# Physics considerations for utilization of thorium in power reactors

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Thorium is approximately three times more abundant in nature than uranium and therefore is important for supplying energy to the world in a sustainable manner. The thorium fuel cycle offers certain advantages vis-a-vis uranium fuel cycle. India has modest deposits of uranium but vast reserves of thorium, and hence Indian nuclear programme envisages large-scale utilization of thorium. The third stage of the Indian nuclear programme envisages use of $^{233}$U-fuelled reactors with thorium as fertile material. With this aim there has been pioneering research efforts in all aspects of the thorium fuel cycle. There have been several studies in India on the use of thorium in different reactor systems from thermal to intermediate and fast spectrum, molten salt reactors, high temperature reactors. In this talk, we present some of the research studies on use of thorium in Advanced Heavy Water Reactor (AHWR) and the Indian Molten Salt Breeder Reactor under consideration at present.

AHWR is being designed with many attractive features like negative coolant void reactivity, heat removal through natural circulation and other passive safety features. The main objective for development of AHWR is to demonstrate thorium fuel cycle technologies, along with several other advanced technologies required for next generation reactors. It is a 920 MWth, vertical pressure tube type thorium-based reactor cooled by boiling light water and moderated by heavy water. There are two variants under consideration. The first variant called as AHWR-Reference, is primarily being designed for utilisation of thorium in closed fuel cycle with minimum additional requirement of plutonium as fissile feed. The equilibrium fuel cycle is based on the conversion of naturally available thorium into fissile $^{233}$U driven by plutonium as external fissile feed and achieving self-sustenance in $^{233}$U. The power obtained from thorium in this core is very high. The second variant called AHWR-LEU, is primarily being designed for utilisation of thorium in open fuel cycle. The fuel is based on (Th-LEU)MOX. The LEU has been assumed to contain 19.75% $^{235}$U and 80.25% $^{238}$U. The average LEU content in MOX fuel is 21.3%. It gives high burnup of about 60 GWd/te. The core has enhanced proliferation resistant characteristics and has better safety parameters as all the reactivity coefficients are negative and the reactivity swing from cold to hot standby conditions and to full power is negative.

Molten Salt Reactor design concepts suit the needs of India's Three-Stage nuclear power program for efficient thorium utilization. An effort is being made in BARC to design a MSR configuration for Indian requirements. As a preliminary study, reactor physics analysis of 850 MWe, molten salt reactor operating in fast spectrum is being carried out in hot and static condition. The LiF-$ThF_4$-$UF_4$ is being considered as the primary coolants and fuel. The blanket material is LiF-$ThF_4$.

The talk will give an overview of the neutronic properties of thorium and the bred fissile material and then proceed to present the major design features in AHWR and the Indian Molten Salt Breeder Reactor under consideration at present.

## Prof. P.D. Krishnani

Prof. Krishnani joined Bhabha Atomic Research Centre in the year 1974 after taking Post-graduate degree in Physics from Lucknow University and has received his Ph.D. from Mumbai University while working in BARC. He is from the 17th batch of BARC Training School. Presently, Dr. Krishnani heads Reactor Physics Design Division of BARC and is also a Senior Professor of Homi Bhabha National Institute and has nearly 41 years' research experience. He has developed a number of lattice analysis codes for PWRs, BWRs, HTRs and PHWRs which are most sophisticated and state-of-the-art software for reactor design. He has contributed towards the study of utilization of thorium and MOX fuel in TAPS-1/2 as well as 220 MWe PHWR. He is also associated with the design of PHWRs and PWRs. Presently, he is incharge of physics design of Advanced Heavy Water Reactor, Compact High Temperature Reactor, Innovative High Temperature Reactor for Hydrogen production and IPWR. He is also Chairman of Programme Implementation Committee of Nuclear Data Physics Centre of India. He is member of number of safety committees in AERB and BARC. He has more than 460 publications to his credit in the international journals, National and International symposia and in the form of reports.