INL/CON-09-16974
PREPRINT

Air Shipment of Highly Enriched Uranium Spent Nuclear Fuel from Romania

ENC 2010

K. J. Allen
I. Bolshinsky
L. L. Biro
M.E . Budu
N. V. Zamfir
M. Dragusin

July 2010

The INL is a
U.S. Department of Energy
National Laboratory
operated by
Battelle Energy Alliance

Air Shipment of Highly Enriched Uranium Spent Nuclear Fuel from Romania[1]

K. J. Allen, I. Bolshinsky
Idaho National Laboratory, Idaho Falls, Idaho, USA

L. L. Biro
National Commission for Nuclear Activities Control, Bucharest, Romania

M. E. Budu
R&D Company Sosny, Moscow, Russia

N. V. Zamfir, M. Dragusin
Horia Hulubei National Institute of Physics and Nuclear Engineering, Magurele, Romania

ABSTRACT

Romania safely air shipped 23.7 kilograms of Russian-origin highly enriched uranium (HEU) spent nuclear fuel from the VVR-S research reactor at Magurele, Romania, to the Russian Federation in June 2009. This was the world's first air shipment of spent nuclear fuel transported in a Type B(U) cask under existing international laws without special exceptions for the air transport licenses. This shipment was coordinated by the Russian Research Reactor Fuel Return Program (RRRFR), part of the U.S. Department of Energy Global Threat Reduction Initiative (GTRI), in cooperation with the Romania National Commission for Nuclear Activities Control (CNCAN), the Horia Hulubei National Institute of Physics and Nuclear Engineering (IFIN-HH), and the Russian Federation State Corporation Rosatom. The shipment was transported by truck to and from the respective commercial airports in Romania and the Russian Federation and stored at a secure nuclear facility in Russia where it will be converted into low enriched uranium. With this shipment, Romania became the 3rd country under the RRRFR program and the 14th country under the GTRI program to remove all HEU. This paper describes the work, equipment, and approvals that were required to complete this spent fuel air shipment.

1. Introduction

1.1 RRRFR and GTRI Programs

Fig 1: Loading spent fuel into AN-124-100 airplane in Romania

The United States Department of Energy National Nuclear Security Administration (NNSA), in cooperation with the International Atomic Energy Agency (IAEA), created the Russian Research Reactor Fuel Return Program (RRRFR) to reduce nuclear proliferation risks by assisting the transfer of Russian-origin highly enriched uranium (HEU) research reactor fuel from participating countries to the Russian Federation. The Global Threat Reduction Initiative (GTRI) helps reduce and protect vulnerable nuclear and radiological material located at civilian sites worldwide and RRRFR is one of many programs managed under GTRI. In 2004 the United States (US) and the Russian Federation (RF) signed an agreement to assist countries with the RRRFR shipments of HEU to Russia. GTRI and RRRFR work closely with IAEA and the Russian Federation State Corporation for Atomic

[1] Work supported by the U.S. Department of Energy Office of National Nuclear Security Administration under DOE Idaho Operations Office Contract DE-AC07-05ID14517.

Energy (Rosatom) to safely and securely transport this material. By April 2010, RRRFR had transported over 1239 kg of HEU to Russia and additional shipments are planned for the near future.

1.2 Romanian Participation in the RRRFR Program

Fig 2: Spent fuel ISO containers inside airplane

Romania was an early adopter of the RRRFR program and transported 14.3 kg of HEU unirradiated (fresh) fuel to Russia in 2003, making it the second RRRFR country to ship HEU. Planning for the HEU spent fuel shipment from the VVR-S reactor began in 2004 and was completed with the shipment in June 2009. This was the world's first air shipment of spent nuclear fuel in Type B(U) casks under existing international laws without special exceptions for the transportation licenses. This shipment made Romania the 3rd country under the RRRFR program and the 14th country under the GTRI program to remove all HEU from their country. This action clearly demonstrated Romania's commitment to nuclear nonproliferation goals.

