CONVERSION OF THE GHANA'S MINIATURE NEUTRON SOURCE REACTOR FROM HEU TO LEU: 2017 REPORT

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ABSTRACT

The shipment of spent nuclear fuel from former Soviet Union countries as well as United States of America allies has been conducted since 1996. In 2006, efforts were initiated to convert Chinese designed Miniature Neutron Source Reactors (MNSRs) from Highly Enriched Uranium (HEU) to Low Enriched Uranium (LEU) fuel. Feasibility studies were performed including neutronics and thermal hydraulics analyses and the results indicated that conversion from HEU to LEU is safe and nominal flux is attainable with a ten percent increase in power. The Ghana Research Reactor-1 (GHARR-1) is the first of five such MNSR reactors to request support for conversion and work towards its implementation. Under a project sponsored by the United States of America Department of Energy (USA DOE)/NNSA, the International Atomic Energy Agency (IAEA), and China, the HEU core is to be repatriated to China and a new LEU core is to be installed. Other physical changes were also necessary for a successful replacement of the fuel. The present paper describes the details of the work done from 2006 to 2017.

1. Introduction

When the GHARR-1 was commissioned it had a nominal power 30 kW and employs 90.2% 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 i.e. the Operating Organization) of Ghana Atomic Energy Commission (GAEC) [1].

The repatriation of Russian and US origin fresh and spent, HEU research reactor fuel has been conducted since 1996. 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 Ghana Research Reactor-1 (GHARR-1) is the first of five such MNSR reactors outside of China eligible for conversion and fuel return to China. Under a project involving China and Ghana as operating country, as well as the U.S.A and the IAEA the HEU core is to be repatriated to China and a new LEU core is to be installed.

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 of Expert and Consultancy Meetings over the last two to three years to identify key areas and milestones to be accomplished.

2. Tasks

Neutronics and Thermal Hydraulics computations were done with the 12.5% enriched LEU, but this was revised to 13.0 % to ensure that not more than 350 fuel pins would be needed for normal operation of the Core.

Table 1 shows some criticality results computed, the last is that of results from the Zero Power Test performed at the China Institute of Atomic Energy (CIAE).

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	339	4.32
*UO_2	13.0	334	4.00

*Results from Zero Power Test performed at CIAE [3].

3. Project Management Plan Tasks [4]

A Project Management Team (PMT) had been formed to ensure successful planning and execution of the Reactor Core Conversion Activities. Major tasks and various subtasks which had been accomplished include the following:

i. *Transport Package and Licensing*

The Nuclear Regulatory Authority granted approval for the use of the Type B and C Casks as well as the Interim Transfer Cask (ITC). This is after the PMT submitted the necessary documents to the NRA and Request for Additional Information had been addressed.

The ITC was used for the removal of the irradiated fuel from the reactor and it was also used for the interim storage of the removed HEU core.

ii. *GHARR-1 Reactor Building Preparations and Modifications*

Several modifications were undertaken at reactor hall and its environs to facilitate the removal and shipment of the HEU core. The overhead crane at the hall had been replaced. A new concrete platform was put up, and the roads leading to the platform was re-coated with asphalt after compact assessment had been performed and certified for its strength.

Staffs of the Reactor Centre were trained for the various activities.

The National Security were also alerted of the activity and were briefed on the related risks. Hence, a number of Military and Police personnel were at post right from the onset of activities.

iii. *Removal of the HEU Core*

Activities for the core removal started on the 19th August 2016 and lasted for ten (10) days.

International stakeholders that participated include SOSNY R&D Company (Russia), CIAE (China), Idaho National Laboratory (INL) USA, and IAEA (Austria) with CERT (Centre for Energy Research and Training, Nigeria) and Nigeria Nuclear Regulatory Authority (NNRA) as observers.

