The Proposed Use of Low Enriched Uranium Fuel in the High Flux Australian Reactor (HIFAR)

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ABSTRACT

The Australian Nuclear Science and Technology Organisation (ANSTO) operates the High Flux Australian Reactor (HIFAR). HIFAR commenced operation in the late 1950's with fuel elements containing uranium enriched to 93%. From that time the level of enrichment has gradually decreased to the current level of 60%. It is now proposed to further reduce the enrichment of HIFAR fuel to <20% by utilising LEU fuel assemblies manufactured by RISO National Laboratory, that were originally intended for use in the DR-3 reactor. Minor modifications have been made to the assemblies to adapt them for use in HIFAR.

A detailed design review has been performed and initial safety analysis and reactor physics calculations are to be submitted to ARPANSA as part of a four-stage approval process.

HIFAR DESCRIPTION

The Australian Nuclear Science and Technology Organisation (ANSTO) operates the High Flux Australian Reactor (HIFAR), at the Lucas Heights site approximately 30 kilometers south of Sydney. The reactor directly supports ANSTO's aim of benefiting all Australians and the international community through the innovative applications of nuclear science and technology. HIFAR is a 10MW DIDO class reactor consisting of 25 fuel elements with uranium-aluminium alloy fuel sections. HIFAR is heavy water moderated and cooled and is surrounded by a graphite reflector. Reactor control and shutdown is achieved with six europium tipped cadmium control blades, which move between the rows of fuel elements. Two cadmium shutdown rods placed at the periphery of the core provide additional shutdown capacity.

HIFAR commenced operation in the late 1950's with fuel elements containing uranium enriched to 93% U235. Since that time, the level of enrichment has been reduced to 80% in 1962, to 75% in 1981, to the current level of 60% in 1983. Throughout HIFAR's operation, fuel elements containing uranium from both the United States and the United Kingdom have been used. The fuel elements currently used to operate HIFAR are aluminum concentric tube type elements containing a hollow central axial region for high flux irradiations for the production of medical isotopes. Irradiation facilities are also available in the heavy water and graphite reflectors. HIFAR is a multi-purpose reactor, used primarily for neutron scattering, industrial and medical isotope production and neutron transmutation doping of silicon.

REGULATORY REQUIREMENTS

The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) provide oversight of HIFAR operation and are responsible for monitoring and reviewing the safe operation of ANSTO's plant. HIFAR is operated and maintained in accordance with the requirements of the Facility Licence issued by ARPANSA. The Licence identifies the requirements that ANSTO must meet to ensure safe operation. The requirements include the provision of a Safety Analysis report, Operational Limits and Conditions and a Quality Assurance system. HIFAR is accredited to the AS/NZS ISO 9001:2000 standard.

RERTR ACTIVITIES

ANSTO has been a participant of the RERTR program for many years, supporting the program's non-proliferation objectives. During this time, ANSTO has performed benchmark calculations (1,2) and detailed studies for converting the HIFAR reactor to low enriched uranium (LEU) fuel. McCulloch and Robinson (3) have previously investigated the neutronic and operational consequences of converting HIFAR to LEU fuel, and a working party (4) was established in 1986 to report on the technical matters relating to the conversion. These studies have been of a generic nature with respect to the details of the LEU fuel elements. The results of these investigations confirm that HIFAR can operate successfully using LEU fuels.

In more recent years, ANSTO has focussed efforts on replacing the existing HIFAR reactor with a 20MW pool type reactor designed to operate with LEU fuel. After a comprehensive tender review process, a contract for the construction of this replacement research reactor has been awarded to the Argentinian company, INVAP. A Preliminary Safety Analysis Report for the new reactor has been approved by ARPANSA and a construction licence has been issued.

HIFAR LEU PLAN

Based on the current inventory of nuclear fuel for HIFAR, it is necessary to procure further fresh fuel elements to achieve operational objectives until the replacement reactor becomes operational. HIFAR is due to cease operation in 2006, at which time the replacement reactor is expected to have been commissioned for routine use. An opportunity for HIFAR to procure and utilize LEU fuel has arisen following the permanent shutdown of the PLUTO-type DR3 reactor at RISO National Laboratory, Denmark.

