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Smallest Thinkable LEU Elements for FRM II with Most Progressive and Also Most Conservative Fuel Options

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ABSTRACT

A real LEU fuel element is an ambitious goal for conversion of FRM II, while obligation is to go below 50% enrichment. This work will present the smallest possible LEU element sizes to reach again at least 1200 MWdays/element with most progressive monolithic fuel and on the other side with the current and most conservative U_3Si_2 fuel, qualified till 4.8gU/cc since 1988. The principle study for the two extremes stays without changes to major reactor systems like pumps or the drive system for the control rod respectively the shutdown rods.

Any LEU element requires an axial extension of the fuel zone of usually 15 cm (at least 10 cm) to H_a=85cm, what could be already a hard demand for the reactor conversion, while some radial gain is also necessary. The minimum gain is with the option of a new and thinner central channel tube (CCT), thanks to the very resistant zircaloy material, supposed in any study here.
Staying at the current outer CCT radius r_{ac}=13.1cm for FRM II is then thinkable, but only with the new monolithic fuel and at progressive plate dimensions with thinner cladding and thick foils (here d_c/d_f=0.3/0.45mm). Up to now, TUM expected to need an extra complication with particularly tapered foils to avoid too high power loads in the outer fuel area. Another way would be here to come with an outer burnable absorber (cmp. [RRFM-16]) in the outer fuel element tube to reduce that way heat loads for the outer hot coolant stripes. The axial extension could then stop at H_a=80cm due to a substantial reactivity gain with flat UMo monolithic foils, thus without extra complications for fabrication and plates production.

When supposing the other extreme on the conservative side with backup fuel U_3Si_2 of density 4.8gU/cc, the radial extension must become rather high with at least extra ~10mm to r_{ac}=14.1cm or 14.3cm, if staying at more conservative plate dimensions with actual clad at thicker U_3Si_2 meat (d_c/d_f=0.38/1.0mm). But a radial extension is only thinkable with smaller Hf cylinders attached to the safety rod (SR) systems, which approach the CCT. And here comes another main advantage with the outer burnable coat solution for FRM II conversion. The reactivity course over the cycle is much more flat, the necessary grasp for control and safety systems much smaller at maximum, what would clearly allow a reduced

radius of the five Hf rods to guaranty the shutdown case in any 4of5 SR scenario besides a viable technical issue.

The flux loss data are very comparable here, even though extreme cases were regarded in this LEU study; the losses are high with ~13-14% at the thermal beam tubes in average. The cold beam tubes should have a loss of ~10% cold flux intensity at the nominal reactor power of 20 MW, irradiation positions are in between, while any comparable case without outer absorber would be only about 1% better in thermal flux for (all) the users at typical MOC situation. A power increase of 5%to10%, if allowed, would bring the losses into the marginal or equal rate.