INL/CON-09-15414
PREPRINT

Fresh and Spent Nuclear Fuel Repatriation from the IRT-2000 Research Reactor Facility, Sofia, Bulgaria

RRFM 2009

T. G. Apostolov
I. S. Dimitrov
K. J. Allen

March 2009

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

FRESH AND SPENT NUCLEAR FUEL REPATRIATION FROM THE IRT-2000 RESEARCH REACTOR FACILITY, SOFIA, BULGARIA[1]

T. G. APOSTOLOV, I. S. DIMITROV
Bulgarian Academy of Sciences - Institute for Nuclear Research and Nuclear Energy
72 Tzarigradsko Chaussee, Blvd., 1784 Sofia – Bulgaria

K. J. ALLEN
Idaho National Laboratory
P.O. Box 1625, Idaho Falls, Idaho 83415-3740 – USA

ABSTRACT

The IRT-2000 research reactor, operated by the Bulgarian Institute for Nuclear Research and Nuclear Energy (INRNE), safely shipped all of their Russian-origin nuclear fuel from the Republic of Bulgaria to the Russian Federation beginning in 2003 and completing in 2008. These fresh and spent fuel shipments removed all highly enriched uranium (HEU) from Bulgaria. The fresh fuel was shipped by air in December 2003 using trucks and a commercial cargo aircraft. One combined spent fuel shipment of HEU and low enriched uranium (LEU) was completed in July 2008 using high capacity VPVR/M casks transported by truck, barge, and rail. The HEU shipments were assisted by the Russian Research Reactor Fuel Return Program (RRRFR) and the LEU spent fuel shipment was funded by Bulgaria. This report describes the work, approvals, organizations, equipment, and agreements required to complete these shipments and concludes with several major lessons learned.

1. Introduction

1.1 Reactor Description

The IRT–2000 research reactor is situated in the Nuclear Scientific Experimental and Education Centre (NSEEC), which is part of the Institute for Nuclear Research and Nuclear Energy's (INRNE), Bulgarian Academy of Sciences, located on the east side of Sofia, Republic of Bulgaria. IRT-2000 was constructed in 1959 by the Kurchatov Institute of Moscow, Russia and is operated by INRNE. The reactor went critical in 1961 with a nominal power of 1.0 MW, increased power to 1.5 MW in 1965, and increased again in 1970 to 2.0 MW. The reactor was temporarily shut down in 1989 and is now being reconstructed into a 200 kW reactor to meet increased safety requirements.

Figure 1: Cask Loading

IRT-2000 is a pool type, light water cooled and moderated reactor that operated with Russian-origin type EK-10 (10% enrichment) and type C-36 (36% enrichment) fuel assemblies, all of which were shipped to the Russian Federation (RF) in July 2008 as spent nuclear fuel (SNF). Twenty eight (28) type IRT-2M fuel assemblies (36% enrichment) were returned to Russia in December 2003 as fresh (unirradiated) fuel. The spent fuel storage pool, which connects to both the reactor pool and the hot cell laboratories, contained seventy three (73) SNF assemblies until shipped in 2008.

[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.

1.2 Fuel Shipment Background

In September 2000, Mr. Mohamed ElBaradei, Director General of the International Atomic Energy Agency (IAEA), invited the governments of 16 countries to participate in a new program to transfer Russian/Soviet-origin highly enriched uranium (HEU) research reactor fuel to the Russian Federation to reduce potential proliferation risks associated with HEU in research reactors. The United States (US) Department of Energy (DOE) agreed to fund this program and Russia agreed to accept and process HEU nuclear fuel from these countries into low enriched uranium (LEU). Bulgaria agreed to participate in this program and, as the result of one fresh fuel shipment and one spent fuel shipment, all HEU has been removed from Bulgaria. The Russian Research Reactor Fuel Return Program (RRRFR) was created by the DOE National Nuclear Security Administration (NNSA) to assist participating countries with this transfer of HEU. RRRFR is one of multiple nuclear nonproliferation programs administered by the NNSA Global Threat Reduction Initiative (GTRI) and works in close cooperation with the IAEA and the RF Rosatom State Corporation.

