

## Study on Required Legislations for Safeguards on Spent Nuclear Fuels in Dry Storage Facilities

Woojin Kim, Seokryung Yoon, Heejun Chung\*  
Korea Institute of Nuclear Non-Proliferation and Control

\*Corresponding author: [hjchung2@kinac.re.kr](mailto:hjchung2@kinac.re.kr)

### 1. Introduction

The Ministry of Trade, Industry and Energy, the Republic of Korea, in 2016, published the national policy statement for the management of highly-radioactive nuclear waste [1]. The decision involves the installations of long-term interim dry storage facilities and Underground Research Laboratory (URL) to meet operational criteria for the permanent geological repository. Conventional nuclear safeguards approaches, however, do not provide sufficient capabilities for the re-verification of spent nuclear fuels accommodated in those facilities. This is because the facilities obstruct the accessibility to the spent fuels and technical measures are not mature enough to be deployed [2]. As being transferred to such facilities, thus, the fuels are being difficult to access for the reliable implementation of safeguards.

The International Atomic Energy Agency (IAEA) [3] and national laboratories in the United States [4][5][6] have been prioritizing the development of technical methodologies to overcome the limited accessibility stemming from the dry storage. In response to the raised concern across the globe, the Republic of Korea has also been initiating research and development projects for the technical safeguarding measures. As a preparatory phase, this study intends to suggest amendments to Nuclear Safety Act for the feasibility of safeguarding measures for difficult-to-access items in dry storage.

This paper first explores safeguards approaches that have been applied to dry storage in the Republic of Korea, Kazakhstan, and Ukraine. The study then reviews legislations in Nuclear Safety Act of the Republic of Korea and federal regulations in the United States in comparison with the IAEA safeguards manual. We then suggest a proposal on amendments for the effective implementation of safeguards for the interim dry storage system designed for Pressurized Water Reactors (PWR) spent fuel assemblies.

### 2. Safeguards Regime in Dry Storage

This chapter summarizes out safeguards activities that have been performed at dry storage facilities in the Republic of Korea, Kazakhstan, and Ukraine.

#### 2.1. Pressurized Heavy Water Reactors (PHWR) at Wolsong, the Republic of Korea [7][8][9]

Since 1983, the Republic of Korea has been operating Canadian Deuterium Uranium (CANDU)-type PHWR in Wolsong nuclear power plants. Three hundred dry bulk storage silos were installed in order to accommodate the spent fuel assemblies at reactor site. Additional installations of MACSTOR/KN-400 were completed in 2010, which aimed to cope with diminishing storage space at the site. The IAEA safeguards performed at the silos and vaults to maintain Continuity of knowledge (CoK) and Containment and Surveillance (C/S) are as follows.

- Radiation monitors for verification of core fuels, such as Core Discharge Monitor (CDM), Spent Fuel Bundle Counter (SFBC), and VXI Integrated Fuel monitor (VIFM)
- Unattended monitoring systems for verification of spent fuel at wet storage with Digital Surveillance System (DMOS)
- Installation of re-verification tube positions and use of the dual Seals (Cobra and Metal Seals) for verification of spent fuel at dry storage

#### 2.2. Sodium-Cooled Fast-Breeder Reactors (FBR) at Aktau, Kazakhstan [10]

Kazakhstan operated sodium-cooled FBRs, BN-350, which produced electricity from 1972 to 1999. Discharged spent fuel assemblies stored in their interim dry storage system have been under the IAEA safeguards. The safeguards inspections have been employing following approaches.

- Quantitative analysis of the spent fuel assemblies using Spent Fuel Coincidence Counter (SFCC)
- Initial and periodic verifications using Dual Slab Verification Detector (DSVD)
- Installation of an unattended monitoring system, Unattended and Remote Monitoring (UNRAM)
- Installation of ultrasonic sealing

#### 2.3 Light Water Reactors (LWR) at Zaporozhe, Ukraine [11]

Six reactors utilizing Russian VVER-1000-type fuels have been operated at Zaporizhzhia nuclear power plants since 1984. In 2004, they began the operation of a dry storage facility constructed at reactor site. The facility was designed to hold three hundred eighty spent fuel casks. The safeguards conducted at the site includes;