All RRRFR activities in Romania were managed by the National Commission for Nuclear Activities Control (CNCAN), the nuclear regulator for Romania. The Horia Hulubei National Institute of Physics and Nuclear Engineering (IFIN-HH) operated the VVR-S research reactor at Magurele, Romania, and assisted with both the fresh and spent fuel shipments.

1.3 VVR-S Research Reactor

The VVR-S is a light water moderated and cooled research reactor that began operation in 1957 with 10% enriched type EK-10 fuel assemblies. The reactor converted to 36.6% enriched type C-36 fuel assemblies in 1984 and was permanently shut down in 1997. IFIN-HH used the reactor for nuclear physics research and radioisotope production during the 40 years of operation. Decommissioning of the reactor is now in progress.

1.4 HEU Spent Fuel Quantity

Seventy (70) type C-36 spent fuel assemblies containing 23.7 kg of HEU were shipped in 18 Russian TUK-19 shipping casks. Four assemblies were loaded into each cask and each cask was loaded into a specially designed container that complied with International Organization for Standardization (ISO) rules for freight containers. Three casks were loaded into each ISO container for a total of six ISO containers in the shipment. All six ISO containers were loaded into one AN-124-100 cargo aircraft and transported to the Russian Federation by the Volga-Dnepr Airlines Company.

2. Shipment Preparations

Shipment preparations began in October 2004 and required about 4-1/2 years to complete. Major preparation tasks are discussed below.

2.1 Spent Fuel Cask Selection

All available casks suitable for shipping type C-36 fuel assemblies were evaluated for use at VVR-S. The casks included the Russian TUK-19, Czech Republic Skoda VPVR/M, and the US NAC type LWT casks. CNCAN and IFIN-HH selected the TUK-19 cask as most suitable because the weight could be handled by the existing reactor hall overhead crane, all HEU assemblies would fit into the available number of casks, and only one shipment to Russia would be required. All facility modifications, equipment designs, preparations, and licensing were based upon this cask choice.

Fig 3: TUK-19 cask

2.1.1 Facility Modifications

Several facility modifications were required to safely load the TUK-19 casks. The inside and outside truck lock access doors were replaced to provide better containment of potential contamination and to improve security during cask loading. Reactor hall access truck lock floor hatches were replaced to support the weight of a truck with loaded casks. A linoleum floor covering was removed from the reactor hall, the underlying concrete was decontaminated, and an epoxy surface was applied to the reactor hall floor. A small cantilever crane was installed in the cask loading area to install the TUK-19 lids. IFIN-HH funded and installed new personnel access doors and repaved roads leading to, and within, the IFIN-HH site to support the weight of loaded trucks. IFIN-HH also increased security during loading by installing a secondary fence inside the primary IFIN-HH site boundary, a new guard post, and various new security devices around the reactor building and cask storage area.

2.1.2 Spent Fuel Inspections

Fig 4: Spent fuel in the storage pool

Dimensional inspections, radiological conditions, and thermal calculations of the HEU spent fuel were completed in 2007 to provide data necessary for the transportation licenses. Review of the storage pool water records confirmed no C-36 fuel assemblies were leaking fuel. Because the spent fuel was to be shipped to the Production Association "Mayak" in Ozersk, RF, representatives of Mayak reviewed the inspection data, confirmed that all C-36 assemblies could be loaded into the TUK-19 casks, and accepted the assemblies as suitable for receipt by Mayak.