1.3 Fuel Quantities Shipped

INRNE successfully and safely shipped the following nuclear fuel to Russia:

Fresh Fuel – December 23, 2003
- HEU: 16.91 kg, 28 type IRT-2M fuel assemblies (36% enrichment)

Spent Fuel – July 5-17, 2008
- HEU: 6.44 kg, 16 type C-36 fuel assemblies (36% enrichment)
- LEU: 72.48 kg, 58 type EK-10 fuel assemblies (10% enrichment)

Total HEU: 23.35 kg

2. Fresh Fuel Shipment

Per contract between INRNE and IAEA, and with cooperation of the US and Russia, Bulgaria shipped 16.91 kg of HEU fresh fuel by air to Russia on 23 December 2003. Twenty eight (28) unirradiated IRT-2M fuel assemblies were loaded into Russian transportation casks, sealed by IAEA inspectors, transported by truck to the Gorna Oryahovitsa airport, then air shipped in a Russian commercial aircraft to Dimitrovgrad, Russia, where the HEU was down-blended into LEU. This shipment took about 4 months to plan and execute.

Figure 2: Loading IRT-2M HEU into Casks

3. Spent Fuel Removal

Spent fuel shipment planning began in October 2004 and the shipment was completed in July 2008, requiring about 45 months of activities. This length of time was required by local and international requirements to conduct the shipment safely and securely and by the availability of the casks selected for the spent fuel shipment. The activities can be summarized into the headings categories that are discussed below.

3.1 Shipment Planning and Management

When shipment planning began, the Bulgaria project lifecycle was defined to include all activities expected to complete the shipment. However, at that time no RRRFR shipments of spent fuel had been completed and Russia was developing new procedures to import spent fuel, so some activities were defined as work progressed. As other RRRFR spent fuel shipments were planned or completed, the Bulgarian tasks were refined to use lessons learned from those shipments. The final project ended up with 17 major tasks and 37 subtasks. The tasks fit into general categories of planning and management, facility

modifications, spent fuel inspections, shipping licenses, cask loading, and transportation. Each task and subtask required deliverable documents to prove completion of the required activities. Table 1 shows the times required for each task activity, including task approval, performance, and acceptance of the final deliverables.

General Task Activity	2004	2005	2006	2007	2008
Planning & Management					
Facility Modifications					
Spent Fuel Inspections					
Shipping Licenses					
Cask Loading					
Transportation					

Table 1: General Task Activity Schedule

INRNE provided a Project Manager to plan and manage all activities. A large number INRNE operators, technicians, and administrative personnel were required to support the multitude of complex arrangements and activities. Both Bulgarian and international contracts were required to complete some tasks.

3.2 Cask Selection and Loading

Several potential shipping casks were considered and the Škoda VPVR/M high capacity cask was selected for Bulgaria. This top and bottom loading cask allowed fuel assemblies to be loaded into the cask basket at the bottom of the reactor pool, minimizing radiation exposure during loading, and allowed the baskets to be remotely unloaded from the top when received at the Production Association Mayak facility using their standard equipment. Three (3) VPVR/M casks were used: one (1) cask contained 15 HEU assemblies and two (2) casks contained a total of 58 LEU assemblies. Six (6) LEU fuel pins were loaded into an approved by Mayak canister, welded closed, and inserted into the basket as though it were a normal fuel assembly.

Figure 3: Loading Cask into ISO Container

Prior to cask loading, the Nuclear Research Institute (NRI), Rez, Czech Republic, and representatives of Škoda provided cask handling training to INRNE and cask loading began one week after this training was completed. All cask loading was witnessed by IAEA and Euratom safeguards inspectors who applied tamper indicating seals on each cask. The loaded and sealed casks were stored inside the secure reactor hall until all final transportation approvals were obtained.

3.3 Facility Modifications

Facility modifications were performed to allow use of the VPVR/M casks in the IRT-2000 reactor hall. Structural analyses of the reactor shielding and reactor hall floor were performed and core samples of the reactor access pavement were analyzed to assure the loaded casks and transport trucks would not cause structural problems. The facility modifications included:

- Replacement of the reactor hall crane with a new 12.5-ton capacity bridge crane;
- Fabrication of a VPVR/M support platform above the reactor pool;
- Fabrication of weight distribution frames to support the cask and truck weights in the reactor hall and avoid structural modifications to the building:
- Replacement of the reactor building access pavement;

- Installation of an underwater camera and lights;
- Upgrade of the reactor hall electrical power supply; and
- Modification of the ventilation air-ducts above the reactor pool.

3.4 Spent Fuel Assembly Inspections

Accurate spent fuel assembly data was required to obtain shipping licenses from Bulgaria, Russia, and the transit countries of Romania and Ukraine. The fresh fuel supply data, irradiation data, and physical conditions were determined and recorded on a passport for each assembly. To assure compliance with Russian requirements, the spent fuel inspection and irradiation calculation procedures were reviewed and accepted by Mayak. No failed fuel was found. The final spent fuel data was reviewed by Mayak and accepted for delivery prior to shipment.

