RERTR 2017 - 38th INTERNATIONAL MEETING ON
REDUCED ENRICHMENT FOR RESEARCH AND TEST REACTORS

NOVEMBER 12-15, 2017
EMBASSY SUITES CHICAGO DOWNTOWN MAGNIFICENT MILE HOTEL
CHICAGO, IL USA

Completion of Ghana's MNSR Conversion from HEU to LEU

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ABSTRACT

Ghana acquired a Miniature Neutron Source Reactor in the mid 90's. The research reactor was operated for over twenty years using a Highly Enriched Uranium (HEU) fuel. In 2006, plans were made to convert the fuel to Low Enriched Uranium (LEU). Feasibility studies, which include neutronics and thermal hydraulics analyses, were completed in 2012 and implementation plans commenced almost immediately. Various International Institutions played different roles leading to the Completion of the Conversion of Ghana's MNSR from HEU to LEU with the support from IAEA and U.S. DoE. The presentation gives a summary of the feasibility studies performed and elaborates the various roles played by the International Institutions.

1. Introduction

The Ghana Research Reactor-1 (GHARR-1) is product of China with a design similar to that of the Canadian SLOWPOK. The GHARR-1, a Miniature Neutron Source Reactor (MNSR), is tank-in-pool type of reactor which was installed in 1994 by the Chinese. It achieve criticality on December 17, 1994. It is used mainly for Neutron Activation Analysis (NAA), Research and Development (R&D) and Training of Manpower for the Ghana's Nuclear Power Project. The Operating Organization is the National Nuclear Research Institute (NNRI) of Ghana Atomic Energy Commission (GAEC). For the first twenty (20) years of operation the GHARR-1 used a 90.2 % enriched uranium as fuel, a level of enrichment considered to be a weapon graded material.

The International Atomic Energy Agency (IAEA) initiated in 2005/6, a Coordinated Research Project (CRP) to perform a feasibility studies on the conversion of the reactor fuel from a Highly Enriched Uranium (HEU) to Low Enriched Uranium (LEU). The feasibility studies included neutronics and thermal hydraulics computations, estimation of radiation levels before, during and after the conversion of the core, among others. On completion of the CRP in 2011/12, it was concluded that a 12.5 % (later revised to 13.0 %) enriched fuel is applicable to MNSRs in general.

At the time of completion the CRP, a Consultancy Group was formed to see to the implementation of the Core Conversion of MNSRs. Ghana opted to be the first to convert her Core after/outside China, the origin of MNSR. The conversion of the MNSR in China does not include shipping of the irradiated core. In the agreement to supply the HEU fuel to the MNSR operating countries, it was alluded to the return of the fuel to China whenever it is of no further used for the purpose of which it was acquired. Several consultancy meetings were held to schedule the activities which led to the successful conversion of the Ghana MNSR.

2. Major Activities of GHARR-1 Core Conversion

The main institutions that form the consultancy group and the country of origin is shown in the table 1 with the major roles played have been indicted.

Table 1. Countries, Institutions and major roles played in Core Conversion of GHARR-1

Country	**Institute(s)**	**Major roles played**
Czech	UJV, SKODA	1. Provision of SKODA Cask 2. Design and Fabrication of MNSR Basket 3. Dry runs 4. Vacuum Drying 5. Organized/Host Meetings 6. Etc.
USA	DoE, ANL, INL, Y12, STS, etc.	1. Provision of Codes and Training 2. Organization/Host meetings 3. Consultants 4. Provision of Casks for LEU fuel 5. Shipment of Fuel 6. Financial Support 7. Etc.
	IAEA	1. Consultants 2. Financial Support 3. Organization of Meetings 4. Organized CRP on Feasibility Studies of Core conversion of MNSRs
Russia	SOSNY R&D	1. Design and fabrication of TES including ITC 2. Provision of TUK-145 3. Arrangement for airline (Volga Dnpr) for the shipment of HEU 4. Training of staff on the use of ITC

		5. Dry runs 6. Etc.
China	IAE, CNEIC	1. Fabrication of LEU Fuel 2. Onsite and offsite Zero Power Test 3. Road transport of LEU and HEU in China 4. Loading and Commission of LEU 5. Licences, Approval, Permits, Authorizations, etc. 6. Organized/Host Meetings 7. Etc.
Ghana	GAEC, NRA	1. Site Preparation 2. Organise/Host Meetings 3. Licenses, Approval, Permits, Authorizations, etc. 4. Clearing of items from Airports and Ports 5. Shipment of items 6. Etc.

