Shipment of Irradiated HEU Nuclear Fuel from Nigeria to China

J. Dewes[1], I. Bolshinsky[1], S. Tozser[1], Y.A. Ahmed[2], H. Adamu[2]
[1]Idaho National Laboratory, Idaho Falls, ID, USA;
Center for Energy Research and Training, Ahmadu Bello University, Zaria, Nigeria;

ABSTRACT

The repatriation of the Nigerian Research Reactor 1 (NIRR-1) irradiated high enriched uranium (HEU) nuclear fuel core to China was completed in December 2018. This effort was conducted by the Center for Energy Research and Training (CERT) of the Nigerian Atomic Energy Commission (NAEC) with the support of the International Atomic Energy Agency (IAEA), the China Institute of Atomic Energy (CIAE), and the U.S. Department of Energy (DOE) National Nuclear Security Administration's (NNSA) Office of Material Management and Minimization (M3). The NIRR-1, which is a Miniature Neutron Source Reactor (MNSR) type, is operated by CERT and is located at the Ahmadu Bello University in Zaria, Nigeria. MNSRs were designed and built by CIAE and are located in China, Ghana, Iran, Nigeria, Pakistan, and Syria

The NIRR-1 HEU removal process involved upgrades to the facility to support the shipment process, as well as development of licensing and packaging for the handling of the irradiated HEU nuclear materials. The HEU core was transferred from the NIRR-1 facility using a shielded transfer cask and was then packaged in the TUK-145/C transport package, which provided shielding and protection for the HEU core during transport to China. Following importation into China and unloading, the irradiated core was placed into interim storage. The present paper describes the details of the preparation and execution of this shipment and the lessons learned.

1 INTRODUCTION

Since 1978, various national and international activities have been underway to convert Research Reactors and Test Reactors from the use of high enriched uranium (HEU) to low enriched uranium (LEU) fuel or shutdown and decommission the facility. Based on the interest of Member states, the International Atomic Energy Agency (IAEA) initiated a Coordinated Research Project (CRP) in 2006 with the overall objective of assisting institutions in Member states with HEU fueled Miniature Neutron Source Reactors (MNSR) to convert to LEU fuel. The MNSR is a pool type Reactor designed and built by China Institute of Atomic Energy (CIAE) and can be found in China, Ghana, Iran, Nigeria, Pakistan and Syria.

The MNSR in Nigeria is the Nigeria Research Reactor 1 (NIRR-1), which is operated by the Centre for Energy Research and Training (CERT) of Nigeria Atomic Energy Commission (NAEC) and located at the Ahmadu Bello University, Zaria. NIRR-1, is a 30kW nominal power reactor, commissioned in February 2004 and it has been in operation since then. As part of its plan to convert NIRR-1 from HEU to LEU fueled reactor, NAEC requested in a letter to the IAEA, dated 25th January 2015, assistance in the removal and transportation of their HEU from Nigeria to China, its country of origin. The IAEA responded favorably by agreeing to coordinate the program through the Research Reactor Section of its Department of Nuclear Energy. The US Department of Energy (DOE) offered to support the HEU shipment under its

National Nuclear Security Administration's (NNSA) Material Management and Minimization (M^3) program. UK and Norway also provided support to this project.

The NIRR-1 HEU shipment program commenced when the Idaho National laboratory (INL), on behalf of US DOE, signed a Blanket Master Contract (BMC) with CERT. The BMC covered the preparation of the HEU shipment while two separate contracts signed between the IAEA and CERT handled the HEU core discharge from NIRR-1, packaging it into transport container, and its shipment to China.

The bilateral contract between the IAEA and CERT (as a sole source contractor) for NIRR-1 core discharge and HEU materials packaging has been prepared by the IAEA and assented by CERT on behalf of Nigeria. The signed tripartite contract for transportation of HEU loaded TUK 145/C transport package from Nigeria to China which was also prepared by the IAEA is a follow-up to the Memorandum of Understanding (MOU) between Nigeria and China on transfer of ownership of the irradiated HEU. Also finalized was the Project and Supply Agreement (PSA) signed by China, Nigeria and the IAEA which the various MOUs depends upon.

