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ABSTRACT

On December 8, 2007, the largest shipment of high-enriched uranium spent nuclear fuel was successfully made from a Russian-designed nuclear research reactor in the Czech Republic to the Russian Federation. This accomplishment is the culmination of years of planning, negotiations, and hard work. The United States, Russian Federation, and the International Atomic Energy Agency have been working together on the Russian Research Reactor Fuel Return (RRRFR) Program in support of the Global Threat Reduction Initiative. In February 2003, RRRFR Program representatives met with the Nuclear Research Institute in Řež, Czech Republic, and discussed the return of their high-enriched uranium spent nuclear fuel to the Russian Federation for reprocessing. Nearly 5 years later, the shipment was made. This paper discusses the planning, preparations, coordination, and cooperation required to make this important international shipment.

Introduction and Program Background

In December 1999, representatives from the United States, Russian Federation, and International Atomic Energy Agency (IAEA) began working on a program to return Soviet and Russian-supplied high-enriched uranium (HEU) fuel, currently stored at foreign research reactors, to Russia. This effort is being funded under the Russian Research Reactor Fuel Return (RRRFR) Program. The RRRFR Program is a nuclear nonproliferation initiative for eliminating stockpiles of HEU nuclear materials by encouraging eligible countries to convert their research reactors from HEU to low-enriched uranium (LEU) fuel upon availability, qualification, and licensing of suitable LEU fuel.

In May 2004, the "Agreement Between the Government of the United States of America and the Government of the Russian Federation Concerning Cooperation for the Transfer of Russian-Produced Research Reactor Nuclear Fuel to the Russian Federation" was signed. This agreement provides legal authority for the RRRFR Program and establishes parameters whereby eligible countries may return fresh and spent HEU fuel assemblies and fissile materials to Russia.

Czech Republic Project Background

In February 2003, a team of technical representatives from the United States, Russian Federation, and IAEA conducted a fact-finding mission of the Nuclear Research Institute (NRI) in Řež, Czech Republic, which is about 20 km north of Prague along the banks of the Vltava River (see Figure 1). The purpose of this mission was to discuss the RRRFR Program with NRI and to obtain preliminary information about the physical and mechanical state of their fresh and HEU spent nuclear fuel (SNF), their facilities, and their transportation capabilities and experiences. During this mission, NRI expressed a desire to participate in the RRRFR Program.

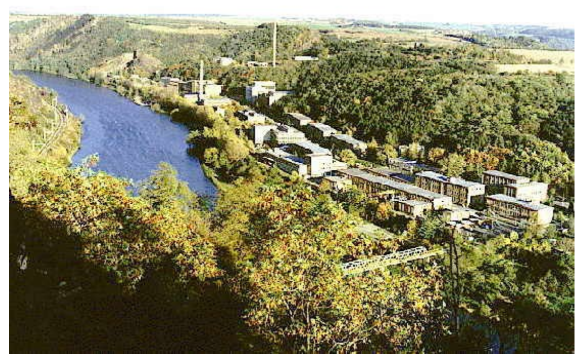

Figure 1. Nuclear Research Institute, Řež.

NRI owns and operates a LVR-15 Russian-designed type research reactor (see Figure 2). The reactor is a light-water moderated and cooled tank nuclear reactor with forced cooling. A combined water-beryllium reflector is used. The reactor was placed in operation in 1957 and operated until 1974 when it was upgraded to 10 MWt and the fuel was changed to the IRT-2M configuration with 80 weight percent ^{235}U. It then operated until the core was converted in 1996 to IRT-2M fuel with 36 weight percent ^{235}U with three or four tubes. Plans exist for further reducing the enrichment of the core to 19.7 weight percent ^{235}U fuel of the IRT-4M configuration. When the project began, NRI had 299 HEU SNF and 206 LEU SNF assemblies available for return to the Russian Federation.

In 2004, the U.S. Department of Energy (DOE) began negotiating NRI's participation in the RRRFR Program. In March 2005, an umbrella contract was signed for NRI to perform all activities needed to prepare for transporting their HEU SNF to the Russian Federation. In May 2007, the contract was amended to include actual HEU SNF handling, transport, and disposition.