The activities of the core conversion spanned over ten years. The first years, as indicated earlier, for feasibility studies, four years of site preparation and fabrication/purchase of equipment and two years of removal, storage and shipment of irradiated HEU fuel to China. During this period, there is about four concurrent years of fuel fabrication, zero power test, plus shipment of the LEU fuel to Ghana and final loading of the LEU into the reactor vessel.

Timelines of some the activities leading to the conversion of the core are shown in Table 2

Table 2 Timelines of main Core Conversion activities

Date	Activity
February 28, 2014	Project and Supply Agreement (GOV/2014/17)
July 1, 2016	Shutdown of Research Reactor
July 24 to August 5, 2016	Zero Power Test in China
August 28, 2016	Removal of irradiated fuel from Reactor Vessel
August 28 to October 13, 2016	Temporary storage of irradiated fuel at Waste Management Facility
October 13 to 16, 2016	Packing of irradiated fuel into TUK SKODA MNSR Cask
July 3	Chinese arrived in Accra, Ghana
July 4-7	Assembling of fuel rods into fuel cage
July 9 – 11	Setup of Instruments and detectors
July 12	Loading of fuel cage into Reactor Vessel; Arrival of Observers
July 13	Reactor went critical at 13:23 GMT
July 14 – 28	Measuring the value of Cd tubes and Cd rabbits; Determining the final excess reactivity.
July 31 - Aug. 4	Power Calibration, low power operation
Aug. 7 – 10	Full Power operation Ceremony; Environment measurement

Aug. 11 – 17	Reactivity release experiment and documents preparation
Aug. 18	Chinese team departure from Ghana
August 27 – 29, 2017	Shipment of HEU irradiated Fuel from Ghana to China in TUK-145_SKODA_MNSR Cask

3. Documents Submitted to the Regulatory Body

Over twenty documents were submitted to NRA; the Regulatory Body at the time of executing GHARR-1 Core Conversion. These were given QAQC tags as follows:

QAQC1 Procedure for MNSR Core Displacement from GHARR-1 Vessel and Loading into Skoda MNSR Cask

QAQC2 Fire Safety Plan for Irradiated HEU Core Removal and Loading

QAQC3 Security and Safeguards Plan for Irradiated HEU Core Removal

QAQC4 Radiation Protection Plan for GHARR-1 Core Conversion

QAQC5 Transport Preparation Plan for GHARR-1 Core Conversion

QAQC6 Emergency Preparedness Plan for GHARR-1 Core Conversion

QAQC7 Reports On Effects Of 0.5 % Increment in Enrichment of Proposed LEU Fuel for GHARR-1 Core Conversion

QAQC8 Reports On Refurbishment of Instrumentation and Control System for GHARR-1 Facility

QAQC9 LEU Core Loading and Initial Tests Procedure for GHARR-1 Core Conversion

QAQC10 Ghana MNSR (LEU) Loading Procedure

QAQC11 Ghana MNSR (LEU) Commissioning Test Procedures Criticality Experiments

QAQC12 Ghana MNSR (LEU) Commissioning Test Procedures On-Site Zero Power Experiments

QAQC13 Ghana MNSR (LEU) Commissioning Test Procedures Power Rising Experiments

QAQC14 Ghana MNSR (LEU) Commissioning Test Procedures Full Power Experiments

QAQC15 Ghana MNSR (LEU) Commissioning Test Procedures Environment Monitoring Experiments

QAQC16 Ghana MNSR (LEU) Commissioning Test Procedures Safety Performance Characteristics Experiments

QAQC1 The Experimental Summary Of Ghana MNSR ZPTF With LEU Core

QAQC18 Safety Analysis Report for MNSR Core Displacement from Vessel and Loading into Skoda MNSR Cask

