RERTR 2015 – 36TH INTERNATIONAL MEETING ON
REDUCED ENRICHMENT FOR RESEARCH AND TEST REACTORS

OCTOBER 11-14, 2015
THE PLAZA HOTEL
SEOUL, SOUTH KOREA

Implementation of Reactor Core Conversion Program of GHARR-1

H. C. Odoi, R. G. Abrefah, I. J. K. Aboh, J. K. Gbadago, S. A. Birikorang and E. O. Amponsh-Abu
National Nuclear Research Institute
Ghana Atomic Energy Commission, Atomic Road, Kwabenya, Accra – Ghana

ABSTRACT

The Ghana Research Reactor-1 (GHARR-1) is one of Chinese's Miniature Neutron Source Reactor (MNSR) which was purchased under a tripartite agreement between Ghana, China and the IAEA. The reactor was installed in 1994 and has since been in operation without any incident. It has been used chiefly for Neutron Activation Analysis (NAA) and Training of students in the field of Nuclear Engineering. The GHARR-1 has been earmarked for the Conversion of Core from HEU to LEU which is in accordance with the then GTRI program and other related and/or associated programs. Over the past few years the National Nuclear Research Institute (NNRI), the Operating Organization of the Research Reactor for the Ghana Atomic Energy Commission (GAEC), has undertaken various tasks in order to implement the replacement of the reactor core. These include Neutronics and Thermal Hydraulics computations to ascertain the feasibility of changing the reactor core from HEU to LEU. The computations were done in collaboration with Argonne National Laboratory (ANL), International Atomic Energy Agency (IAEA) and other MNSR operating countries including China. Recently, a Project Management Team has been established to plan and execute necessary activities in order to successfully complete the Reactor Core Conversion to the latter; this is under the auspices of Idaho National Laboratory (INL). Various tasks that have been accomplished lately and others which are line up for the near future are presented in this paper.

1. Introduction

The Ghana Research Reactor-1 (GHARR-1) has nominal power 30 kW and employs 90.2 % highly enriched uranium (HEU) as fuel, light water as moderator, coolant and shield, and beryllium as reflector. The reactor is cooled by natural convection. GHARR-1 is a commercial type of the Miniature Neutron Source Reactor (MNSR) designed, manufactured and constructed by China Institute of Atomic Energy (CIAE), Beijing, China. It is designed for use in universities, hospitals and research institutes mainly for neutron activation analysis, production of short-lived radioisotopes, education and manpower development. The reactor is located at the National Nuclear Research Institute (NNRI) of Ghana Atomic Energy Commission (GAEC) [1].

Other features include: the fuel elements are all enriched uranium-aluminium (U-Al) alloy extrusion clad with aluminium. They are arranged in 10 multi-concentric circle layers at a pitch distance of 10.95 mm. The element cage consists of 2 grid plates, 4 tie rods and a guide tube for the control rod. Screws connect the 2 grid plates and 4 tie rods. The total number of lattice positions is 354 and the number of fuel elements is 344. The remaining positions are occupied with 6 dummy aluminium elements.

In 2006, the IAEA put together all the MNSR Operating Countries to undertake a Coordinated Research Project (CRP) that will ascertain the feasibility of replacing the HEU fuel of Reactor with LEU. This CRP was successfully completed in March 2012 after various meetings were held to discuss results and prepare the way forward. Subsequently, a Working Group was established to monitor the progress of the various MNSRs Conversion Activities and to share lessons learnt with the fraternity [2].

The NNRI is in support of the conversion of fuel from HEU to LEU and has undertaken various steps to achieve this. There has been a number on Expert and Consultancy Meetings over the last two or three years to

The proposed LEU fuel is basically expected to come with:

1. A change in fuel material from UAl_4 to UO_2 [3].
2. The enrichment of fuel to be changed from 90.2 % to 13.0 %. The enrichment proposed earlier was 12.5 % and was changed to make room for manufacturer's inbuilt features.
3. Number of fuel pins may change from 344 to 339. This was expected to be 348 for the 12.5 % enrichment proposed earlier; it does not give enough room for additional fuel pins which may be needed due to error in manufacturing of the 12.5 % fuel. (Maximum number of fuel pins that may be placed in the reactor core is 350)
4. The fuel pin clad will change from Al to Zrc-4.
5. The radius of Control rod will be slightly increased.

2. Tasks

Neutronics and Thermal Hydraulics computations were done with the 12.5% enriched LEU and subsequently with a 13.0 % to ensure the not more than 350 fuel pins would be need for normal operation of the Core.
Table 1 shows the some criticality results of the computed

Table 1 Comparison of Excess Reactivity Computed for various Cores

Fuel Material	Enrichment %	No. of Fuel Pins	Excess Reactivity, mk
UAl_4	90.2	344	4.00
UO_2	12.5	348	3.76
UO_2	13.0	348	> 4.5
UO_2	13.0	339	4.32

In other developments, computations to estimate the reactivity for various core layouts inside the reactor vessel and transfer cask will be done. These will be calculated and analyzed to support the GHARR-1 fuel cage removal operations. It is imperative that sub-criticality must be guaranteed with substantial margin, i.e., **k-effective +3σ < 0.95** [4] for the most reactive configurations conceivable during normal operations or accident scenarios.

The spent fuel inventory will be calculated for the whole core of 344 pins. The depletion will cover the whole GHARR1 operational history **from 17 December, 1994 through 25 December, 2016**. Bounding operational conditions are assumed as follows: reactor operated at 15 kW power level, 6 hours per day, 5 days per week, 4 weeks per month, and 12 months per year.

Fuel composition at the End-of-Life (EOL) plus 30-day cooling will be taken from the ORIGEN-S output. Only the actinides and 2 fission products Pm-149 and Sm-149 which are important to reactivity are expected to be kept separately in MCNP5 models. Most of I-135 and Xe-135 will have decayed away after 30-day cooling.