The HEU core was finally discharged from NIRR-1 on 23rd November 2018 and arrived in Beijing on 6th December 2018, the same day possession was transferred to the Chinese Authorities.

2 PREPARATION AND ACTIVITIES LEADING TO THE SHIPMENT

Following Nigeria's request for assistance through the IAEA, the Idaho National laboratory under the GAP Materials Program of the U.S. DOE NNSA's Office of M^3, NIRR-1 nuclear fuel containing HEU materials was planned for repatriation to China. As part of this program, a project management concept was developed to support the repatriation of the HEU MNSR nuclear materials from the NIRR-1 Facility to China. The preparation for the shipment was supported by a contract between CERT and the Idaho National Laboratory. The DOE/NNSA MNSR Gap Materials Program assigned the Program Manager and a supporting Country Officer to manage the INL/CERT contract and provide technical support.

At the initial stage of the program, a broad project team was formed consisting representatives from Nigeria, the IAEA, DOE/NNSA, and CIAE, the HEU core manufacturer from China, as well as the China Nuclear Energy Industry Corporation (CNEIC), the company authorized to import nuclear materials in China. The IAEA assigned a Project Manager for the MNSR removal program, who was responsible for managing the IAEA/CERT and IAEA/CERT/CNEIC contracts and coordinating multiple consultancy meetings in Abuja, Beijing and Vienna.

Nigeria on its part appointed a Project Director who served as the primary point of contact for the internal and external interfaces in the legal framework, intergovernmental agreements and licensing process. He also served as the primary contractual point of contact for the CNEIC, INL and IAEA contracts. In addition to the project management team, several key vendors were included to support the project. CERT convened a stakeholder group comprising various government agencies that would play some role in the preparation for and shipment of the HEU material from Nigeria to China. The Blanket Master Contract (BMC) signed between INL and CERT in May 2016 is the contract that supported the preparation for the shipment of the nuclear materials at NIRR-1 site in Nigeria. This umbrella contract covered the various project management tasks carried out in preparation for the HEU materials shipment.

2.1 Project Management

CERT formed a project management team to ensure successful implementation of the contract signed with INL for planning and preparations for shipment of the HEU material from the NIRR-1, in Zaria, Nigeria to Beijing, China. Tasks that had been accomplished include: project management, transport planning, facility modifications, and development of equipment to support the shipment, as well as licensing and human resource developments.

To achieve project implementation success, CERT took the lessons learned and the experiences of Ghana into account while developing Nigeria's procedures for HEU core removal. The cooperation with Ghana authorities included sharing of conversion documents and expertise and training of CERT staff at the International MNSR Training Center (IMTC) constructed at National Nuclear Research Institute (NNRI), GAEC Accra, Ghana.

The training and qualification programme for the personnel involved in the core removal activities included dry runs for procedures important to safety. Feedback from these dry runs was used for further improvements of Nigeria project.

2.2 Transport Concept

A two-part transport concept was developed for the NIRR-1 HEU material shipment from Nigeria to China. The first part involved onsite activities related to the facility modification needed to be carried out for a successful HEU core removal from NIRR-1 and its loading into a suitable transport container. The transport container was selected from a number of options available for consideration. The TUK-145/C-MNSR Type C shipping package was selected by the team based on its suitability for air transport of spent nuclear fuel and its successful use in Ghana. All needed authorizations/licenses/approvals needed for the successful handling and shipment of the HEU materials from Nigeria to China were also identified.

The other component of the transport concept was related to offsite activities of the shipment itself. The offsite portion included selection of a shipping package, selection of routes, and identifying means of transport. In this case, shipment by air was selected as the primary option based on the significantly lower risk associated with rapid air transport. Emergency preparedness and Physical protection needs for both onsite and offsite activities were highlighted and discussed.

