RERTR 2014 – 35TH INTERNATIONAL MEETING ON
REDUCED ENRICHMENT FOR RESEARCH AND TEST REACTORS

OCTOBER 12-16, 2014
IAEA VIENNA INTERNATIONAL CENTER
VIENNA, AUSTRIA

Efforts Made for the Conversion of Ghana's MNSR to LEU

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ABSTRACT

Ghana Research Reactor-1 is one of the Miniature Neutron Source Reactors in operation outside China, and it has been in operation since it was commissioned in March 1995. The fuel of the reactor is UAl_4 in an aluminum matrix and has an enrichment of 90.2 %. The reactor core has been earmarked for conversion from the 90.2 % enriched HEU to about 13.0 % enriched LEU in the form of UO_2; hence various studies have been undertaken in pursuance of this course. A Project and Supply Agreement for LEU fuel has been signed by all stakeholders. Currently, UJV/SKODA in collaboration with CIAE is designing a cask which will be used for the shipment of the spent HEU fuel from Ghana to China.

1. Introduction

The Ghana Research Reactor-1 (GHARR-1) is a commercial version of the Chinese Miniature Neutron Source Reactor (MNSR) and belongs to the class of tank-in-pool type reactors [1]. It is under-moderated with an H/U atom ratio of 197. Thermal power is rated at 30 kW with a corresponding peak thermal neutron flux of 1.0×10^{12} cm^2s^{-1}. It's the cold clean excess reactivity of the fresh core is about 4 mk. Cooling is achieved by natural convection using light water. Presently, the GHARR-1 core consists of a UAl_4 alloyed HEU fuel assembly with fuel elements arranged in ten concentric rings about a central control rod guide tube, that houses the reactor's only control rod. The control rod's reactivity worth is about -7 mk, providing a core shutdown margin of -3 mk. The small core has a low critical mass. However, its relatively large negative temperature coefficient of reactivity is capable of boosting its inherent safety properties [2]. The small size of the core facilitates neutron leakage and escape in both axial and radial directions. To minimize such losses and thereby conserve neutron economy, the core is heavily reflected on

[1]This work was supported by the U.S. Department of Energy, National Nuclear Security Administration, Office of Defense Nuclear Nonproliferation, under contract DE-AC02-06CH11357.

the side and underneath the fuel cage by a thick annulus and slab of beryllium material. Regulated shims of beryllium added to the top tray can compensate for loss of reactivity due to axial neutron leakage.

The Nuclear Reactors Research Centre (NRRC) of National Nuclear Research Institute (NNRI) which operates GHARR-1 is undertaking steps to convert the reactor core. This is in response to the global trend in converting research and test reactors from the use of High Enriched Uranium (HEU) to Low Enriched Uranium (LEU) in civil nuclear applications. The conversion of MNSRs is being performed as part of the Global Threat Reduction Initiative (GTRI) – Conversion Program of the United States Government at Argonne National Laboratory and the IAEA's Coordinated Research Project (CRP) on Conversion of Miniature Neutron Source Research Reactors to Low Enriched Uranium [3]. The CRP started in 2006 and various neutronics, thermal hydraulic and numerical computations have been performed. As a result, a report on "Analysis for Core Conversion of Ghana Research Reactor-1 from HEU to LEU Fuel" has been submitted to the International Atomic Energy Agency. Request for additional information (RAI) and other comments and recommendations have also been addressed.

It was shown in the report that throughout the lifetime of the proposed LEU core:

- The shutdown margin meets technical specification limits;
- Reactivity coefficients meet required limits and are comparable to the existing HEU core;
- Fuel integrity is maintained under all operating conditions;
- Dose to the public from the BDBA is below maximum permissible limits; and
- There will be no trade-off in the thermal neutron fluxes in the experimental channels. This will be achieved by increasing the power of the LEU core by 13%.

The report also reveals that 12.5 % enriched UO_2 fuel has been proposed in lieu of the 90.2 % UAl_4 fuel. It is quite obvious that the H/U atom moderation ratio will be reduced from 197 to about 145 by changing from UAl_4 to UO_2 fuel.

Some few computational codes were employed in the feasibility studies undertaken during the CRP, these include, but not limited to:

- Monte Carlo N-Particle (MCNP) Code; for neutronics
- Reactor Burnup System (REBUS) Code; for burnup
- Programme for Reactor Analysis and Transients (PARET); for thermal hydraulics transients
- PLATE; for Steady state analysis

Table 1 shows comparison of key parameters of the HEU core and the proposed LEU core.

Table 1. Comparison of Key Parameters for Reference GHARR-1 HEU and LEU Cores

Key Parameters	**HEU**	**LEU**
Fuel Meat	$U\text{-}Al_4$	UO_2
U-235 Total Core Loading, g	~ 998	~ 1358
U-235 Enrichment, wt %	90.2	12.5
Density of Meat, g/cm^3	3.456	10.6
Meat Diameter, mm	4.3	4.3
Cladding Diameter, mm	5.5	5.5
Thickness of He Gap, mm	None	0.05
Cladding Material	Al-303-1	Zirc-4
Number of Fuel Rods	344	348
Material for Grid Plates	LT-21	Zirc-4
Number of Dummy Elements	6	2

Subsequently, a Core Conversion Safety Analysis Report (CC SAR) has been completed. The CC SAR is an edited version of the HEU SAR with crucial parameters modified to reflect the LEU core as per the outcome of the CRP. The report has been submitted to the local regulatory body, the Radiation Protection Board (RPB), whose Request for Additional Information (RAI) are being addressed in phases. The RPB has also requested the steps for both the removal of the HEU fuel and the loading of the LEU fuel amongst the others.

