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NUCLEAR POWER PROGRAMME - STAGE 3 (THORIUM UTILIZATION)

For providing energy security on sustainable basis, thorium utilisation is the long term core objective of the Indian Nuclear Power Programme. The efforts in this direction have resulted in the successful design and operation of 30 kW reactor KAMINI at Kalpakkam. This reactor is using Uranium-233 fuel obtained from irradiated thorium. The technologies relating to production of Uranium-233 have been established and thorium fuel bundles have been successfully used in reactors for flux flattening.

Towards thorium utilisation in power generation, BARC has been engaged in the research and development activities.

The vast reserves of thorium found in the country can provide long term solution to energy problem of the country. Third stage of Nuclear Power Programme, is thus based on thorium utilisation.

BARC is engaged on developing Advanced Heavy Water Reactor (AHWR), which will use both thorium-uranium-233 and thorium-plutonium mixed oxide as fuel.

Thorium Utilization

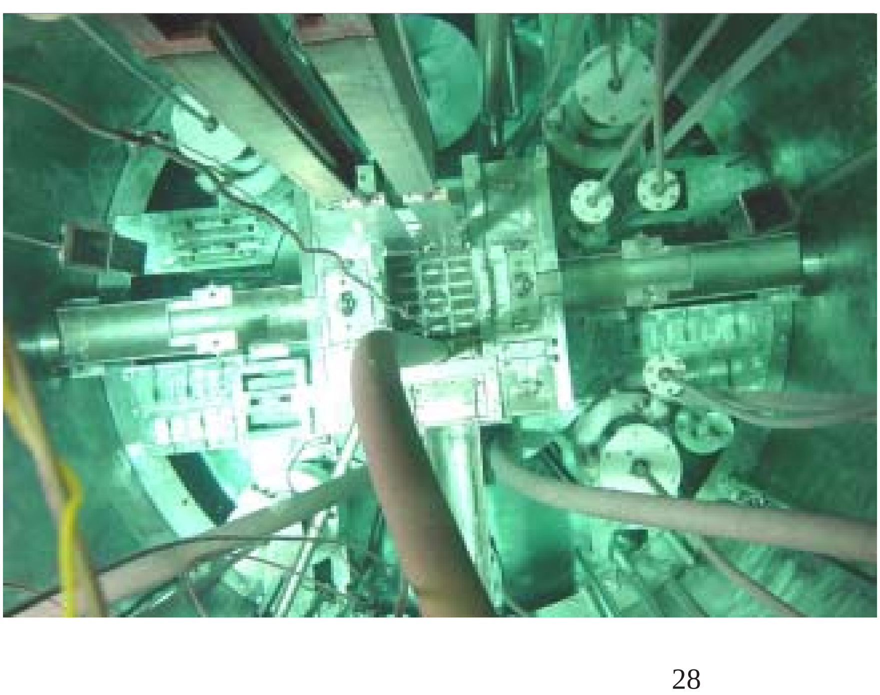
Kalpakkam Mini Reactor (KAMINI)

During the report period, KAMINI reactor was operated upto a nominal power of 30 kW for neutron radiography of various materials. The quality of neutron radiograph images was very good. In addition, many samples of different materials were irradiated in the reactor for activation analysis. The reactor was available for various experimental works for the centre and other organisations.

