DRAFT REPORT - REVISION A

Central Spent Fuel Storage Facility Review of Spent Nuclear Fuel Transportation

Prepared for

Central Storage Safety Project Trust

March 2017

CH2M HILL Engineers, Inc.

Document ID: PR0313171154BOI

Acronyms and Abbreviations

CSFSF	Central Spent Fuel Storage Facility
EA	NNEGC EnergoAtom
EIA	Environmental Impact Assessment
EZ	Exclusion Zone
HI	Holtec International
IAEA	International Atomic Energy Agency
km	kilometer
MPC	multipurpose container
mSv	millisievert
NPP	nuclear power plant
SFA	Spent Fuel Assembly
SNF	spent nuclear fuel
SNRIU	State Nuclear Regulatory Inspectorate of Ukraine
U.S.	United States
VVER	water-water energetic reactor

1.0 Introduction

1.1 Project Background and Report Scope

In December 2005, NNEGC EnergoAtom (EA) signed an agreement with the United States (U.S.)-based Holtec International (HI) to implement the Central Spent Fuel Storage Facility (CSFSF) project for Ukraine's water-water energetic reactors (VVERs). October 2011, parliament passed a law related to management of spent nuclear fuel (SNF), which was approved in the upper house in February 2012. The law provides for construction of the dry storage facility within the Chernobyl-exclusion area, situated between the evacuated villages of Buryakivka, Chystohalivka, and Stechanka in Kiev Region, southeast of Chernobyl. Ukraine requires all spent fuel to be stored in double-wall, multipurpose canisters.

In April 2014, the government approved the 45-hectare site for the facility, to take fuel from the Rivne, South Ukraine, and Khmelnytska nuclear power plants (NPPs). Fuel from the Zaporizhzhya NPP is currently managed at an onsite dry storage facility and will not be taken to CSFSF. The total storage capacity of the facility will be 16,529 used fuel assemblies, including 12,010 VVER-1000 assemblies and 4,519 VVER-440 assemblies.

The proposed method for transferring and handling the Spent Fuel Assemblies (SFAs) is similar to what is already in place at the existing NPPs for transporting SNF to Russia. The HI system that has been selected for SNF storage and handling consists of multipurpose containers (MPCs) that can be placed within a transport overpack (HI-STAR) or a long-term storage module (HI-STORM). The fuel will be transported from the NPPs to the CSFSF via rail using the HI-STAR overpack on a specialized rail car.

The scope of this report is to review the information available regarding transportation of the SNF from the point at which it leaves the NPP until it reaches the CSFSF with regards to protection of the environment. The Environmental Impact Assessment (EIA) considers some of the potential impacts of SNF transportation through the exclusionary zone to the CSFSF. Specifically, the EIA assessed the impacts of the following:

- Emissions and noise as a potential source of environmental impact
- Potential radiation impacts associated with spread of contamination due to the Chernobyl accident

However, the EIA did not consider potential accidents and radiological releases associated with SNF transportation. This report is intended to be a companion document to the EIA and provides this additional information.

1.2 Approach and Methodology

The approach taken in this report was to review available documentation and provide a summary of the information regarding SNF transportation. The documents listed in the references section were reviewed as part of the transportation evaluation and are included in Appendix A.

2.0 Results

2.1 Technology

The HI system that has been selected for SNF handling, transportation, and storages consists of MPCs that are utilized throughout the entire process. Once loaded with SNF, the MPCs will be transferred to an overpack (HI-STAR) for transport to the CSFSF. At the CSFSF, the MPCs will be removed from the rail transport and the HI-STAR overpack and moved to a HI-STORM long-term storage module.

The MPC is a double-walled, stainless-steel canister with a honeycomb inner basket sized to fit the SFA specific to each NPP. The MPC will be loaded at the transfer tube of the power unit reactor department, similar to what is currently being used to load spent fuel. A transfer cask (HI-TRAC) with the loaded MPC will be positioned and aligned to the HI-STAR with a mating device. The MPC will be lowered into the HI-STAR; once positioned, the closure lid of the HI-STAR unit will be placed and secured by bolts. The cavity within the HI-STAR will be purged and backfilled with helium. Ports will be sealed and closed with reusable seals and leak tested. The HI-STAR loaded with an MPC will be classified as a B(U)-type package in accordance with "On Approval of Rules of Nuclear and Radiation Safety During Transportation of Radioactive Material" (PBPRM, 2006). Type B packages must withstand the normal transport conditions and provide additional resistance to release of radiation or radioactive material due to accidental damage.

