
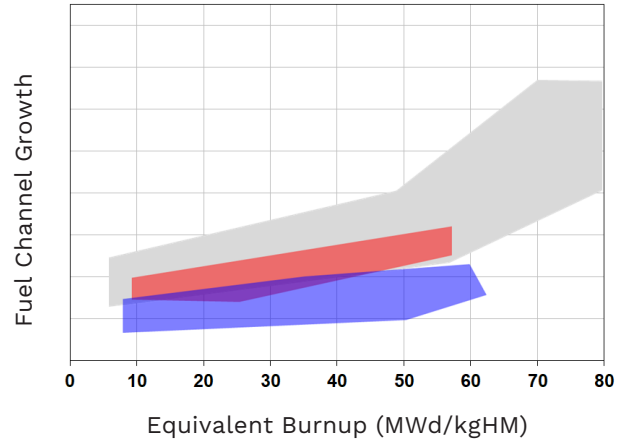
- Dimensionally stable fuel channels
- Low corrosion and hydrogen uptake
- Margin for extended burnup
- Simplified fuel shuffling
- No increase in activated metal

Your performance
is **our** everyday **commitment**

The Z4B Alloy has a lower corrosion rate than Zircaloy-4, proportionately reducing total hydrogen pickup



In-reactor data confirms that Z4B-BQ fuel channels satisfy all dimensional performance objectives



- Zry-4 RXA Database
- Z4B-BQ Fuel Channels
- Z4B RXA Fuel Channels



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Contact: Sales-fuel@framatome.com www.framatome.com

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