Figure 2. LVR-15 reactor at Řež.

Project Planning and Execution

NRI was responsible for the entire project, including overall project management. DOE provides funding and oversight of NRI. The scope, cost, and schedule for activities were negotiated, and NRI issued task plans. DOE would authorize the work by issuing a task assignment that established the scope of work, deliverables, schedule, and a fixed price.

NRI assigned a highly qualified senior technical person with extensive management experience to manage the project. The success of this project can be attributed to the excellent planning, scheduling, cost estimating, managing, and communications skills of the project manager. The project manager being fluent in Czech, Russian, Slovak, and English was a significant attribute.

Successful completion of the NRI SNF shipping and disposition project required a significant amount of planning and coordination, including obtaining a new transportation cask system, preparing both shipping and receiving facilities, participation of four countries, and involvement of numerous organizations, regulatory agencies, and contractors. On December 8, 2007, the shipment was completed. This shipment was the largest shipment of HEU SNF from a Russian designed nuclear research reactor.

Transportation Cask System

To accommodate the need for a large-capacity cask system to haul HEU SNF in support of the RRRFR Program, the IAEA, funded by DOE, competitively bid and selected the ŠKODA VPVR/M cask by ŠKODA JS a.s. of Plzeň, Czech Republic. A tripartite contract was negotiated and signed between IAEA, ŠKODA JS a.s., and NRI for the cask system. ŠKODA provided 10 VPVR/M casks and ancillary equipment and agreed to maintain and store the casks for 10 years (the life of the RRRFR Program). NRI took ownership of these casks in exchange for allowing DOE to use the six casks they procured for hauling their LEU SNF. The IAEA, with support from DOE, performed quality audits and inspections of ŠKODA to ensure that regulatory requirements and design and fabrication specifications in the contract were satisfied.

The VPVR/M cask (see Figure 3) has a unique top or bottom loading/unloading design. The cask consists of a massive, cast steel, cylindrical body that is 300-mm (12-in.) thick. The upper and lower parts of the body are tapered to minimize the total cask weight, which is needed to better accommodate the limited overhead crane capacities in the research reactor facilities. The cask's external dimensions are 1,505 mm (59-in.) high (without shock absorbers) by 1,200-mm (47-in.) diameter. Its cavity is 885-mm (35-in.) high by 600-mm (24-in.) diameter. Internal cask walls have a hot aluminium spray coating for cask internal decontamination. The cask SNF basket is made of Atabor (i.e., 1.5% boron-treated) steel sheets that are 3.63-mm (0.14-in.) thick. The basket is 833-mm (33-in.) high by 553-mm (22-in.) wide and has a 36-square port for the fuel assemblies. A central suspension/hanger rod, running down the middle of the basket, is used to raise or lower the basket in and out of the cask.

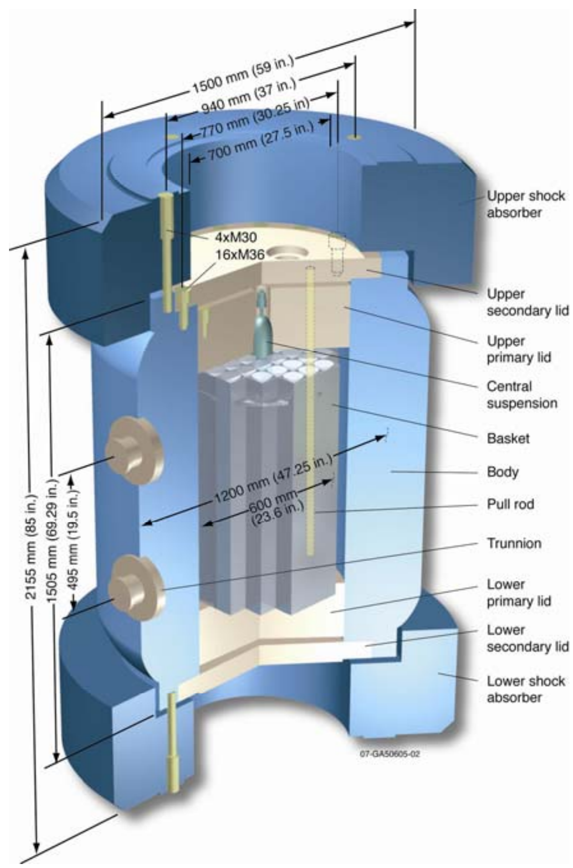

Figure 3. Schematic of the VPVR/M transport and storage cask.