RISO have made modifications to the non-fuel structure of their remaining stock of LEU silicide fuel elements to make them compatible with the MTR mark IV/23 fuel currently used in HIFAR. The fuel element modifications have not involved changes to the fuel tubes or the method of fixing the fuel tubes to the fuel element structure. The modifications include:

- The addition of 24 rig coolant holes
- The addition of 16 emergency core coolant holes
- Replacement of the guide nose

ANSTO plans to introduce gradually the modified RISO LEU silicide fuel into the HIFAR reactor and operate with a mixed core of HEU/LEU fuel until all stocks of HEU fuel have been used. It is then expected that HIFAR be converted to a full LEU core prior to the permanent shut-down date. This date is expected to coincide with the commencement of routine operation of the replacement reactor.

IMPLICATIONS OF CONVERTING HIFAR TO LEU

The introduction of a specific type of LEU fuel element (i.e. specific geometry, composition, etc) into HIFAR has required comprehensive reactor physics calculations to be performed as part of the safety analysis for the utilisation of the RISO LEU silicide fuel in HIFAR. The philosophy adopted has been to use the same calculation procedure for both HEU and LEU fuelled cores. This has necessitated repeating most of the calculations for the HEU core to ensure consistency. A detailed 3-dimensional MCNP model of HIFAR has been used which includes control absorbers, irradiation and beam facilities. For cases where a MCNP approach is either not applicable or is more difficult to apply, a 3-dimensional POW3D diffusion model of HIFAR has been used. A full LEU core with the same excess reactivity as a full HEU core has been taken as the basis for comparing the two cores (i.e. equivalent cores), with an average core burnup of approximately 50 MWd/element in both cases. On this basis, the reactivity worth of the control absorber bank is slightly less in the LEU-fuelled core than in the HEU- fuelled (equivalent) cores.

The calculations have included analyses of delayed and photoneutron data, reactivity worth of control absorbers, fission product poisons, reactivity coefficients, fuel element powers, neutron flux and gamma dose rates.

The thermal power produced in each fuel element (at a reactor power of 10MW) has also been calculated and compared for equivalent HEU and LEU fuelled cores. The peak power occurs when a fresh fuel element is loaded into the central core position. The central fuel element peak powers observed in a LEU core were approximately 5% lower than that of a HEU core.

The thermal fluxes in irradiation facilities were also calculated and compared for equivalent LEU and HEU fuelled cores. The flux in fuel element irradiation positions was calculated to be approximately 11% lower in LEU fuelled cores. Fluxes in other irradiation positions and neutron beam guides were calculated to be 4% - 6% lower in LEU fuelled cores.

PROJECT MANAGEMENT

The irradiation and complete conversion of HIFAR to LEU silicide fuel is a major modification in terms of HIFAR licensing and operation, therefore a four stage submission process consistent with a safety category 1 project has been initiated in order to obtain approval from ARPANSA.

- First Stage – Conceptual Design and Project Plan
- Second Stage – Detailed Design and Safety Analysis

- Third Stage – Procurement and Inspection, Procedures and Instructions

- Fourth Stage – Commissioning and Inspection, Final Completion

Each submission requires review by ANSTO's Safety Assessment Committee and the Reactor Manager prior to being submitted to ARPANSA for approval. First stage approval was granted by ARPANSA on the 5th September 2001.

The scope of the project covers:

- Design and drafting of the fuel element modifications required to the RISO fuel
- Neutronic and thermal-hydraulic analyses of reactor operation under normal and accident conditions for both a mixed HEU/LEU core and a complete LEU core
- Development of a Safety Analysis report for reactor operation with LEU fuel
- Amendments to the HIFAR Safety Document and Descriptive Manual
- Amendments to HIFAR Operational Limits and Conditions
- Amendments to operational Procedures, Instructions and physics data
- Procurement and inspection of LEU fuel
- Commissioning

The introduction and conversion of HIFAR to LEU fuel requires detailed analysis of the fuel element and reactor performance under both normal operation and accident conditions. Specific issues include a new technical evaluation of neutronic and thermal-hydraulic parameters and the revision of reactor physics data.

REFERENCES

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