3.5 Cask and Shipping Licenses

Approved cask and shipping licenses were required from Russia, Ukraine, Romania, and Bulgaria, in sequential order from destination to origination. The VPVR/M cask had been previously licensed in Russia for the Czech Republic RRRFR spent fuel shipment and the license was still valid for the Bulgaria shipment. The Competent Authority in each country reviewed the Russian cask certificate, accepted it in accordance with their rules, and issued a cask license for Bulgaria. Russia issued a combined cask and shipping license.

Figure 4: Casks on Barge

The Russian shipping license required the completion of technical activities, an environmental assessment, public education, and expert reviews, collectively called the Unified Project task, and required a long time to complete. The Romania and Ukraine license approvals were assisted by the Kozloduy Nuclear Power Plant (NPP), which periodically ships its commercial spent fuel through these countries to Russia. The Kozloduy NPP prior experience expedited procedural, transportation, and security arrangements for license approvals from Bulgaria, Romania, and Ukraine.

3.6 Legal Framework

The legal basis for the RRRFR program is a government-to-government agreement between Russia and the United States, signed in May 2004, allowing the US to assist third countries with the repatriation of Russian-origin HEU research reactor fuel. Bulgaria signed agreements with the US to assist with the transport and with Russia to import the spent fuel. No new agreement was required to transit Romania. Ukraine transit complied with an existing agreement between Bulgaria, Ukraine, and the Russian Federation used for Kozloduy NPP shipments but a transport conditions document specific for the IRT-2000 research reactor spent fuel was provided and approved.

3.7 Shipment Logistics

The Bulgarian SNF was transported by truck, barge, and rail. After all shipment authorizations were obtained, the VPVR/M casks were loaded into ISO containers and placed on nuclear shipment licensed trucks. On 5 July 2008, the truck convoy left IRT-2000 and travelled by public roads to the Kozloduy NPP, located on the Danube River, where the casks were transferred into a licensed barge owned by the Kozloduy NPP. After clearing a Romanian final check and Bulgarian Customs, the barge departed down the Danube River.

The shipment cleared Romanian Customs a few days later at Calarasi and finished the river transport at Izmail, Ukraine. After clearing Ukrainian Customs, the ISO containers were transferred from the barge onto Russian railcars and transported to the Ukraine-Russian border. At the border, title to the SNF was transferred from INRNE to Mayak. The shipment continued by rail to Mayak where it was received and accepted on 17 July 2008. Armed security personnel accompanied the shipment from the time it left IRT-2000 until it was accepted at Mayak and no security or other incidents were encountered. To meet a constrained schedule for the Hungarian RRRFR SNF shipment, the emptied casks were shipped by air in a commercial Russian cargo aircraft from Chelyabinsk, Russia, to Budapest, Hungary.

4. Conclusion and Lessons Learned

With RRRFR assistance, Bulgaria planned and safely shipped fresh and spent HEU and LEU fuel from the IRT-2000 research reactor to Russia in 2003 and 2008. These fresh and spent fuel shipments removed all HEU from the Republic of Bulgaria, a significant global nuclear non-proliferation accomplishment. Key lessons learned are:

Figure 5: Transferring SNF Title at Russian Border

- Use a carrier with experience shipping nuclear materials to Russia to expedite the process and avoid problems;
- Sign carrier and security contracts in advance to minimize last-minute delays;
- Draft and review shipping papers in advance with the help of experienced carriers (Kozloduy NPP) and Mayak to avoid last-minute delays;
- Have all permits and licenses in place as far in advance as possible;
- Procure nuclear liability, cargo, and personnel insurance in advance of the shipment;
- Provide a senior technical person to accompany the shipment with the authority to resolve issues enroute;
- Pre-arrange a method for 24-hour monitoring and reporting during shipment to provide “Need-to-Know” information to obtain immediate technical support, if needed;
- Develop a coded location tracking system in advance to send shipment monitoring reports to DOE without compromising security;
- Provide the senior technical person accompanying the shipment with communications equipment, a laptop computer and a printer;
- Establish good cooperation with the nuclear regulator and safety authorities early in the project to help with planning and implementation;
- Establish good cooperation with other important partners, such as the carrier, security forces, and emergency response organizations, to help plan and provide support during the shipment; and
- Assure that main points of contact personnel in all involved organizations have a sufficient security level for the shipment details.