Indian Nuclear Power Programme – Role of Thorium and the Challenges Ahead

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Thorium is three to four times more abundant than uranium and is widely distributed globally. This led to a lot of worldwide focus on thorium fuel based systems during the early years of nuclear energy development. The initial enthusiasm to supplement uranium with thorium in view of the predictions of uranium shortage waned later, due to discovery of new deposits of uranium and saturation in electricity demand among the developed nations. In the context of Indian nuclear programme, thorium has always had a prominent place due to our unique resource position of having large thorium deposits, but limited uranium reserves. A three-stage programme has been devised to effectively utilize the available resources efficiently and in a sustainable manner. The first stage involves utilisation of natural uranium in PHWRs (Pressurised Heavy Water Reactors). The second stage involves the utilisation of plutonium obtained from reprocessing the spent PHWR fuel in fast reactors. The second stage will also provide the required 233U for the third stage which involves the Th–233U cycle based reactor system.

Work on thorium fuel has therefore been carried out right from the inception of our nuclear programme. Studies have been carried out on all aspects of thorium fuel cycle - mining and extraction, fuel fabrication, utilisation in different reactor systems, evaluation of its various properties and irradiation behaviour, reprocessing and recycling. In India, thoria fuel has been irradiated in the research reactors CIRUS and Dhruva. The irradiated thorium has been reprocessed to recover 233U and this has been used for fabrication of fuel for the(Th-233U) based test reactor KAMINI which is at present the only operating thorium fuel based reactor in the world. Thoria fuel bundles have been used for flux flattening in the Initial Core of PHWRs. Thoria based MOX fuel pins have been test irradiated in research reactors CIRUS and Dhruva to study their performance characteristics. Post-Irradiation Examinations have been carried out on these fuels.

To provide impetus to these studies and to embark on a large-scale programme, the thorium fuel cycle based Advanced Heavy Water Reactor (AHWR) has been developed. AHWR-Pu is being designed for closed fuel cycle while AHWR-LEU is being designed for operation in the open fuel cycle mode and will provide the globally recognised features of thorium fuel cycle like the advantage of having greater proliferation resistance, improved waste-management and better safety with high fuel burnups. The large-scale deployment of thorium based reactors will also require the adoption of several additional features such as economic competitiveness, practically no impact on public domain, and enhanced safety features such as elimination of hydrogen generation, fuel melting, etc. which has several technological challenges to be overcome. With this in view, development studies have been initiated for an AHWR-EM (Advanced Heavy Water Reactor – Economic Model). The paper would present the design goals of the AHWR-EM besides the ongoing work on other thorium based reactors such as the High Temperature Reactors (HTRs) and Molten Salt Reactors (MSRs)

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Prof. P.K. Vijayan a chemical engineer from the 1975 batch of the University of Calicut and obtained his PhD from the Department of Energy Systems Engineering, IIT Bombay in 1989. A Distinguished Scientist, Dr Vijayan is currently working as Director, Reactor Design and Development Group at the Bhabha Atomic Research Centre (BARC). His field of expertise is thermal hydraulics of nuclear reactors and has nearly four decades of experience in this field. He played a key role in the thermal hydraulic design of thorium based Advanced Heavy Water Reactor (AHWR) and is currently participating in the thermal hydraulic design validation for AHWR and Pressurised Heavy Water Reactor (PHWR-700). He is also leading the Indian High Temperature Reactor and molten salt reactor program. Dr Vijayan and his group established several major test facilities for the Indian PHWR and the AHWR. Besides he is leading the group developing the solar thermal power plant based on the beam down concept. He participated in several International Atomic Energy Agency (IAEA) coordinated research projects and bilateral research projects like Indo-Italian, Indo-German, Indo-UK, Indo-Korea and AERB-US NRC. He also worked as a guest scientist at Gesselschaft for Reaktor Sicherheit (GRS), Garching, Munich, Germany and International Atomic Energy Agency (IAEA), Vienna, Austria. He was one of the experts invited by IAEA to formulate a training course on 'Natural circulation phenomena and passive safety systems for advanced water cooled reactors' and is a lecturer for this IAEA training course since 2004. He has delivered invited talks at several national and international conferences and served as an examiner for PhD thesis of several reputed national and foreign universities.

He is professor and was convener, Board of Studies, Homi Bhabha National Institute (HBNI). He has guided eight doctoral thesis students of HBNI and several at the Indian Institute of Technology (IIT), Bombay. He has been the external advisor for two students of Tokyo Institute of Technology along with Prof. Masanori Aritomi. In addition, he has been the external advisor for one student at Tokyo Metropolitan University along with Professor Yutaka Asako. Besides, he participated as co-supervisor for Masters thesis at the University of Pisa jointly with Prof Walter Ambrosini. He has more than two hundred publications to his credit. He is a recipient of the DAE technical excellence and Homi Bhabha Science and Technology awards. He is a life member of several professional bodies like the Indian Nuclear Society, Indian Institute of Chemical Engineers and Indian Society for Heat and Mass Transfer. He was also the vice president of the Indian Society for Heat and Mass Transfer during the period 2009-13.