Once sealed and prepared, the HI-STAR will be loaded onto the specialized rail car and lowered into a horizontal position. Impact limiters will be installed at the front and rear of the unit. Radiological surveys and visual inspections of the unit will be performed, and any issues identified will be resolved. The tie-down system will be installed and security seals applied.

The HI-STAR units are intended to be reused at the various NPP facilities, and once received at the NPP for loading, they will be inspected to ensure there is no damage and the units are ready to receive the next set of MPCs.

2.2 Rail Transportation and Routes

MPCs contained within HI-STAR shipping units will be transported via rail to the CSFSF. The train unit is expected to consist of 10 cars, including five cars dedicated to transporting five HI-STAR units, one rail car for shipping the HI-TRAC transfer cask to the CSFSF, one platform rail car housing welding and auxiliary equipment, one convoy car, and two escort cars.

An estimated 20 HI-STAR overpacks will be transported yearly, with up to five loaded HI-STAR overpacks per train. Existing mainline railways, under the jurisdiction of the Ministry of Transport of Ukraine, are available to transfer the SNF from the NPP to the rail spur operated by the CSFSF. The transport will occur on both national public railroads and railroads within the exclusion and compulsory resettlement zone.

The closest railroad line to the CSFSF site is 5 kilometers (km) to the north (EnergoAtom, 2007), and the distance to the nearest station (Yanov) is 10 km. This line is currently out of service and requires refurbishment in the section between Vilcha and Shepelychi stations. The Ministry of Transport and Communications of Ukraine operates the rail system and is responsible for refurbishing the line. The CSFSF would be responsible for constructing a rail spur connecting the project to the existing track in the vicinity of Shepelychi Station (approximately 6 to 7 km).

As part of the Investment Feasibility Study (EnergoAtom, 2007), an analysis was performed on the potential routes to transport spent fuel to the CSFSF, including use of existing mainline railways:

- Western - Ovruch-Vilcha-Shepelichi-Yanov
- Eastern - Chernigov-Nedanchichi-Yanov

This analysis found that the Western route was preferred. The transport distance from each NPP to the CSFSF is as follows:

- Khmelnytska – 240 km
- Rivne – 250 km

- South Ukraine – 670 km

Based on current spent fuel inventory and annual reactor reloading at each NPP, it is anticipated that the number of shipments each year will be:

- Khmelnytska – two shipments
- Rivne – four shipments
- South Ukraine – three shipments

2.3 Regulatory Controls

Transport will be in accordance with transportation rules for special consignments under the Ministry of Transport. Transportation of radioactive materials in Ukraine is governed by State Nuclear Regulatory Inspectorate of Ukraine (SNRIU) SNRI Order 30.08.2006 N 132, "About approval of Rules of nuclear and radiation safety in transit radioactive materials" (PBPRM, 2006). These regulations incorporate the requirements set forth in IAEA series of Safety Standards "Regulations for the Safe Transport of Radioactive Material. 2005 Edition, TS-R-1" (IAEA, 2005)

The regulations establish controls to ensure the protection of persons and property and environment from radiation exposure during transportation of radioactive material. It incorporates the principles set out in "Safety Fundamentals on Radiation Protection and the Safety of Radiation Sources" (IAEA Safety Series No. 120 [IAEA, 1996]) and "International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources" (IAEA Safety Series No. 115 [IAEA, 1996]).

The regulations are supplemented by guidelines on safety and security practices that meet requirements in the following IAEA documents:

- Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material, TS-G-1.1 (ST-2) (IAEA, 2002)
- Planning and Preparing for Emergency Response to Transport Accidents Involving Radioactive Material, TS-G-1.2 (ST-3) (IAEA, 2002)
- Radiation Protection Programmes for the Transport of Radioactive Material, TS-G-1.3 (IAEA, 2007)
- The Management System for the Safe Transport of Radioactive Material, TS-G-1.4 (IAEA, 2008)

The document "Construction of the CSFSF for VVER Nuclear Power Plants of Ukraine, Volume 1.1, Explanatory Note," 571402.201.001-P301 (EnergoProjekt, 2016) states that PBPRM (2006) also establishes design criteria of biological protection assurance during SNF transportation for the HI-STAR transport and storage container, which is classified under PBPRM (2006) as a type B(U) package. According to these requirements, dose rate for HI-STAR 190 shall not exceed:

- 2 millisieverts/hour (mSv/hour) at any point of the package surface at normal operating conditions
- 0.1 mSv/hour at any point at the distance of 2 meters from the package surface at normal operating conditions
- At accident conditions radiation rate at the distance of 1 meter from the package surface shall not exceed 10 mSv (when at maximum radioactive content)

To ensure physical protection during nuclear fuel transport, measures are taken by the National Guard to provide information security and protection of spent fuel shipments through Ukraine.