2.3 Facility Modifications

Site evaluation conducted at the commencement of the project implementation revealed the need for the adequate preparation of the NIRR-1 facility for a successful HEU material shipment. From the Transport concept developed, facility modifications were identified that would ensure the smooth transfer of the HEU core from the reactor to the shipping package. This included refurbishment or replacement of systems critical to the safe transfer of fuel, installation of equipment, and some construction work. Major works carried out were:

(a) Installation of dual-axes Crane
(b) Construction of a concrete loading area pad capable of handling the 30-ton TUK-145/C-MNSR transport cask
(c) Provision of 50 kVA Generator
(d) Procurement of Underwater radiation resistant camera
(e) Refurbishment of Roadways to allow for access by cranes and the dedicated transport cask trailer to the site

(f) Refurbishment of Reactor instrumentation and construction of reactor pool cover
(g) Procurement of radiation aerial monitor
(h) Procurement of contamination measuring instrument

2.4 Support for Shipment

Areas of support for the preparation of the shipment were some of the components of the project that were identified at the early stage of the project planning. These included technical support for the core discharge and loading and the regulation requirements that were outside Nigeria, since the shipment traversed several sovereign nations. Based on the lessons learned from the similar shipment conducted earlier and the specifics of the NIRR-1 site, some technical equipment had to be developed for a successful shipment of NIRR-1 core. Some of the support services offered were handled by foreign subcontractors, notably SOSNY R&D of Russia and UJV-Rez of Czech Republic.

2.5 Licensing

Shipment of spent nuclear fuel is governed by the individual nations involved, and follows the guidance provided by the IAEA. Authorization of shipments typically is based on a kind of gov-to-gov agreement between the concerned two counties, and then includes the development of several licenses and certifications. It is on this note that a Memorandum of Understanding (MoU) for the return of the Chinese origin HEU MNSR materials from the Federal Republic of Nigeria to the People's Republic of China was signed on the 4th of June 2018 between the two countries. This MoU refered to the original PSA in the form of which the recently effected HEU materials were delivered from China to Nigeria in 2003, as well as the willingness of the two countries to return the Chinese origin HEU materials from Nigeria to China under the auspicious a commercial contract. This MoU served as basic legal document in the implementation of all licensing activities.

The operation of nuclear facility in every country is licensed and monitored by the national regulatory authority assigned with the responsibility. The body saddled with this responsibility in Nigeria, the NNRA, gave CERT all the regulatory conditions that needed to be satisfied for CERT to be authorized to proceed with the HEU shipment project implementation. These authorizations/approvals/licenses included:

(a) Approvals to shutdown NIRR-1 for conversion program; and to remove reactor core
(b) Authorization for Site Modification/Construction
(c) Notification of Status of Nuclear Fuel, INFCIRC/358
(d) Approval to Import/Export Specified/Dual use Equipment
(e) Authorization to Export Nuclear Materials
(f) License to Transport Irradiated Nuclear Material
(g) Approval for Packages (Transport Cask for HEU)
(h) Operator License

All the listed documents were obtained before the shipment of the HEU materials from Nigeria to China was authorized by the NNRA

2.6 Human Resources Development

Given the uncertainty of access by supporting contractors to the loading site, it was determined early on that the CERT crew needed to be capable of executing the removal mission independent of outside support. For this reason, an extensive training program was

developed and executed. Four NNRR-1's health physicists participated on a one-week hands on training at the Budapest Research Reactor (Hungary) focusing on the radiation protection services at core offloading and packing and transport operation. The training included the needed preparatory activity and the real monitoring tasks that shall be made during the core removal, packing and transport operation. The health physicist became familiar also with requirements and rules of the dose rate and contamination measurements on the transport package, as well as the preparation of the protocols on radiation measurements, including criticality index calculation and package placarding.

An operator training was developed for CERT personnel with the view to preparing them for the task of HEU core discharge and its loading into transport container. The training was held at the International MNSR Training Center (IMTC) in Accra Ghana. The training center was constructed by NNSA in support of the program of repatriating all MNSR HEU material back to China.

The training program developed for the Nigerian crew consisted of three main elements; familiarization with the equipment, familiarization with the procedures for core removal and packaging, and finally demonstration of the processes. The training was scheduled over a six-month timeframe, with three training sessions of one week in duration, followed by a one-week Dry Run. Once proficiency was achieved by the operating crew after the third training session, a two-part examination was conducted to provide for the issuance of certificate of competence to the trainees. A written test was administered after which the dry run exercise was carried out, where the crew demonstrated their capability of independently performing the core removal and packaging evolution in a timely manner.

