Thorium Fuel in LWRs
An Option for an Effective Reduction of Plutonium Stock Piles

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Worldwide, the commercially operated light water reactors (LWR) use uranium based fuel. In some countries the plutonium generated in that operational mode is recycled as uranium/plutonium mixed oxide fuel (MOX).

An alternative for the re-use of plutonium in LWRs is thorium/plutonium fuel. This is an attractive fuel cycle option for an effective reduction of the stockpiles of plutonium. The once through fuel cycle with plutonium as initial fissile material reveals the potential for significant plutonium reduction rates and for proliferation resistant spent fuel characteristics. The degradation of the plutonium composition and the reduced solubility of thorium based fuel make a misuse of the spent fuel unattractive. This is a feature especially appealing for plutonium from the dismantlement of nuclear warheads.

In the past, research institutes and industry of Germany and but also other countries investigated the options of the Th-based nuclear fuel cycle in LWRs, PHWRs, and HTRs in detail. The conclusion from those studies was, that the use of thorium fuel offers the potential for improved resource utilization. This holds particularly for advanced reactor concepts specifically designed for thorium application. But even in PWRs of present type substantial advantages can be anticipated in case of a thorium based fuel.

Extensive core design studies performed for modern PWRs of the 193-fuel-assembly type demonstrated their capability of being operated with exclusively Th/U or Th/Pu fuel without major changes of the fuel assembly design or the safety related reactor systems. Investigations of reactor cores loaded with thorium fuel concluded in very similar accident behavior compared to common U and U/Pu loaded cores. In comparison to U or U/Pu fuel thorium fuel mainly affects reactivity coefficients. Using enriched boron, a common procedure in several of the actual PWRs, can compensate for the somewhat higher demand on soluble boron. Starting from an uranium based operation the introduction of thorium based fuel is feasible. With an appropriate fuel assembly design cores can be designed meeting all safety requirements at the simultaneous presence of U, U/Pu, Th/U and Th/Pu fuel assemblies. The possibility of higher Pu concentrations together with thorium offer the potential of concentrating the Pu to fewer fuel assemblies and of an improved utilization of the provided fuel without reprocessing.

The operational experience and results from post irradiation examinations on LWR thorium fuel (BWR, Lingen power plant, Germany) verified the appropriate accuracy of cross sections and proofed the applicability of spectral codes for the design of Th/Pu fuel assemblies at that time. The exposure of that fuel was in the range of about 20 MWd/kg.

For a commercial introduction of thorium fuel in LWRs the qualification basis has to be extended to higher plutonium concentrations and significantly higher exposures. The irradiation of lead test assemblies and the follow-up of the power history, subsequent post irradiation examinations with isotopic analyses and theoretical benchmarks for thorium fuel assemblies and thorium-loaded cores are essential for improving the confidence in the design tools.

As an important step, besides others, an irradiation test program with thorium/plutonium fuel is planned for the upcoming cycle of the Obrigheim power station KWO in Germany. KWO is a commercially operated reactor with a thermal power of 1050 MW_{th}. The first phase of the test suite covers 3 irradiation cycles of the test rod and is partially funded by the EC in the frame of the 5^{th} R&D Framework Program. As a subcontractor, Framatome ANP is responsible for the thermal mechanical, thermohydraulic and neutronic design of the test rod. The irradiation test is planned as close as possible at representative commercial LWR conditions. This makes it easy to directly gaining as much experience as possible out of the experiment without further interpretation. The fuel and the fuel rod are manufactured by the Institute for Transuranium in Karlsruhe. The pellet geometry and the outer fuel rod diameter of 9.5 mm are consistent to the majority of commercial LWRs. The plutonium used is of high quality (> 90 w/o fissile content) and, accordingly, the degradation rate is expected to be representative also for weapons grade material. The sample has an active length of about 20 cm and will be inserted in a guide tube of a regular U/Pu MOX fuel assembly (average fissile Pu concentration of 3.8 w/o in natural uranium). The neutronic characteristic of the irradiation environment is therefore representative for MOX neutron spectra at commercial power reactor conditions. The experience resulting from the experiment can be transferred to future LWR projects without interpretation. The linear heat generation rate is limited to about 200 W/cm due to the thermal hydraulic conditions of the test geometry. A continuation of the experiment is planned for a 4^{th} cycle. The final burnup after 4 irradiation cycles in 2 different MOX assemblies is expected to be about 40.000 MWd/t and is therefore close to discharge exposures of actual commercial fuel. The initial characterization of the fuel rod and the measurements planned for each shut down of the plant for refueling are the basis for an evaluation of the fuel rod behavior and for post irradiation examinations with isotopic analysis.

This experiment will provide extensive information on the operational behavior of Th/Pu fuel and the measurement of the isotopic composition of the spent fuel is an important contribution to the qualification of the cross section base and future design codes.

The presentation is intended to tie the irradiation experiment and its evaluation to the code qualification process and to discuss different options of thorium usage.