Utilization of Thorium in PHWRs

Ashok Chauhan

The thorium fuel cycle involves naturally abundant isotope of thorium (Th^{232}) as the fertile material. Since thorium does not contain any fissile component, requires additional fissile material for the initiation of the thorium cycle, leading to generation of fissile isotope U^{233}.

The ThO_2 fuel material has better physical and chemical properties in comparison to UO_2 fuel and is expected to exhibit better thermal behavior in reactor. U^{233} produced from thorium has several favorable neutron characteristics which makes thermal reactors suitable for effective utilization of our extensive thorium reserves. In heavy water reactors, the 2.6 MeV gammas from Tl^{208} (decay chain of Th^{232} or U^{232}) will give rise to photo neutrons that will aid during start-up as well as in transient situations. Due to the presence of hard gamma emitter in thorium fuel, it is one of the best suited fuels from non-proliferation point of view and is gaining world-wide attention to be used as a carrier for disposition of highly enriched uranium as well as reactor grade plutonium. Thorium is also a better candidate for these purposes compared to inert matrix carriers from operational point of view due to negative fuel temperature coefficient.

In the 220 MWe PHWR units, 35 zircaloy clad thoria bundles per unit, which are of 19-element type, were used for flux flattening in the initial core, such that the reactor can be operated at rated full power without violating specified channel power and bundle power limits. An initial fuel loading pattern has also been worked out for the upcoming 700 MWe PHWR units consisting of 28 thoria and rest natural Uranium bundles.

Short length fuel bundles and on-power refueling provision in PHWRs provides flexibility to use variety of fuel loading patterns and different fuel types and consequently permits optimum use of fuel in the reactor. Using this flexibility, alternative fuel concepts of irradiating ThO_2 bundles either in combination with NU bundles or with SEU has been studied for Indian PHWRs. The investigation has led to the conclusion that irradiation of few pure thoria bundles along with NU bundles on regular basis in peripheral channel locations is best solution for the production of U^{233}. The burnup penalty can be compensated by slight increase in natural Uranium feed rate or use of SEU alongside thoria bundles. This scheme does not warrant any engineering change in the existing reactor. The U^{233} thus produced over the years can be used in future Indian reactor designs namely AHWR and MSBR.

The feasibility of burning highly enriched U and Pu in thorium matrix in Indian PHWRs was also studied. Also enriched U to the tune of 20 % U^{235} can be mixed with thorium and effectively used in PHWRs. For such an advanced fuel cycle, modification in reactor systems like suitable locations of shutdown system have been worked out to address the safety aspects.

The talk covers the use of thorium bundles so far and presents analysis for exciting future use of thorium fuel cycles in Indian PHWRs to meet ever growing energy needs of India.

Mr. Ashok Chauhan

Mr Ashok Chauhan, a “Distinguished Scientist”, is presently Director (Technical), on NPCIL Board. He joined 22nd Batch of BARC Training School in 1978 after completing his B. Tech in Mechanical Engineering. Initially he was a Design Coordinator for NAPP & KAPP and subsequently moved to Reactor Safety Analysis group. Since 1988 he has been involved with all aspects of LWR technology, specifically Kudankulam NPP. Right from the “Technical Assignment“, he developed the advanced VVER model V-396 along with the Russian developers. Shri Chauhan is a trained “Probabilistic Safety Analyst” and has established the PSA group in NPCIL, independently for LWR and PHWR PSA analysis. Shri Chauhan is a specialist in complete fuel cycle and is responsible for entire fuel front end to back end activities & IAEA safeguards in NPCIL. He played a key role in the construction & commissioning of KKNPP-1&2..