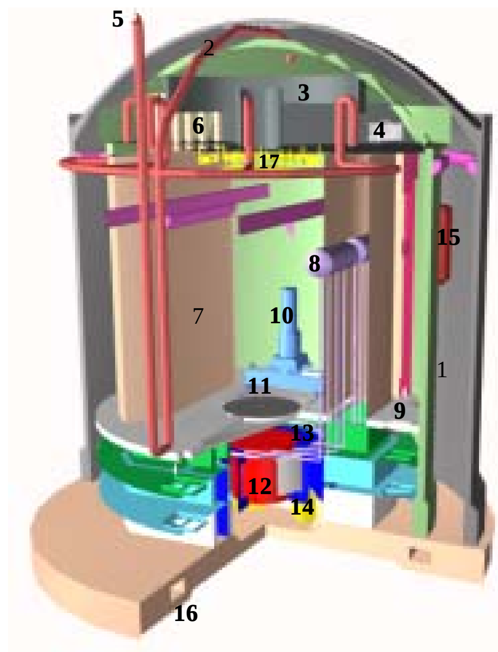
Advanced Heavy Water Reactor

Engineering development activities related to Advanced Heavy Water Reactor (AHWR) Project were continued. The project report for setting up of a 300 MWe AHWR was completed and was undergoing a peer review. Detailed engineering of the fuel handling system and design validation of passive system progressed. Studies were in progress to evolve a process flow sheet for the reprocessing of AHWR spent fuels. Civil works related to critical facility for conducting reactor physics experiment for AHWR and 500 MWe PHWRs has picked up. Fabrication of critical equipment for this project reached advanced stages.

Design of structure, equipment and piping: Piping design of AHWR was completed. The containment structure of AHWR incorporates new concepts like gravity driven water pool, tail pipe towers etc. A structural



Top View of KAMINI Reactor



Schematic of Advanced Heavy Water Reactor, being developed at Bhabha Atomic Research Centre

analysis was performed considering the loads due to postulated internal pressure, pre-stress and the maximum credible earthquake. The design was also evaluated for the envisaged life of 100 years as well as its constructability.

Probabilistic Safety Assessment and Human Reliability Studies: Probabilistic Safety Assessment Studies of AHWR was carried out. Preliminary Human Reliability Studies (HRA) was also carried out alongwith PSA Level-1 and methods of reduction of human error probabilities used in quantification of operator interactions in AHWR accident sequence were analysed.

Advanced Reactor Development Programme

AHWR Engineering Development: For data generation and design qualification, a state of the art Distributed Control System having high level Fault Tolerant Architecture was provided for all experimental facilities.

Experimental work was continued for design qualification of fuel cluster. Thermal hydraulic studies were continued and effect of two-phase flow (air & water) on various components of AHWR fuel bundles, and vibration signatures of fuel bundles were measured to obtain base line data. As a part of leak - before-break (LBB) qualification of AHWR piping, fatigue and fracture testing were carried out on stainless steel test pipes.

A high pressure, high temperature natural circulation test facility was set-up to visualize flow patterns and their transitions. Instability studies for AHWR using neutron radiography were done. To measure void fraction in high temperature and high pressure facility, conductivity probes are installed in experimental facility at APSARA Reactor.

For the safety studies on the reactor, a direct electrically heated Fuel Cluster Simulator is designed and fabricated in-house simulating nuclear heat generation of AHWR fuel bundle for extensive experimental investigation of the reactor fuel elements under normal and accidental conditions. Performance test was conducted successfully.

The detailed analysis of the reactor building structure for various loads were completed in-house. The design drawings and design basis reports were completed for fuelling machine.

Critical Facility for AHWR: The detailed design of Critical Facility for AHWR & 500 MWe PHWR was completed. Civil construction was commenced and construction of basement was completed. A prototype fuel element for the reference core was fabricated. Bulk production of the first fuel charge was in progress. Majority of materials/equipment related to reactor components, process systems, control & instrumentation, electrical and ventilation system were in advanced stage of fabrication.

Core Conversion & Refurbishing of Existing Apsara Reactor Core: Detailed design of the core & pool block components and various reactor systems were completed.

Injector Cyclotron for ADSS : The development of low energy high current accelerator in the space charge domain is the latest field of activity in the accelerator technology design. Work on the microwave ion source and injection line with space charge calculations was taken up at VECC.

THORIUM FUEL CYCLE

Thorium Mining

Indian Rare Earth Limited is involved in mining and procuring of beach sands for production of minerals such as Ilmenite, Rutile, Zircon, and Rare Earths products.

The Company achieved MoU rating of 'Very Good' from the Department of Public enterprises, Ministry of Industry, Government of

India for its performance during 2001-02. The Company also received for the second consecutive year, the Enterprise Excellence Award from the Indian Institute of Industrial Engineering.

The production of Ilmenite during the year was 3% more than the previous year. It was an all time high production. The OSCOM Unit also achieved an all time high production of 1.96 lakh tons which was 90% of the installed capacity.

During the year, the company received approval for implementation of the Thorium Retrieval and Restorage Project (THRUST) at the Rare Earth Division, Alwaye. The project, which has an estimated investment of about Rs. 9 crore, envisages retrieval of thorium concentrate from the stock pile at Rare Earths Division, and also reprocess it to recover rare earths.