2.4 Safety Analysis

The HI Accident Analysis Report (HI, 2016) examines various loading conditions on the HI-STAR transport cask, including handling loads, normal transportation loads, and hypothetical accident loads. Normal transportation loads include changes in external pressure, a free drop from a 0.3-meter height onto an unyielding surface, and normal vibratory loads. The hypothetical accident loads include the following cases:

- Free drop (9 meters)
- Puncture (1 meter drop onto a steel bar)
- Engulfing Fire of 800 degrees C
- Water immersion of at least 15 meters
- Deep water immersion of 200 meters

These hypothetical cases are as described in TS-R-1 (International Atomic Energy Agency [IAEA] 2005) and PBPRM (2006).

The results of these analyses are summarized below:

- **Free drop –** A structural analysis was performed on the closure lid, containment shell, containment bottom forging, and lid bolts. The results showed that calculated stress intensities are less than the allowable values in each case. It was concluded that the structural integrity of the HI-STAR package remains intact in the case of drop onto an unyielding surface.
- **Puncture –** The structural analysis performed for this postulated case concluded that, while some plastic deformation would occur locally around the puncture location, there is no through-wall penetration of the containment boundary or the shielding enclosure shell. Also the stress limits are below the allowable values. Therefore, the HI-STAR maintains its structural integrity and containment boundary for this case.
- **Fire –** A thermal analysis was performed to evaluate an engulfing fire at 800 degrees C. The analysis showed that the internal temperature and pressures for the fire accident scenario are all below the maximum allowable design condition limits. Hence, it can be concluded that the fuel cladding temperature and component temperatures are below the accident design limits and that the HI-STAR is adequately designed for this design basis accident.
- **Water immersion –** The water immersion case is within the parameters of the deep water immersion case described below.
- **Deep water immersion –** A structural analysis was performed to evaluate this accident. Analysis of the HI-STAR containment shell for this condition showed no yielding of the vessel or instability of the containment shell. Therefore, structural integrity and containment boundary of the inner shell is maintained for deep submergence.

3.0 Summary and Conclusions

Spent fuel transportation has been occurring between Ukraine and Russia for 25 years and there have been no transportation accidents that resulted in radioactive release from containers or violation of nuclear safety requirements. The CSFSF project has undergone extensive analysis of the transportation routes and potential accidents. The accident analysis shows that the design is compliant with regulatory requirements and the structural integrity and containment boundaries are maintained during the postulated accident scenarios. Any fuel movement is governed by a rigorous regulatory process and oversight that is based on IAEA safety requirements. As long as the work is performed in accordance with the governing regulations, potential impacts to the environment during transport would be negligible.

4.0 References

EnergoAtom. 2007. Centralized Spent Nuclear Fuel Storage Facility (CSNFSF) for VVER-Type Reactors of the Ukrainian Nuclear Power Plants, Investment Feasibility Study, Analytical Summary.

EnergoProjekt. 2016. Construction of the Central Spent Fuel Storage Facility for the VVER Nuclear Power Plants of Ukraine. Volume 1.1. Explanatory Note. Final. 571402.201.001-P301

Holtec International (HI). 2016. Accident Analysis Report. Revision 4. Holtec Report No: HI-2083899. August 17.

International Atomic Energy Agency (IAEA). 1996. "International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources" (IAEA Safety Series No. 115).

International Atomic Energy Agency (IAEA). 1996. "Safety Fundamentals on Radiation Protection and the Safety of Radiation Sources" (IAEA Safety Series No. 120).

International Atomic Energy Agency (IAEA). 2002. Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material, TS-G-1.1 (ST-2)

International Atomic Energy Agency (IAEA). 2002. Planning and Preparing for Emergency Response to Transport Accidents Involving Radioactive Material, TS-G-1.2 (ST-3).

International Atomic Energy Agency (IAEA). 2005. Regulations for the Safe Transport of Radioactive Material. IAEA Safety Standards, No. TS-R-1, 2005 edition. Available at http://www-pub.iaea.org/MTCD/publications/PDF/Pub1225_web.pdf.

International Atomic Energy Agency (IAEA). 2007. Radiation Protection Programmes for the Transport of Radioactive Material, TS-G-1.3.

International Atomic Energy Agency (IAEA). 2008. The Management System for the Safe Transport of Radioactive Material, TS-G-1.4.

PBPRM. 2006. On Approval of Rules of Nuclear and Radiation Safety During Transportation of Radioactive Material.

Appendix A
Supporting Documents