Ancillary equipment for the VPVR/M cask system includes a basket alignment tool, cask manipulating frame, cask tiedown system, drying/leak-testing equipment, a cask lift fixture, fuel-handling tools, and specially designed and certified International Shipping Organization (ISO) containers.

The VPVR/M cask is licensed in four countries (i.e., Czech Republic, Russian Federation, Slovakia, and Ukraine). The State Office for Nuclear Safety (SONS) of the Czech Republic issued the original license (CZ/048/B(U)F-96 [Revision 1]) for both transport and storage. The cask is licensed for transport by road, railway, river, and sea. It also is licensed to transport 10 fuel types and store three types of Russian-origin research reactors fuels.

In January 2006, Rosatom issued certificate RUS/3065/B(U)F-96 for the VPVR/M cask. This cask is the first foreign cask to be licensed for multiple uses in the Russian Federation. Obtaining this license involved the efforts of numerous Russian companies and organizations, including Sosny R&D Company, a privately owned Russian company who coordinated the licensing effort in Russia; FSUE "VNIIEF," a government company who performed safety analysis and confirmed the structural, thermal, leak tightness, radiation, and nuclear safety of the cask design under normal and hypothetical accident conditions; FSUE "IPPE," a government company who provided safety analysis that demonstrated the radiation and nuclear safety for the cask design under normal and hypothetical accident transportation conditions; Mayak, a government company who uses and is responsible for the cask system in Russia; and Rosatom and Rostechnadzor, the Russian regulators who licensed the casks in Russia. The certificate is valid until January 23, 2009.

Obtaining competent authority certification for transport of the VPVR/M cask through Slovakia and Ukraine was fairly simple because the design meets the IAEA TS-R-1 international transportation requirements and is already licensed by the Czech Republic and the Russian Federation. Both countries approved use of the cask within their territory without performing a detailed evaluation.

The cask system was thoroughly demonstrated at the SKODA JS a.s. manufacturing facilities in Plzen, Czech Republic; the NRI facilities at Řež; and the Mayak facilities in Ozyorsk, Russia. Improvements, deficiencies, and lessons learned from those demonstrations were incorporated into the cask design and operations.[1]

Cask-handling operations resulted in several improvements being identified. The first was with the cask tiedown systems. During rail transport of the empty cask from the Czech Republic to the Mayak facility for the dry run, the tiedown turnbuckles loosened, allowing the casks to undergo fairly rapid, vibration-induced wear on the trunnions as shown in Figure 4. The tiedown system was redesigned to alleviate this problem.

Figure 4. Cask trunnion wear, resulting from loosening of the tiedown system during transport.

The second improvement involved damage caused to one of the cask lids at Mayak. During reassembly of VPVR/M Cask Number 012 (after being decontaminated at Mayak, Russia), the outer bottom lid was damaged. One of the two lid guide pins screwed into the cask body bolt holes was suck and could not be unscrewed during reassembly of the lid to the cask body. After the lid was guided into position on the cask, one of the pins was removed easily by hand. However, the other guide pin was stuck and could not be removed. Several attempts were made to remove the pin; however, efforts were unsuccessful. Finally, Mayak operators tried to remove the lid from the cask body using a hand-operated chain winch and overhead crane. The stuck guide pin caused the lid to tilt, which resulted in the guide pin breaking and the outer rim of the lid being deformed; this caused a bulge on the side of the lid (see Figure 5). The outer, first three bolt-hole threads in the cask body also were damaged. A root cause analysis was performed, the lid and cask bolt hole threads were repaired, and actions were taken to prevent reoccurrence of the problem.

