THORIUM BASED FUEL FOR AHWR

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INTRODUCTION

Advanced Heavy Water Reactor (AHWR) is a 300 MWe, thorium fuel based, vertical pressure tube type reactor designed at BARC. It is heavy water moderated and boiling light water cooled reactor that has been designed for hundred years of plant life. The reactor design has evolved from the presently operating PHWRs and BWRs in India. AHWR has extensive deployment of passive safety features for its operation and accident mitigation at par with the present international standards and provides a robust design against external as well as internal threats [1]. The physics design ensures inherent safety characteristics of the reactor. Heat removal from the core under both normal full power operating condition as well as shutdown condition is by natural circulation of water coolant. The physical characteristics of Thoria based fuel offer potential for high performance in reactor and slower fuel deterioration. With inherent feature of fuel cycle flexibility, a variety of fuel-types could be used in AHWR for generating power efficiently. AHWR-Pu version makes use of (Th-Pu) MOX and (Th-U$^{233}$) MOX fuel in the closed fuel cycle mode. The adoption of the closed thorium fuel cycle on an industrial scale is for the first time and is important in view of very little global experience. The experience generated on the various fuel cycle activities will be useful in utilisation of the large thorium reserves as envisaged in India’s three-stage nuclear power programme.

This paper provides an overview of the various design aspects of the thorium based fuel for AHWR and its associated developmental activities.

DESCRIPTION

AHWR fuel cluster is designed to meet the structural requirements of the vertical pressure tube of circular cross-section. Each of the coolant channels of the reactor contains a single long cylindrical fuel assembly. The fuel design of the reactor has progressively undergone modifications and improvements based on the feedbacks from the analytical and the experimental R&D to the present day configuration.

The schematic arrangement the present configuration of AHWR fuel cluster is shown in Figure-1 and the fuel parameters are given in Table-1. The fuel cluster has 54 fuel pins arranged in three concentric rings around a central displacer rod. The central displacer rod is multipurpose viz., first, it acts as a passage for ECCS injection onto fuel pins; second, it acts as support structure (spacer capture rod) for the cluster and, third, it helps in achieving desired void reactivity coefficient. The design of fuel pin as well as fuel cluster is amenable for remote handling and automation. Various components of fuel assembly with structural components have been successfully fabricated and assembled for ascertaining the design parameters and evolving the assembly procedure. The experimental testing to study the thermal-hydraulic behaviour and mechanical design aspects of the fuel assembly have been completed like pressure drop test, endurance test and vibration tests at Flow Test Facility and Integral Test Facility at BARC.

The physics design has evolved from a seed-blanket core design with widely varying cluster types to a core consisting of a single type of cluster with 54 pins. The design provides for inherent safety characteristics through achievement of required reactivity coefficients. AHWR can be used for diverse fuel cycle options including once through and closed fuel cycles and has flexibility to accept a wide range of fuel compositions without compromising on its safety and performance parameters. AHWR-Pu version will make use of (Th-Pu) MOX and (Th-U$^{233}$) MOX fuel in the closed fuel cycle mode. The adoption of the closed thorium fuel cycle on an industrial scale is for the first time in the country and is important in view of very little global experience. AHWR-LEU version will use the fissile material in the form of low enriched uranium and is expected to be operational in the once through fuel cycle mode.

The average fuel discharge burn-up for AHWR fuel is about 64 GWd/t. Thorium based fuel is expected to perform for longer time (higher burnup) owing to the better thermophysical properties, chemical & metallurgical stability, slower degradation of fuel in reactor. This requires improved clad properties in terms strength, toughness, creep etc. as it has an effect on the corrosion/oxidation of cladding. The remote handling tools and procedures are required for $^{233}$U based fuel because of the radiation from U-232 isotope.
As a part of fuel developmental activities, the various experimental campaigns have been carried out in India for thoria based fuels [2, 3] to gather the required reactor physics and performance database. Thoria fuel test irradiations have been carried out for a variety of fuel materials- UO₂, ThO₂, (U-Pu) MOX, (Th-Pu) MOX fuel in research reactors CIRUS, DHRUVA. The fuel pellets were made by different fabrication routes like Powder Pellet route as well as Coated Agglomerate Pelletisation route. The fuel pins and the fuel cluster have been fabricated and irradiation has been completed to desired burnup levels. The fuel performance analysis shows all parameters within acceptable limits. The observed irradiation power history has been in good agreement with predictions by physics evaluations. AHWR Critical Facility has been in operation at BARC for the experiments to validate reactor physics evaluations pertaining to AHWR fuel. The experimental irradiations planned along with the Post-Irradiation Examination (PIE) will provide an insight into the performance behaviour aspects of the thorium-based fuels. A considerable amount of data on all aspects of thoria fuel cycle; fabrication, in-reactor behaviour, reprocessing, and health physics have been generated from the various fuel campaigns carried out. The various fuel cycle technologies developed for AHWR have given the much-required experience in almost all aspects of thorium fuel cycle in India.

CONCLUSIONS

India has large thorium deposits and thorium has been the main stay of its nuclear power programme right from the inception. AHWR fuel design has evolved towards optimum utilisation of domestic fuel resources. The experimental irradiations with thorium-based fuels have given the much-required experience for large scale utilisation of fissile materials. There is now experience available in almost all aspects of thorium fuel cycle for the large-scale deployment of thorium in third stage of Indian nuclear power programme.

REFERENCES