Day 1

A meeting was held to brief the participants on the task ahead. The technical equipment set (TES) which includes the ITC was transferred from the stores to the working platform at the GHARR-1 premises and subsequently inspected by the SOSNY R&D Company – the designer and manufacturer of the TES.

Day 2 and 3

The TES was installed at the dry-run facility. The SOSNY R&D Company tested the ITC and it proved functional after a couple of maintenance works.

Day 4, 5 and 6

The SOSNY R&D Company organized a classroom and hands-on training on the ITC for the Ghanaian team. After the training, SOSNY R&D Company certified the Ghanaian team for operation of the ITC.

Day 7

Demonstration of ITC operation to IAEA and Nuclear Regulatory Authority of Ghana (NRA).

Day 8

Dismantling of TES from the dry-run facility. The IAEA seal on the reactor was broken by the IAEA safeguard inspectors that were present. The metal barricade around the reactor pool was cut off. The Chinese installed helium detector and ionization chamber in the inner irradiation tubes together with cadmium absorbers.

Day 9
The control rod, drive mechanism and the beryllium shim tray were removed from the reactor vessel. The control rod and the beryllium shim tray were placed in the reactor pool. TES was installed in the reactor hall. The under-water cameras were installed in the reactor vessel and signal projected on a TV screen in the control room.

Day 10
The HEU core was removed from the reactor vessel by using the ITC. The Core while inside the ITC was left on top of the reactor vessel to allow water to drain off for one hour. The ITC was then closed at the bottom with the Core inside. The crane in the reactor hall was used to lift the ITC onto the dolly which was positioned at the entrance of the reactor hall.

iv. Interim Storage
The ITC containing the HEU core was lifted together with the dolly at the entrance of the reactor by a mobile crane and was placed on the road in front of the reactor building. The ITC containing the HEU core with the dolly was lifted by a forklift and taken to the National Radioactive Waste Management Centre (NRWMC) for safe keeping. Police and Military personnel were stationed on GAEC premises to maintain 24 hour surveillance and protection services. The ITC was at the NRWMC for 49 days.

v. LOADING INTO TUK-145
SOSNY R&D Company and UJV arrived on GAEC site on 13th October. There was a meeting organized for all teams around for a briefing on the loading into TUK-145 activity. SOSNY R&D Company and UJV unpacked their equipment from the ISO containers. The IAEA safeguard team inspected the seal that was placed on the ITC during the HEU unloading from the reactor. The ITC was brought from the NRWMC by using forklift. The IAEA safeguard team broke the seal on the ITC. The SKODA cask, the TUK-145 and all other equipment were placed in position by using mobile cranes and forklift. The ITC was placed on top of the SKODA cask using a mobile crane and the HEU core was transferred into the SKODA cask. The Skoda cask was closed. The IAEA safeguard team placed a seal on the SKODA cask. Vacuum drying which took about twenty (20) hours was carried out prior to leak test which was performed on the SKODA cask. The SKODA cask was then loaded into the TUK-145 by using mobile cranes. The TUK-145 was then finally assembled and the IAEA safeguard team placed a seal on it.

4. The Nuclear Regulatory Authority (NRA)

A new Regulatory Body had been formed and hence the Regulatory Body (RB) is no more under the umbrella of the GAEC as it were a couple of years back, i.e. the RB and Operating Organization (OO) used to be under the same Commission. The NRA is been alerted of all activities relating to the HEU removal and LEU insertion. Representatives from the NRA were present at all the events stated earlier to ensure the OO conforms to acceptable procedures. There were representatives from the IAEA and ANL as well as observers from Centre for Energy Research and Training, Zaria – Nigeria.

6. Conclusion

The regulatory body gave approval for all activities that were undertaken and the OO complied with directives. The HEU has been removed from the GHARR-1 but the LEU is yet to arrive for it to be loaded into the GHARR-1 at the time of issuing this paper. It is expected to be delivered soon. All activities were done successfully without any incident that needs to be reported.

7. 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.

8. References

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