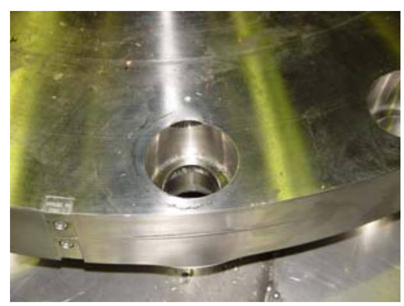

Figure 5. Damaged VPVR/M cask lid.

The third improvement involved spacer plates at the bottom of the cask baskets. During the receipt and maintenance inspection of the 16 VPVR/M casks at NRI after being returned from Mayak, three baskets had deformed fuel assembly ports and one basket had the spacer plates at the bottom of the baskets were broken off (see Figure 6). A root cause analysis was performed, the baskets were repaired, and actions were taken to prevent reoccurrence of the problem.

Figure 6. Photographs showing the broken spacer and the bottom of the cask basket where the spacer was attached.

Nuclear Research Institute Preparations/Operations

NRI had three spent fuel storage facilities that needed to be prepared for fuel and cask-handling operations. Those facilities are the At Reactor Pool (ARP), the Reactor Annex Pool (RAP), and the Away from Reactor (AFR) or High-Level Waste Storage Facility (HLWSF).[2]

ARP and RAP are both located within the research reactor building. ARP is connected to the research reactor vessel inside the main reactor building (see Figure 7), whereas RAP is located in a room connected to the main reactor building, which is accessible by a special rail system (see Figure 8).

Figure 7. LVR-15 reactor At Reactor Pool for spent nuclear fuel storage.

Figure 8. The VPVR/M cask being moved into the Away from Reactor storage area.

Preparations for handling fuel assemblies and the cask in both storage pool areas involved overhead crane upgrades (adding a nomadic load cell and speed controls); setting up the ŠKODA VPVR/M cask manipulation frame; installing specially designed cask basket support in the RAP; modifying the AFR pool cask transport device; adding special shielding around the cask pool and support/fuel loading stand; setting up numerous specialized tools and equipment for handling the fuel and transport cask; and setting up cask drying and leak tightness testing equipment.

Figure 9. The High Level Waste Storage Facility.

The HLWSF (see Figure 9) is located on a hill overlooking the main NRI complex. Preparing HLWSF for fuel and cask-handling operations involved upgrading the overhead crane (adding a nomadic load cell and speed controls), setting up a specially designed cask manipulation frame, installing a cask-loading support bridge over the storage pool. Miscellaneous tools and equipment, including a cask drying and leak tightness testing machine, were installed.

NRI made two major facility modifications to HLWSF that were not funded by DOE. A state-of-the-art, semiportable, modular hot cell was installed with specially designed remote-handling cutting and welding equipment and a cask basket-loading and storing system. The hot cell was used to repackage and load the EK-10 LEU SNF assemblies and the damaged IRT-2M fuel assemblies into specially designed stainless-steel canisters, which were hermetically sealed by being welded, loaded into a cask basket, and stored, pending loading into the casks.

An extension was built onto the front of HLWSF for handling and storing the transport casks. A cask-transfer device on rails was installed in this extension (see Figure 10). A specially designed cask storage vault, used for storing both the loaded and empty VPVR/M casks, was installed on one side of the extension. This vault is designed to protect, isolate, and provide physical protection for the casks during storage at NRI (see Figure 11).

Figure 10. Specially designed cask-transfer device on rails in the High-Level Waste Storage Facility entrance hall.

Figure 11. High-Level Waste Storage Facility extension cask storage vault.

Every NRI operation, procedure, new piece of equipment, and facility modification required special analysis and documentation. Examples include the following: (1) operations manual, (2) operation condition/limitation plan, (3) quality assurance manual, (4) emergency plan, (5) hot cell inspection and test plan, (6) permission for hot cell construction, (7) list of equipment to be controlled by SONS, (8) decommissioning plan, (9) list of controlled actions, (10) cask and SNF-handling operations procedures, and (11) safeguards and security plan, including the IAEA design information questionnaire. Many of these documents were used to obtain facilities and operations licenses.