2.1.3 Planning for Spent Fuel Air Shipment

When the TUK-19 cask was selected in early 2006 they were licensed only for transport in type TK-5 railcars. In late 2006, the R&D Company Sosny (Sosny) proposed that the VVR-S spent fuel could be transported by air in TUK-19 casks in accordance with existing international regulations. Three international air shipments of spent fuel in Type B(U) casks had been previously completed under other programs, but those shipments used military aircraft and required special exceptions to approve the shipment licenses. Sosny pointed out that both the IAEA *Regulations for the Safe Transport of Radioactive Material* (TS-R-1) and the Russian Federation *Safety Rules in Transportation of Radioactive Material* (NP-053-04) allow the air shipment of spent fuel in Type B(U) casks if the radioactive content does not exceed 3000 times the "A_2" radionuclide values listed in the regulations. Sosny performed preliminary calculations that showed the total VVR-S HEU spent fuel activity would be less than $3000A_2$ so the regulations would allow air shipment in civilian aircraft without special exceptions. As the nuclear regulatory authority for Romania, CNCAN agreed that if the Russian Federation issued an air shipment license for the VVR-S spent fuel and if the Russian licensing documents met Romanian requirements, then CNCAN would also issue an air shipment license for Romania. After much discussion, the RRRFR program agreed to proceed with the proposal to ship the VVR-S spent fuel by air.

Fig 5: Casks in ISO container

2.1.4 Air Shipment Equipment

Because TUK-19 casks had not been previously shipped by air, new freight containers and cask tiedowns had to be designed and fabricated. To allow the flexibility for multi-modal transport of the casks it was decided to use standard sized ISO freight containers. By complying with ISO rules, the cask containers could be handled by most transportation carriers worldwide and make use of common carrier equipment. Sosny designed the ISO container and cask tiedown system to hold one, two, or three casks per container. This required a modified floor and wall structure to support the total weight of three loaded casks.

The tiedowns were designed to support the casks in an upright position and securely fastened to the container floor. The containers and tiedowns were fabricated and tested in Russia and certified for road, rail, water, and air modes of transport. The Volga-Dnepr Airlines Company, the planned air carrier, assisted with the design and testing to assure the containers would meet all Russian and international air transport requirements.

2.1.5 Spent Fuel Loading Transfer Cask

Fig 6: Transfer cask

The TUK-19 casks were too large to be submerged in the VVR-S spent fuel storage pool for underwater loading so they were positioned on the reactor hall floor for loading. Because the Romanian nuclear regulator would not allow remote loading by crane for radiological safety reasons, Sosny designed a lead shielded stainless steel transfer cask to safely load the TUK-19 casks on the reactor hall floor. The transfer cask moved TUK-19 cask baskets between the storage pool and the TUK-19 casks by using an automatic basket grapple suspended from a wire cable in the transfer cask. This allowed fully loaded cask baskets to be raised out of the pool, into the shielded transfer cask, positioned on top of an empty TUK-19 cask, and lowered into the cask. Except for a brief time while the lids were installed on the loaded TUK-19 casks, this transfer cask kept the spent fuel assemblies radiologically shielded during all loading operations. The equipment was fabricated and tested in Romania and worked well during cask loading. Use of this transfer cask kept the personnel radiation exposure well below allowable limits.

2.1.6 Training and Procedures

As the designer, Sosny developed procedures to handle the transfer cask, the ISO containers, the cask tiedowns, and the TUK-19 cask loading procedures. These procedures were converted by IFIN-HH into approved VVR-S facility documents. As the TUK-19 cask owner, Mayak reviewed and concurred with the cask loading procedures. Sosny and Mayak trained the IFIN-HH operators at the VVR-S reactor and the operators passed written examinations given by CNCAN before being allowed to load casks. Because the empty TUK-19 casks would not be delivered to VVR-S until immediately before loading, IFIN-HH operators used the transfer cask equipment, a mock-up of the TUK-19 cask, and dummy fuel assemblies for the cask loading operator training.