QAQC19 Inspection Report for GHARR-1 Facility after Removal of HEU Core

QAQC20 Inspection Report for GHARR-1 Facility after Removal of HEU Core

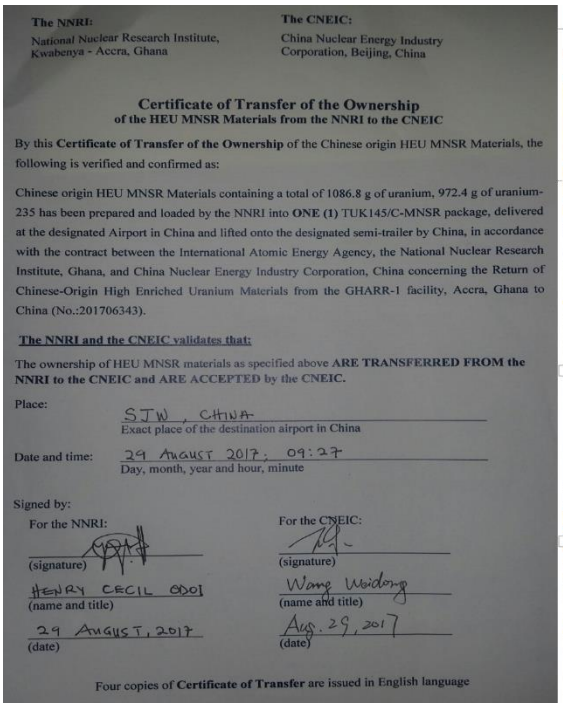
The Centre responded to *request for additional information* by the regulatory authority NRA. Consequently approvals, authorizations and/or licenses were given at various stages for work to progress steadily to the very end. In addition, representatives from the regulatory body were present at various instances to inspect equipment and procedures set for the activities. Representatives from IAEA were also invited to inspect some equipment and procedures as well as *seal* and *unseal* packages.

4. Interesting Pictures

Arrival of Fresh LEU Core – June 22, 2017

A Report sent by one custom officer

Clearance of the LEU was successfully carried out today. The consignment arrived at 07:30, left the airport at 10:30 and arrived at GAEC at 10:58 under Police escort.



The NNRI:
National Nuclear Research Institute,
Kwabenya - Accra, Ghana

The CNEIC:
China Nuclear Energy Industry
Corporation, Beijing, China

Certificate of Transfer of the Ownership
of the HEU MNSR Materials from the NNRI to the CNEIC

By this **Certificate of Transfer of the Ownership** of the Chinese origin HEU MNSR Materials, the following is verified and confirmed as:

Chinese origin HEU MNSR Materials containing a total of 1086.8 g of uranium, 972.4 g of uranium-235 has been prepared and loaded by the NNRI into **ONE (1)** TUK145/C-MNSR package, delivered at the designated Airport in China and lifted onto the designated semi-trailer by China, in accordance with the contract between the International Atomic Energy Agency, the National Nuclear Research Institute, Ghana, and China Nuclear Energy Industry Corporation, China concerning the Return of Chinese-Origin High Enriched Uranium Materials from the GHARR-1 facility, Accra, Ghana to China (No.:201706343).

The NNRI and the CNEIC validates that:

The ownership of HEU MNSR materials as specified above **ARE TRANSFERRED FROM the NNRI to the CNEIC and ARE ACCEPTED** by the CNEIC.

Place: SJW, CHINA
Exact place of the destination airport in China

Date and time: 29 August 2017; 09:27
Day, month, year and hour, minute

Signed by:

For the NNRI:
(signature)
HENRY CECIL ODOI
(name and title)
29 AUGUST, 2017
(date)

For the CNEIC:
(signature)
Wang Weidong
(name and title)
Aug. 29, 2017
(date)

Four copies of **Certificate of Transfer** are issued in English language

5. Conclusion

The conversion of the fuel/core from HEU to LEU is not likely to pose any threat to the day to day utilization of the reactor. The Removal and Shipment of the HEU fuel has been completed successfully and subsequent Loading of LEU Fuel completed successfully with 335 fuel pins. Dose Measurements recorded during all activities were within acceptable limits. This makes Ghana the second to convert its MNSR; of course the first outside the country of origin, and in relation to this our President the following statement at the 2016 UN summit:

"*In talking about sustainable relations, Africa, and, indeed, Ghana, remains committed to remaining a nuclear-weapon-free continent. Three weeks ago, highly-enriched uranium was flown out of Ghana back to China, signaling the end of the removal of all such material from the country. Our research reactor has, subsequently, been converted to use low-enriched fuel for research. A world, free of nuclear weapons, must be in all our collective interest*."