NRI conducted two demonstrations that tested the procedures, operations, equipment, and facility modifications. One demonstration used dummy fuel assemblies and the second demonstration used real HEU SNF assemblies. Both demonstrations confirmed NRI's preparedness, provided training for the operators, and were used to obtain approval from SONS for actual fuel and cask-handling and loading operations.

NRI loaded the first cask with SNF in March 2007 to confirm adequacy for the VPVR/M shielding. All 16 casks were loaded and placed in the HLWSF extension cask storage vault by the end of August 2007. Cask-loading operations went smoothly with no significant problems. It took about 3 days to load, seal, and prepare each cask for shipment. The 16 loaded casks left Řež for Russia on December 1, 2007.

Russian Federation Preparations/Operations

Russian Federation law requires that thorough planning, review, and evaluations of the environmental impacts of importing nuclear materials be performed. The evaluations must show that importation will have a positive impact on the environment. A formal process, called State Ecological Review, was performed. This process evaluates the impact of transporting nuclear material within the Russian territory, including identifying potential emergencies, consequences, and responses; nuclear and radiation risks and mitigation of the risks' impact on the public and environment; anti-terrorist planning and training; and reprocessing the SNF, stabilizing the high-level waste, and storing it in Russia for 20 years or less. The law also requires that the total cost of performing Czech shipment activities in Russia be identified and a 30% surcharge be added to the project. The added funds were used for "Special Environmental Programs" that had a positive impact on the public and environment at Mayak and in the Chelyabinsk Region.

Approval to make the shipment into the Russian Federation was obtained after completion of the following: (1) the Unified Project and Special Environmental Programs; (2) the State Ecological Review (3) the Foreign Trade Contract between Russia and Czech Republic; (4) the Russian transport and cask licenses; (5) the Transport Conditions Plan between the Czech, Slovak, Ukraine, and Russian governments; (6) Mayak preparations; and (7) the Russian Transport Decree.

Figure 12. Cask unloading from the International Shipping Organization container in Building 855.

Preparing Mayak for the NRI shipment involved two facilities (i.e., Buildings 855 and 101A) and modifying a specially designed railcar. Mayak's fuel reprocessing, high-level waste vitrification process, and waste storage systems already existed and did not need to be changed to handle the NRI fuels.

Upon arrival at Mayak, the ISO containers, loaded with VPVR/M casks, were received by rail in Building 855 (a large rail/truck high-bay area with a heavy capacity overhead crane [see Figure 12]). The loaded casks were transferred to specially designed railcars and transported to Building 101A (a larger hot shop with remote operations capabilities for handling casks and SNF assemblies [see Figure 13]). Specialized remote-handling equipment and tools were used to handle the VPVR/M cask system and transfer the NRI SNF to a special basket on a modified, storage pool, fuel-handling cart. A high-pressure, heated-water, decontamination facility was used to clean the emptied cask baskets before reinstallation into the casks.

Figure 13. Loaded VPVR/M cask basket being transferred into the Building 101A hot shop/pool area.

Mayak prepared the following documents for receiving and handling the NRI shipment: (1) "Technical Description and Operation Manual for the ŠKODA VPVR/M Cask at Mayak;" (2) design drawings, sketches, and descriptions of special tools and equipment; (3) detailed operating procedures; and (4) safety analysis.

Mayak successfully completed a "dry run" of the cask and fuel-handling operations from May 30 through June 2, 2006. Mayak received the Czech shipment December 8, 2007, and completed unloading of the shipment, storage of the SNF, decontamination and reassembly of the empty casks, and shipment of the empty casks back to NRI on April 13, 2008.