GHARR-1 was obtained under a Project and Supply Agreement (PSA) between the IAEA, CIAE and the Government of Ghana in 1994 [4]. A similar PSA has been prepared and signed by stakeholders regarding the supply of LEU fuel from China to Ghana.

2. Working groups

The MNSR Conversion Working Group (WG) was inaugurated in February 2011 at the Vienna International Centre. The main objective of the working group is to coordinate activities and decision making process related to the conversion of MNSRs to LEU and shipping of the HEU fuel to China. Lessons learnt from each conversion will be shared by all for improvement of the process in subsequent conversions. Additional scope of the working group may include exchange of information and experience in the following: utilization, maintenance, code upgrading (validation, benchmarking), equipment and facility upgrading, training and R&D applications. Ghana has participated in all four preceding meetings and will be part of the fifth, which is scheduled for December, 2014. It was established in the first meeting that GHARR-1 will be the first MNSR to be converted outside China [5].

3. Expert Missions

Two expert missions and a consultancy meeting have been hosted by the Ghana Atomic Energy Commission to strengthen preparations for the reactor core conversion.

In the frame of the Technical Cooperation Project RAF4022, the first IAEA mission was conducted from 29 July to 2 August 2013 to review the safety of the core conversion from HEU to LEU fuel of the Ghana Research Reactor-1 (GHARR-1). The mission was conducted by a team consisting of an IAEA staff member (RRSS/NSNI/IAEA) and three IAEA external experts from France, South Africa and Syria [6].

The objective of the mission was to review the safety aspects related to the core conversion project. The review was made on the basis of the draft safety analysis report for the core conversion of Ghana Research Reactor-1 which was transmitted to the IAEA prior to the mission and other documents available at the facility. In the frame of this conversion, the review mission team also made an assessment of the current safety status of the reactor and a follow-up on the implementation of recommendations of the 2009 IAEA mission. The review performed by the mission team covered different safety aspects including the management system, safety analysis, operational limits and conditions, conduct of operations, technical issues and modifications and operational radiation protection.

The second mission, also within the work plan of the EC-Component of the RAF4022, Task 1.4, was conducted from 14 to 18 July, 2014. The Mission was conducted by three Experts from the International Atomic Energy Agency (IAEA), Hungary and Canada. Topics discussed during the expert mission included: licensing process, licensing approval hold points, HEU loading procedure, inspection of SSCs, LEU core loading, commission programme, review of criticality results and emergency planning [7].

Both the operation organization and the regulatory body were represented.

A Consultancy Meeting (CM) to survey the site conditions of the GHARR-1 MNSR was held in Accra, Ghana, from 14 to 15 August, 2014. Participants in the meeting included representatives from the IAEA, U.S. Department of Energy, Argonne National Laboratory, China Institute of Atomic Energy, SKODA JS, UJV (guests) and the National Nuclear Research Institute and Radiation Protection Institute of Ghana Atomic Energy Commission (host) [8].

The main objective of this consultancy meeting was to conduct a site survey at GHARR-1 reactor and define the final design requirements for the modification of MNSR-SKODA package and also the needed site preparatory works that have to be done as prerequisite to the core removal operations.

Some Action Items resulting from the CM are as follows:

- NNRI will provide the detailed drawings of the reactor hall (including the position of all pipes connected to the reactor and other possible structures inside the floor, which could have an influence on the floor load capacity) and entrance route for the cask, drawings of the reactor set up and special tool for core removal and the floor loading capacity of the reactor hall.

- A CM will be organised in Vienna at IAEA HQ on October 1-2, 2014 for regulators from China and Ghana to clarify what legal requirements exist and/or are needed to transfer the irradiated HEU MNSR core from Ghana to China.

- DOE/INL will place a contract with Ghana for site preparations as soon as possible.

- IAEA will sign a purchase order with UJV and/or SKODA JS for the modification of the basket design of the VPVR/M cask per the agreed upon technical specifications and manufacture one basket as soon as possible.

- Regulators of Russia, China and Ghana will meet in Russia around October 23 and 24, 2014 to discuss the necessary licensing for transport of the HEU fuel.

- Ghana and China were invited to witness the removal and transport of spent fuel from Uzbekistan (March – April, 2015).

- After UJV/SKODA JS submits the SKODA MNSR license package to the regulator, a technical meeting between the Czech, Ghanaian and Chinese regulators will be arranged.

4. Conclusion

Ghana is committed to ensuring the success of the IAEA-RERTR HEU-LEU conversion program, and 12.5 % enriched UO_2 has been proposed as fuel for the LEU Core based on preliminary studies performed. Computations have been undertaken which indicates that the conversion is feasible. The regulatory body, RPB has been notified of this activity and they are collaborating well with the Operation Organization for the conversion of the reactor core. Meetings have been held with personnel from RBB to discuss licensing procedures and many others. Recommendations from experts at various meetings and well as request for additional information are being addressed in phases.

5. Acknowledgement

The IAEA, US DOE and ANL have been very supportive and contributive to strides made by the Ghana Atomic Energy Commission in the pursuance of converting the reactor core from HEU to LEU.

6. References

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