AN EVALUATION OF USING METAL FUEL IN LIGHT WATER REACTORS

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Summary

This paper is an evaluation of using metallic fuel, specifically a helical geometry fuel design with a four-lobe cross-section by Lightbridge Corp, in light water reactors (LWRs). The paper summarizes the modeling of the behavior of this metallic fuel under both operational and accident conditions, comparing it to the traditional ceramic UO_2 fuel. The study highlights the enhanced safety features of metallic fuel, such as lower fuel temperatures, reduced cladding oxidation, and elimination of issues like cladding lift-off and ballooning. The document also discusses the thermal and mechanical properties of U-Zr fuel material, the modeling results for normal operation and accident scenarios, and the implications of fuel swelling on the in-reactor exposure limit of metal fuels.

What are the safety benefits of metallic fuel?

The safety benefits of metallic fuel, as highlighted in the document, include:

1. **Lower Fuel Temperatures**: Metallic fuel operates at much lower temperatures compared to ceramic UO_2 fuel, which reduces the risk of overheating and associated safety issues.
2. **Elimination of Free Volume**: The design of metallic fuel eliminates free volume (gaps or plenums), which prevents issues such as cladding lift-off due to over-pressure and cladding ballooning and burst during accident conditions.
3. **Reduced Cladding Oxidation**: Lower fuel temperatures help in reducing the oxidation of the cladding, especially during loss-of-cooling scenarios, enhancing the overall safety of the reactor.
4. **Limited Cladding Stresses**: Although rapid power increases in accident conditions can raise cladding stresses due to fuel thermal expansion, the stresses are not significant enough to damage the cladding.

5. **Improved Performance in Accident Conditions**: In scenarios like loss of coolant accidents (LOCA) and reactivity insertion accidents (RIA), metallic fuel shows lower peak cladding temperatures and shorter durations at high temperatures compared to UO_2 fuel, which reduces the risk of cladding failure and fission product release.

Overall, these benefits contribute to enhanced safety margins and potentially better performance of light water reactors using metallic fuel.

How does metallic fuel compare to UO2 in accident conditions?

In accident conditions, metallic fuel demonstrates several advantages over UO_2 fuel:

1. **Lower Peak Cladding Temperature (PCT)**: Metallic fuel exhibits significantly lower peak cladding temperatures compared to UO_2 fuel during loss of coolant accidents (LOCA). For example, in various simulated conditions, the peak cladding temperature for metallic fuel was consistently lower than that for UO_2 fuel.
2. **Shorter Duration at High Temperatures**: Metallic fuel spends less time at high temperatures during accident scenarios, which reduces the risk of cladding oxidation and failure.
3. **Reduced Cladding Oxidation**: Due to the lower temperatures and shorter high-temperature durations, the cladding oxidation for metallic fuel is expected to be lower than for UO_2 fuel.
4. **Lower Cladding Stresses**: Although cladding stresses can increase due to fuel thermal expansion during rapid power changes, the stresses in metallic fuel are not significant enough to cause cladding damage.
5. **Enhanced Safety Margins**: The overall lower temperatures and reduced oxidation contribute to enhanced safety margins, making metallic fuel a safer alternative in accident conditions.

In summary, metallic fuel offers improved safety performance over UO_2 fuel in accident conditions by maintaining lower temperatures, reducing oxidation, and minimizing cladding stress.