2.1.7 Equipment Demonstrations

To assure that cask loading equipment would work as designed and to validate the operating procedures, the transfer cask equipment was demonstrated in the VVR-S reactor hall with mock-up fuel assemblies and a mock-up TUK-19 cask. This demonstration showed that adding a small cantilever crane in the cask loading area to quickly position the TUK-19 cask lid on the cask body could significantly reduce personnel radiation exposure. This crane was installed prior to loading and the actual exposure during loading was low. After the empty TUK-19 casks were received, all procedures were demonstrated by loading dummy fuel assemblies into the empty casks. Tests were conducted with an empty ISO container and truck to assure adequate access to and from the reactor hall and these tests resulted in minor modifications along the access route. ISO containers were loaded and unloaded from an AN-124-100 cargo aircraft to demonstrate the aircraft procedures and equipment. All of these equipment demonstrations resulted in very smooth operations when the casks were loaded and transported.

Fig 7: Spent fuel leaving for airport

2.1.8 Cask Loading

The TUK-19 cask baskets were suspended in the reactor hall storage pool and loaded manually with reach rods to specific locations within each basket. Each basket was removed

from the pool by raising into the transfer cask and then lowering into an empty TUK-19 cask. The cask lid was positioned with the small cantilever crane, the bolts were tightened, and each cask was leak tested. During loading the IAEA and Euratom safeguards inspectors verified that each assembly contained spent fuel, verified the serial numbers matched the documentation, and applied both IAEA and Euratom tamper indicating seals on each cask. Each loaded and sealed cask was secured inside an ISO container with tiedowns and a new empty cask was loaded. As each ISO container was filled with 3 casks, the container was moved out of the reactor hall to a secured outside storage area until all casks were loaded.

3. Transportation Licenses

The shipment license required considerable effort in both Romania and Russia because there was no precedent for issuing a license to ship spent fuel by air in a Type B(U) cask. This new licensing activity required careful review by all parties. Safety analyses of the air shipment were performed by authorized Russian agencies and multiple formal expert reviews were conducted by Russian authorities before the Russian license was issued. Particular attention was given to modelling the cask behaviour under accident conditions, particularly if the aircraft crashed, to assure there would be no criticality accident, no release of the radioactive contents above the limits imposed by IAEA for such cases, and minimal impact to the general public. When all concerns were resolved, Rosatom issued a Russian Federation combined cask and transportation license *"Certificate of Approval for Package Design and Shipment, TUK-19 Transport Packaging with S-36 SFAs of Romanian VVR-S Research Reactor, Shipment by Road and Air,* document number RUS/3104/B(U)F-96T".

CNCAN reviewed the Russian Federation air shipment license and documents to assure they complied with Romanian law. After completing the Romanian reviews, CNCAN issued a "*Road and Air Shipment Certificate R/400/B(U)F-96T(1/2009)*" authorizing road shipment from the VVR-S reactor to the airport and air shipment within Romania. No transit country licenses were required because the flight path did not pass over any third country.

Fig 8: Unloading spent fuel in Russia

IFIN-HH also obtained multiple Romanian licenses for radiation protection programs, physical protection programs, operator qualifications for fuel handling, air and road carrier licenses, fuel handling equipment licenses, and nuclear material export licenses. Other Russian licenses and permits were also obtained, including a flight permit to transport Class 7 dangerous cargo by air. Mayak obtained licenses to transport the spent fuel by truck from the airport to the Mayak facility.

4. Shipment

The shipment of 18 casks inside 6 special ISO containers on 6 trucks began on 28 June 2010 with road transport to the Bucharest airport. The containers were transferred from the trucks to one AN-124-100 commercial cargo aircraft on 29 June and the plane flew over Romania, the Black Sea, and over Russian territory to a refuelling stop in Ulyanovsk, Russia. The plane continued to the Yekaterinburg airport where the ISO containers were unloaded onto trucks and transported by road to the Mayak facility in Ozersk, Russia, where the spent fuel will be reprocessed into low enriched uranium.

5. Conclusions

The world's first air shipment of spent nuclear fuel in Type B(U) casks under existing international laws was safely and securely completed when Romania shipped all of the VVR-S research reactor HEU spent fuel to the Russian Federation on 29 June 2009. With the cooperation of many international governments and organizations, this shipment helped Romania to achieve the significant nuclear non-proliferation goal of becoming free of all HEU.