IREL has launched its first phase of expansion of capacity for mineral processing at its plants at Chavara and Manavalakurichi, subject to the emerging marketing scenario, the implementation of these projects would be undertaken in the coming years.

IREL has also taken up other projects for productivity of zirconium hydroxide and recovery of rare elements.

Uranium Thorium Separation Facility

Occupational and Environmental Radiological safety support to IRE at Udyogamandal, Chavara (Kerala), Manavalakurichi (Tamil Nadu) and OSCOM (Chhatrapur, Orissa) was provided by BARC. Samples of air, water and effluents, etc. were collected and analysed for different parameters at IRE's facilities. All the levels were within the permissible limits. The mined and refilled areas showed a reduction in the radiation background by a factor of three.

The financial performance of IREL is given in the chapter on Public Sector Undertaking.

A view of Synthetic Rutile Plant and Mineral Separation Plant at OSCOM

Fuel Fabrication

A closed fuel cycle was adopted for thorium fuel in AHWR.Mixed Thoria-Urania and Thoria-Plutonia are the candidate fuels for the Advance Heavy Water Reactor . The fuel pellets were fabricated by conventional powder metallurgy route.

Uranium free inert matrix fuel incorporating plutonium in thermal reactors is a recent approach for disposal of plutonium. In BARC, fabrication and characterization of pellets was done.

Development work for Tellurium- Plutonium oxide and Thorium-Uranium-233 oxide MOX for

AHWR was in progress. Experiments for making $(Th\text{-}U)O_2$ oxide pellets continued. The X Plan Project report was prepared for making (Th-U) oxide fuel pins for the critical facility.

Fuel Reprocessing

A reprocessing facility at Trombay (Uranium Thorium Separation Facility) became operational in August 2002 to separate U-233 from irradiated thorium fuel on a plant scale. This has established a vital link in the thorium fuel cycle activities.

Technology Development for AHWR

Basic engineering of fuelling machine and carriage wascompleted. Fuelling machine oil and water hydraulic system flow sheets and DBR's were completed. Detail conceptualization of certain critical equipment.

Other Thorium Reactor System: Compact High Temperature Reactor (CHTR): CHTR was under development to address specific application areas, such as:

- small unattended power packs for electricity generation in remote areas not connected to the grid system,
- production of alternative transportation fuel such as hydrogen, and
- refinement of low-grade coal and oil deposits to recover fossil fluid fuel.

This reactor with 100 kW thermal power rating is based on the design guidelines such as use of thorium based fuels, compact design to minimise weight of the reactor, passive core heat removal and passive power regulation and shutdown systems. The reactor core and its associated components were modeled and stress analysis of core components- especially thermal stresses was in progress.

Accelerator Driven Subcritical Systems: For breeding fissile Uranium-233 from thorium, development of Accelerator Driven Sub-Critical Systems (ADSS) for nuclear reactor is the latest addition to the Indian nuclear programme. This progr-amme will also help in reducing the technical complexities of geological repositories for storage of long-lived high-level radioactive wastes. Significant progress was made in detailed analysis of this complex reactor system. The broad road map for ADSS development programme was identified.

Fuel design was carried out for sub-critical facility for carrying out physics studies pertaining to accelerator driven sub critical systems.

Continuous energy Monte Carlo method were successfully applied to determine certain quantities.

DAE initiated work to develop technologies for Accelerator Driven sub–critical System (ADS) during the 10th plan period. BARC took up design of a high current proton injector and beam optics studies ware carried out. Also a 14 MeV neutron generator was upgraded with a higher current ion source to carry out experimental studies on sub-critical assemblies. In parallel, using Monte Carlo techniques (MCNP code) and taking into account full 3-dimensional geometry, design optimization calculations were done for various reactors/sub-critical assemblies.

*Materials :*Dysprosium oxide for use as control material for new generation reactor, including AHWR, was separated by a process developed at BARC and evaluated. Another significant achievement was preparation of X-Ray intensifying screens using an indigenous phosphor material based on rare earths. The screen was subjected to field trials and found to compare well with imported screens.

Schematic of Compact High Temperature Reactor