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A COMPREHENSIVE THERMO-HYDRAULIC NEUTRONIC AND SAFETY ANALYSIS OF A 100MWth PEBBLE BED REACTOR CORE

This study investigates the neutronic and thermal-hydraulic modelling of a 100MWth PBR called the HTMR100 which has a core diameter of 2.6 m, a height of 5.226 m, and a core volume of 27.746 m3 producing a core power density of 3.6 MW/m3 with an outer Reactor Pressure Vessel (RPV) diameter of 5.25 . The 100MWth limit ensures that the core power density is kept low.

This reactor uses uranium dioxide fuel (UO2) at 10wt% enrichment (U-235 content) and 10 g of heavy metal in a Fuel Sphere (FS). In this reactor the fuel spheres pass through the core only once, this is known as a Once-Through-Then-Out (OTTO) fuel cycle, this cycle was also chosen for the simplicity of the fuel handling system.

The neutronic and thermal hydraulic design of the HTMR100 reactor was assessed. A transient safety analysis was also performed to determine if the reactor design allows for the fuel temperatures to remain below the set value of 1600˚C for the oxide-based UO2 fuel during design-based accident events e.g. a Loss Of Coolant Accident (LOCA).

The study assessed the core operating at normal conditions. The reactor has been operating continuously at 100% power which is 100MWth with the control rods situated at the nominal position called the equilibrium core position.

The equilibrium core was evaluated by the Very Superior Old Programs (VSOP99) suite of codes to obtain equilibrium burnup results. These results are then utilized in a second code called Multi-group Time Dependent Neutronics and Temperatures (MGT). MGT assesses the dynamic transient results of the accident scenarios such as the Depressurized Loss Of Forced Cooling (DLOFC), Pressurized Loss Of Forced Cooling (PLOFC), a Load Following (LF), Control Rod Withdrawal (CRW) and a Control Rod Ejection (CRE) for the HTMR100 reactor core.

The HTMR100 reactor utilizing the specified uranium dioxide fuel for the enrichment and heavy metal loading specified did indeed produce the targeted 80 000 MWD/THM burnup for the OTTO fuel cycle. The study also proves that the VSOP99 and the MGT codes do in fact yield similar results for the HTMR100 with regards to fuel centerline temperatures, outer sphere surface temperatures as well as moderator temperatures for the postulated accident scenarios that were analyzed. The results also indicate that the design-based transient safety analysis simulations prove that the fuel temperatures to remain below the set value of 1600˚C for the oxide-based fuel.

The beyond-design base events which will rarely ever occur do however exceed the set value of 1600˚C but the fuel only heats up for short periods of time while the transient takes place. The probability that this will lead to fuel damage is estimated to be low since the time at temperature of the fuel is short. A temperature-volume analysis of these beyond-design base events shows that only a portion of the fuel would exceed these values. VSOP provides values of 1% to 2% of the entire fuel amount in the reactor would experience these temperatures.

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Confirm that the work is original and has not been published anywhere else

Yes. Was shown at HTR2021 but not published (will be modified)

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