3 HEU CORE DISCHARGE, LOADING, AND SHIPMENT

Two contracts signed between CERT and the IAEA covered the core discharge and packing at the NIRR-1 site, and then the shipment operation of HEU MNSR materials. The tripartite contract for HEU shipment from NIRR-1 facility in Nigeria to the storage facility in China refered to the liability agreement reached between Nigeria and China for support of their nuclear-related HEU fuel manipulations.

The training conducted for the CERT crew at the IMTF provided for the NIRR-1 HEU core removal, packaging and shipment in one light-day operation. Although core was removed and loaded, together with the three fresh HEU fuel pins, into the transport cask on 23rd October 2018, it could not be shipped the same day as planned. This was due to some licensing challenges that the transporter of the HEU material in China had. Figures 1 and 2 show the photographs of CERT personnel during core discharge and loading operations respectively.

Figure 1: CERT operators discharging HEU Core from NIRR-1 Vessel

Figure 2: CERT personnel loading HEU Core into transport Cask

The loaded transport cask was temporarily kept at NIRR-1 site until 4th December 2018. The HEU MNSR material was shipped from Nigeria, via Kaduna International Airport, on 4th December, 2018. The photograph in Figure 3 shows the loading of the low-bed semitrailer carrying the HEU materials from NIRR-1 site.

Figure 3: Loading of TUK-145/C Cask into Cargo Plane at Kaduna International Airport, Nigeria

Figure 4: Arrival of NIRR-1 HEU Materials at the CIAE Facility in Beijing, China

The HEU material from Nigeria arrived in China on 6th December 2018. The ownership of the MNSR materials was transferred and the materials were handed over to the Chinese Authority on 6th December 2018. Figure 4 shows the arrival of the NIRR-1 HEU at the CIAE facility in Beijing, China.

4 LESSONS LEARNED

From the initiation of the project through preparations and final shipment of NIRR-1 HEU core, the lessons learned as listed below, shall be catalyst to improved performance in subsequent MNSR HEU materials shipment.

(a) Adequate Crane capacity and Crane operator expertise are critical to timely work delivery on site
(b) Capacity and size of fork lift to be used should be adequate
(c) The period for the dry-run exercise at IMTC should be as close to actual shipment date as possible;
(d) The management of CERT accelerated the necessary documents and submittals to the NNRA for their timely review. In view of the timeframe of the project, this activity was given priority to allow for issuance of all required licenses before the shutdown of the reactor and removal of the HEU core;
(e) Regular meetings were held between CERT and NNRA to discuss and resolve all licensing issues that may arise from review process.

5 CONCLUSION

The HEU materials in NIRR-1 site have been successfully returned to China, its country of origin and it can be rightly expressed that Nigeria has joined the list of HEU-free nations

6 ACKNOWLEDGEMENT

We wish to sincerely acknowledge the support and contributions of the following agencies in making the project a complete success.

a. International Atomic Energy Agency
b. US Department of Energy (DOE)
c. Idaho National Laboratory (INL)
d. Argonne National Laboratory (ANL)
e. China Atomic Energy Agency (CAEA)
f. China Institute of Atomic Energy (CIAE)
g. China National Nuclear Energy Industry Cooperation (CNEIC)
h. Government and People of United Kingdom (UK)
i. Government and People of Norway
j. Nigeria Atomic Energy Commission (NAEC)
k. Nigerian Nuclear Regulatory Authority (NNRA)
l. Nigerian Office of the National Security Adviser (ONSA)
m. Nigeria Defence Headquarters
n. Federal Ministry of Finance, Nigeria
o. Federal Ministry of Foreign Affairs, Nigeria
p. Ahmadu Bello University, Zaria-Nigeria
q. Our Contracting Partners (SOSNY, UJV, STS, Sail Bond)
r. Ghana Atomic Energy Commission, Ghana