

# OVERALL PERFORMANCE OF CR-COATED ACCIDENT TOLERANT FUEL CLADDING IN LARGE PWRs AND IMPLICATIONS FOR SMR APPLICATIONS

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## OVERALL PERFORMANCE OF CR-COATED ACCIDENT TOLERANT FUEL CLADDING IN LARGE PWRs AND IMPLICATIONS FOR SMR APPLICATIONS

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After more than a decade of research into the performance of Cr-coated Accident Tolerant Fuel (ATF) cladding, the nuclear industry is now moving toward commercialization, supported by an improved understanding of its overall behavior. In several respects—such as steady-state corrosion resistance [1], steam oxidation resistance [2,3], generally crack-resistant coating behavior at elevated temperatures relevant to normal operation, and slightly reduced inward cladding creep during steady-state [4]—Cr-coated cladding demonstrates desirable performance. It also exhibits comparable fuel ballooning and burst behavior to uncoated zirconium alloy cladding [5,6], and only limited additional oxidation through cracked coatings near burst openings [6], illuminating the promise of the concept envisioned at its inception.

However, recent findings also highlight inherent limitations that may constrain the achievable operational and safety benefits. These include: (i) degradation of coating protectiveness due to Zr diffusion from the substrate, creating oxygen ingress paths through the Cr layer [3]; (ii) formation of a eutectic phase at around 1330 °C, which degrades oxidation resistance in steam and causes a sharp increase in hydrogen generation rate, thereby limiting any meaningful increase in the peak cladding temperature limit [7,8]; and (iii) significant loss of post-LOCA ductility due to oxygen uptake and secondary hydriding near the burst opening, leaving the cladding vulnerable to traditional inner-wall oxidation mechanisms [9,10]. Furthermore, Cr-coating does not mitigate over-pressurization or Fuel Fragmentation, Relocation, and Dispersal (FFRD), which remain key safety concerns for high-burnup fuels in the 24-month cycles sought by the industry [5]. In addition, the potential burnup extensions are competed by modern zirconium alloys, whose excellent corrosion resistance is sufficient to support discharge burnup extension of large PWRs (~75 MWd/kgU).

These concerns highlight the importance of rethinking the synergy between advanced fuel materials and reactor design. In line with it, low power density Small Modular Reactors (SMRs) provide operating conditions in which the advantages of Cr-coated ATF can be most effectively realized. Operating at lower linear heat rates giving lower fuel temperature and offering more graceful accident scenarios with no risk of fuel burst, SMRs can fully capitalize on the superior corrosion resistance of Cr coatings. This could enable ultra-long cycles and burnup extension with LEU+ fuels, aligning with operational and economic incentives. We believe that such applications deserve increased attention and could define a future strategic direction for SMR and Cr-coated ATF deployment.

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