Shipment Preparations/Operations

All shipping preparations were completed in the Czech Republic, Slovakia, Ukraine, and Russian Federation. Preparations for loading the 16 VPVR/M casks into eight ISO containers began the evening of November 30, 2007, at HLWSF. The loaded casks were stored in a specially designed cask storage vault in the newly built annex of HLWSF. After the large concrete lids of the vault were removed, representatives from SONS and IAEA inspected the tamper seal on each cask to verify that it had not been opened while in storage. Once verification was completed, each seal was removed by the IAEA representative and a new seal was installed (see Figure 14).

Figure 14. Photograph showing the International Atomic Energy Agency inspector changing out the security seal.

The first ISO container was backed into the HLWSF annex and prepared for loading. Two VPVR/M casks were removed from the storage vault, loaded into the ISO container, and secured in place by tiedowns (see Figure 15). The ISO container was reassembled and the tractor trailer, with the loaded ISO container, was removed from the annex. The next ISO container was backed in and loaded with two other casks. This sequence of operations were repeated four times. Once the four ISO containers were loaded and removed from the annex, the eight VPVR/M casks were transported several kilometers, under heavy police escort, from the HLWSF area through the small village of Řež into NRI's main complex at the bottom of the hill. The ISO containers were off-loaded from the tractor trailers and stored in a secured area.

Figure 15. Photographs showing VPVR/M casks being loaded into an ISO container and tied down.

Empty tractor/trailers were transported back to HLWSF and the four ISO containers were loaded with the last eight VPVR/M casks. By early afternoon on Saturday, December 1, 2007, the first shipment of four loaded ISO containers was transported about 25 km to the Měšice u Prahy Rail Station (see Figure 16). A significant police force escorted the shipment, and police cars blocked all intersections on the route to the rail station. The rail station was heavily secured with guards at all entrances, exits, and around the parameter of the station. It took about 2 hours to transfer the four ISO containers from the tractor/trailer to the special flatbed railcars.

Figure 16. Photographs showing a loaded tractor trailer being pulled out of the High-Level Waste Storage Facility area and a loaded International Shipping Organization container being transferred from truck to railcar.

The empty tractor/trailers were escorted back to NRI and the last four ISO containers were loaded onto the trailers and transported to the rail station, where they were loaded onto the railcars and secured.

The train configuration was composed of a scout locomotive that traveled ahead of the actual shipment, one locomotive, eight flatbed railcars, two buffer cars, and three passenger cars used to carry the security escorts and technical experts.

The shipment left Měšice u Prahy Rail Station the evening of December 1, 2007, and arrived at Mayak, Russia, a week later, the morning of December 8, 2007. A technical representative from NRI, who was on the train, sent periodic messages to a control center at NRI, identifying general location coordinates of the train while in route through the Czech Republic, Slovakia, and Ukraine. To protect the location of the train in the unlikely event that the message was intercepted by unauthorized personnel, the coordinates were coded in accordance with special maps for each country.

Two minor incidents caused minor delays to the shipment. The first delay was at the Slovakia/Ukraine boarder where a Ukraine customs officer would not allow the shipment to enter Ukraine until the Slovakia security guards and their weapons issue was resolved. Even though this issue had been worked out by both governments before the actual shipment, the customs agent had to be educated about and convinced of the legitimacy of the agreement.

The second, incident occurred at the Ukraine/Russian boarder. One of the buffer cars had a car-to-car hitch that was damaged. One of the technical escorts on the train photographed the damage, which was not allowed by Ukraine security. The shipment was delayed several hours while Ukraine security resolved the issue.

Information about the shipment, schedule, and routes were protected by law in all four countries. However, two television reports were identified during the shipment. The first was from a local television station that heard there were unusual activities at the Měšice u Prahy rail station and sent a reporter and camera crew to see what was going on. The television crew was prevented from entering the station area by security guards. The television station reported the incident that night and had an interview with a manager from SONS that confirmed that a shipment was being done safely and that Czech law prevented any detailed discussion until after the shipment arrived safely at its destination. The second incident was at the Czech/Slovakia boarder. A similar situation occurred. Both reports had minimal coverage and were viewed as being positive reports.