3. Project Management Plan Tasks [5]

A group of staff from the NNRI have been put together to form the project management team. The team is to ensure successful planning and execution of the Reactor Core Conversion Activities. Major tasks and various subtasks have been identified and currently form the basis of activities that are ongoing. The major tasks and subtasks are enumerated below:

i. *Project Leadership*
   a. Project Management
   b. Project Travel

ii. *Transport Package and Licensing*
   a. Type B Cask Licensing
   b. Type C Cask Licensing
   c. Interim Transfer Cask

iii. *GHARR-1 Reactor Building Preparations and Modifications*
   a. Facility Preparations
   b. Core Removal Preparation
   c. Building / Site Security
   d. Outside Loading Area (Layout) and Site Roads
   e. Personnel Training/Certification

iv. *Ghana Shipment Preparation/Approval*
   a. Transport Approval and Export License
   b. Facility Operations Safety Analysis
   c. Ghana Shipping License
   d. Nuclear Data Documents
   e. Transport and Customs Documents.

4. The Regulator

The Radiation Protection Board (RPB) has been notified of the Core Conversion Program and they are preparing for the task ahead in terms of Licensing and Approvals. There have been numerous of interactions between the Operators and the Regulators on activities and expectations. One of imminent activities, a Training Program for Regulatory body and Operating Organization on licensing and documentation procedures, is scheduled for second week in November, 2015 [6].

The RPB has already approved the Specification of 13 % LEU fuel to be fabricated and shipped to Ghana for the replacement of the HEU fuel. This was approved on the condition that some of the criticality and kinetic parameters computed for the 12.5% would be redone for the 13 % fuel

[7].

5. Tools

The Core Conversion activities will require different types of specific tools and other supporting apparatus. These will be used either directly or indirectly for the reactor core removal whiles others may be for storage. The list of such equipment that has been identified at the time of writing this paper is given in Table 2. Potential organizations have been contacted for the supply of the equipment. Some agreements and/or contracts have been finalized in most cases to ensure timely supply of these resources.

Table 2: List of Main Equipment for the Core Conversion Activity

No.	Equipment	Remarks
i.	Interim Transfer cask with dolly and pathway	Housing the irradiated core upon removal from the vessel for interim storage
ii.	SKODA MNSR Cast (Type B) with He leak testing equipment	Contains a basket which will accommodate the irradiated core directly
iii.	TUK-145/C-MNSR-(Type Cask)	For air shipment
iv.	Radiation Tolerant Underwater Camera Systems	For inspection of Reactor Components and observing activities in vessel water
v.	Cranes	Lifting Core and Casks
vi.	Electric Generator	Source of Electrical Power for Core Conversion Activities
vii.	Lead Shield	Shielding against gamma rays
viii.	Stainless Steel Container	For storage of components which will be removed from the reactor vessel and not re-used
ix.	CCTV	For monitoring activities remotely in Reactor Hall
x.	Laser Level	Positioning of components

There is also the need for the renovation of instrumentation and control with replacement of few components to improve the measurements of parameters necessary for the core replacement. There have been level of discussion with the CIAE and there are readily available components for this purpose based on contracts to be reached.

6. Challenges

This is the first time a decision is been made to change the fuel of the Ghana Research Reactor-1. Most of the activities will to be done for the first time in the country and hence not much of experience had been acquired in this area. This has the potential of spending more time in executing tasks which would otherwise take a relatively shorter time. For this reason much training and dry runs would to undertaken to ensure all tasks are done in a professional manner as possible to achieve the successful core conversion with little or no difficulties.

Another factor is the power situation in the country now and for that matter a generator will be employed during the conversion period. Initially the electrical generator was proposed to be a backup but with the crises deepening without any clear solution, it has become necessary to engage the generator fully for the project. This gives rise to an additional fuel cost for running the generator.

7. Conclusion

The regulatory body has given approval for the fabrication of the 13.0 % LEU fuel. Detailed computations were completed under the IAEA CRP but with the increment in the enrichment from 12.5 % to 13.0 % there is the need to re-calculate most of the parameters, especially the reactivity, shutdown margin, etc. and the effects of the increment of thermal hydraulics. Various organizations have been contracted for the supply of most of the equipments listed.

8. Acknowledge

We wish to acknowledge – with gratitude – the DOE, IAEA, INL and ANL for the goals put up to minimize or eliminate the use of HEU in Civil Organizations around the world. Our appreciation also goes to the CIAE for their efforts to support the conversion of MNSR's.

9. References

[1] E. H. K. Akaho et al; Safety Analysis Report - Ghana Research Reactor-1. GAEC-NNRI-RT-90. March, 1995.

[2] Minutes - International Atomic Energy Agency, Coordinated Research Project (CRP) on "Conversion of Miniature Neutron Source Reactors (MNSR) from Highly Enriched Uranium Core to Low Enriched Uranium Core" Third Research Coordination Meeting Vienna International Centre, Room A0531. 13-14 March, 2012.

[3] H. C. Odoi et al; Core Conversion Safety Analysis Report for GHARR-1 (draft) - 2012.

[4] Jay Liaw, (Private Communication) Nuclear Engineering Division – Argonne National Laboratory, USA. August 2015.

[5] Statement of Work; Project Management – Ghana MNSR Shipment. January 2015

[6] MINUTES of the Consultancy Meeting to review the implementation status of the Ghanaian HEU MNSR core removal project Beijing, China; 27-28 August, 2015.

[7] Letter of Approval for the Fuel – Radiation Protection Institute of Ghana Atomic Energy Commission, Ref. No. RPI/RT-30A/Vol. II/43, 4 May, 2015.