

Advanced Cladding and Structural Material M5[®]

An Exceptional Material Designed for High-Duty, High-Burnup Applications

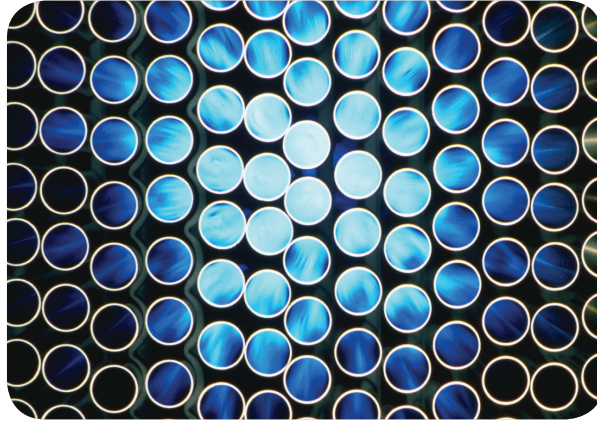
AREVA offers an advanced zirconium alloy for PWR fuel rod cladding and fuel assembly structural components to provide our customers with increased efficiency in their nuclear operations. M5[®] has demonstrated proven performance in a wide range of PWR operating conditions and is well suited for the evolution of operating conditions. M5[®] maintains significant margins to current and changing safety regulatory requirements.

A Truly Unique Alloy

Introduced commercially in the 1990s after a extensive development program, M5[®] is more than an improvement on existing material — it is a breakthrough in the development and fabrication of zirconium alloys. This fully re-crystallized Zirconium-Niobium alloy containing no tin but controlled oxygen, iron and sulfur content produces much improved corrosion, hydrogen, growth and creep behavior. The stable microstructure responsible for these performance improvements is the result of the alloy's composition and innovative manufacturing parameters.

Demonstrated to Be the Best Alloy Available for PWRs

The in-reactor performance of alloy M5[®] is well documented since its introduction nearly 25 years ago. At this time, M5[®] cladding has operated in 94 PWRs worldwide. The alloy is in use in 14x14 to 18x18 fuel assembly designs in PWRs with a full range of operating parameters (moderate to high-duty) such as two-year cycles, high lithium, high power densities, high temperatures and sub-cooled boiling. Over 5 million fuel rods have been irradiated in commercial PWRs to burnups exceeding 80,000 MWd/tU — numbers that continually increase. The most current technical papers and other information documenting the worldwide performance of M5[®] are available upon request.



Alloy M5[®] is the standard for PWR performance

An Ongoing Commitment to Excellence and a Mature Product Licensed Worldwide

M5[®] is the industry standard for PWR performance. AREVA continues to collect fuel performance data in high-burnup irradiation campaigns in PWRs and test reactors worldwide. The alloy is licensed in the United States, United Kingdom, France, Finland, Germany, Sweden, Belgium, China, South Korea, Brazil, Netherlands, Switzerland and South Africa, and the growing high-burnup database provides the technical foundation to license operation above current regulatory limits.

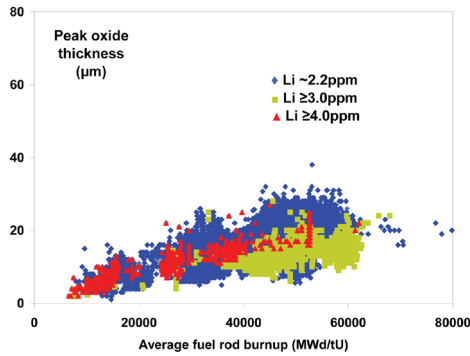
Features

- Low corrosion
- Extremely low hydrogen pickup
- Low free growth
- Increased performance margins at high burnup

Benefits

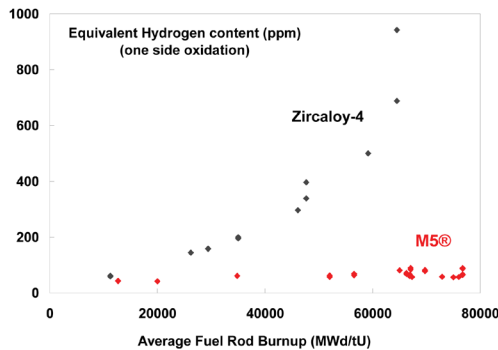
- Proven performance in a wide range of PWR operating conditions and well suited for evolution of operating conditions
- Maintains significant margins to current and changing safety regulatory requirements
- Pushes the technological limits higher
- Higher operational flexibility regarding PCI

High Resistance to Corrosion



A factor of 4 less oxide thickness at high burnup and no increase in data scatter with increasing irradiation demonstrates the stable microstructure and low sensitivity to PWR duty parameters of M5®.

Extremely Low Hydrogen Uptake



The hydrogen pickup of M5® is significantly lower than Zircaloy-4 and other Zirconium alloys, providing for greater ductility.

Performs Excellently in Severe Accident Conditions and Complies with Existing and Future LOCA and RIA Criteria

In fuel rod cladding with hydrogen concentrations above the solubility limit, excess hydrogen precipitates as brittle hydrides, reducing the ability of the cladding to cope with pellet-to-clad mechanical interactions during reactivity insertion accidents. During a LOCA, high hydrogen levels increase the transport and solubility of oxygen at high temperatures, leading to substantial embrittlement of the cladding as it cools and the oxygen precipitates. M5® cladding absorbs less hydrogen than other Zr-based alloys. As a result, M5® does not reach hydrogen levels sufficient to precipitate hydrides, avoiding excess oxygen absorption during a LOCA. LOCA and RIA test results demonstrate that it outperforms Zircaloy-4 and other Zirconium alloys. Thus, M5® retains significant ductility under accidental conditions, which is a key parameter for Safety demonstration.

Dependable Solutions Offering Operational Flexibility in Demanding PWR Conditions

The use of M5® allows utilities to achieve significant fuel cycle cost savings and enhanced operating margins by allowing higher burnups and higher-duty cycles.

Burnup – Excellent corrosion resistance allows higher burnups, extended fuel cycle operation, and fuel assembly design upgrades that enhance operating flexibility.

Dose – The corrosion resistance of M5® allows operation in high pH environments, eliminating the risk of oxide spalling and helping to minimize dose rates.

Power – M5® has been proven to withstand severe operating conditions: high neutron flux, heat flux and high operating temperatures.

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