IAEA dispatched a reporter, videographer, and photographer to document the shipment. Their information was released to the public after the shipment arrived at Mayak. They prepared a feature story, a photo essay, a video clip, and a radio clip, which are found on the IAEA website, http://www.iaea.org/NewsCenter/News/2007/prague.html. The following is a list of some of the other press releases:

CTK: Czech Nuclear Waste from Řež Institute Sent to Russia
http://www.ceskenoviny.cz/news/index_view.php?id=286014

AP: Czechs Move Spent Nuclear Fuel to Russia
http://www.cbsnews.com/stories/2007/12/10/world/main3601009.shtml

REUTERS: Czechs Return 80 kg of Enriched Uranium to Russia
http://www.khaleejtimes.com/DisplayArticleNew.asp?xfile=data/theworld/2007/December/theworld_December364.xml&section=theworld&col=

CBS: Agents Locking Down Loose Nuke Material
http://www.cbsnews.com/stories/2007/12/10/eveningnews/main3603231.shtml

DPA: Czech Spent Nuclear Fuel Used in Research Shipped to Russia
http://news.monstersandcritics.com/europe/news/article_1379953.php/Czech spent_nuclear_fuel_used_in_research_shipped_to_Russia

WNN: Řež Research Reactor Fuel Returned to Russia
http://www.world-nuclear-news.org/explorationNuclearFuel/Rez_research_reactor_fuel_returned_to_Russia-101207.shtml.

Shipment Approvals

Obtaining numerous government agreements and approvals were required to ship the NRI material. This proved challenging at times because the project manager was not able to dictate the governments schedules. Table 1 identifies major agreements, contracts, and licenses that were needed to obtain approval for making the shipment. Participating governments for each activity are marked by an "X." All approvals were received by the end of November 2007 and the shipment was completed by the end of 2007.

Table 1. List of activities needing finalized before making the Nuclear Research Institute shipment.

Activity	U.S. DOE	Czech Republic	Russian Federation	Slovakia	Ukraine	Euratom
U.S.-Russian Federation GTRI Agreement	X		X			
NRI-DOE (NNSA) Contract	X	X				
Czech Republic-U.S. Diplomatic Note Exchange	X	X				
Czech Republic-U.S. Implementing Agreement	X	X				
Government-to-Government Agreement		X	X			
Government-to-Government Transport Agreement		X	X	X	X	

Table 1. (continued).

Activity	U.S. DOE	Czech Republic	Russian Federation	Slovakia	Ukraine	Euratom
NRI-Mayak Unified Project Contract		X	X			
Transportation Technical Conditions Plan		X	X	X	X	
NRI-Russian (TENEX) Foreign Trade Contract		X	X			X
Package/Cask Design License		X	X	X	X	
Country Transport License		X	X	X	X	
Slovakia-Ukraine physical protection border exchange agreement				X	X	
Ukraine-Russian Federation physical protection border exchange agreement			X		X	
Carrier Contracts		X	X	X	X	
Nuclear Damage Liability Insurance		X	X	X	X	
Czech Export License		X				
Russian Import License			X			
Russian Prime Minister Shipment Decree			X			
Czech letter to Russia government guaranteeing high-level waste return		X				
Russian letter to Czech government guaranteeing nonproliferation of SNF		X				
Shipping papers completed		X	X	X	X	
Shipment notification to Mayak		*30 days before the shipment, Mayak is informed all documentation is complete*				

Summary and Conclusions

Preparing to transport the NRI SNF to Mayak for reprocessing and waste stabilization and storage required a significant amount of planning and coordination. Sixteen new VPVR/M transport/storage casks and ancillary equipment were obtained and licensed in four countries. Three NRI SNF storage pool facilities were prepared, tested, and used to load the 16 casks. Two facilities at Mayak were prepared and tested for handling the VPVR/M casks and NRI SNF. The cask system was thoroughly demonstrated at NRI and Mayak. All preparations were completed for transporting the loaded casks through the Czech Republic, Slovakia, Ukraine, and the Russian Federation. Once all of the final approvals were received, the shipment was completed successfully in December 2007.

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