- Installation of remote optical surveillance system
- Installation of VACOSS electronic seals
- Serial number identification of the spent fuel assemblies before fuel loading into casks
- Verification of gamma and neutron spectrum using fork detectors
- Verification of the assemblies by item counting
- Installation of IAEA seals on storage containers before transport campaigns

### 3. Analysis of Legal Framework for Safeguards in the Republic of Korea and the United States in Comparison with the IAEA Safeguards Manual

This chapter presents statutory laws that establish legal backgrounds on nuclear safeguards activities in the Republic of Korea and the United States. Special criteria for the difficult-to-access items, which are stated in the IAEA safeguards manual, are also examined to propose amendments to Nuclear Safety Act (NSA).

#### 3.1 Nuclear Safety Act in the Republic of Korea [12]

The implementation of safeguards in the Republic of Korea is supported by provisions in the NSA, enforcement decree of the NSA, and enforcement regulations for the NSA. In this study, we grouped them into two categories as below.

The first category is associated with State System of Accounting for and Control of nuclear materials (SSAC). As given in Table I, Articles 65 and 69 in the NSA stipulate activities of regulatory bodies to control and manage nuclear materials for the sake of national security and public safety through licensing. The provisions enable regulators to license operators prior to their installations and during operations of facilities. As provisions to be applied mutatis mutandis, Article 106 in the enforcement decree and Article 97 in the enforcement regulations is intended for Material Control and Accounting (MC&A) plan and inspections.

Table I: Provisions for SSAC in Nuclear Safety Act

Category	SSAC
NSA	Article 65 (Inspections)      Article 69 (MC&A Plan)
Enforcement Decree of the NSA	Article 106 (MC&A Plan, Inspections)
Enforcement Regulations for the NSA	Article 97 (MC&A Plan)

The second category is related to the national compliance with the safeguards agreement with the

IAEA. Table II contains Article 98 in the NSA and Article 138 in the enforcement decree that provide operators instructions in association with reporting and inspections for internationally controlled items. Those provisions were involved to satisfy the agreement with the IAEA. Paragraphs in Article 98 contain detailed safeguards measures, such as sampling, installation of surveillance cameras, and seals, to comprehensively support the application of the IAEA safeguards based on the agreement.

Table II: Provisions for the IAEA Safeguards in Nuclear Safety Act

Category	IAEA Safeguards
NSA	Article 98 (Report, Inspection, etc.)
Enforcement Decree of the NSA	Article 138 (Persons subject to Reporting and Submission of Documents)
Enforcement Regulation for the NSA	N/A

#### 3.2 10CFRs in the United States [13]

United States Nuclear Regulatory Commission (NRC) regulates safeguards activities in the United States through Title 10, Chapter I, the Code of Federal Regulations (10CFR)72, 10CFR74, and 10CFR75. 10CFR72 provides license requirements for the independent storage of spent nuclear fuels, highly-radioactive nuclear waste, and reactor-related Greater Than Class C waste (GTCC). 10CFR74 applies to facilities that either operate nuclear power reactors or utilize nuclear materials, and 10CFR75 is associated with the agreement with the IAEA. The mentioned 10CFRs regulate operators in the light of;

- Material balance, inventory, and record requirements of stored materials
- Material status report
- Nuclear material transaction report

#### 3.3 IAEA Safeguards Manual

The IAEA safeguards manual provides criteria for the safeguards regime for different nuclear facilities and items bearing nuclear materials subject to the safeguards inspections. The manual also covers methodologies on fuel items designated difficult to access due to the limited physical accessibility in spent fuel dry storage facilities. For the safeguards of the difficult-to-access items, following methods are utilized.

- Item counting based on sampling plans prior to being difficult to access
- Serial number identification
- Quantitative analysis of special nuclear materials using nondestructive assay
- Dual C/S system on spent fuel containers

### 3.4 Comparison Analysis and Suggested Amendments

Table III: Comparison of Provisions in Nuclear Safety Act and 10CFRs and IAEA safeguards criteria

Category	SSAC	IAEA Safeguards
<b>Nuclear Safety Act (RoK)</b>	<ul style="list-style-type: none"> <li>- Domestic Inspections</li> <li>- MC&amp;A plan</li> </ul>	<ul style="list-style-type: none"> <li>- Reporting</li> <li>- IAEA Inspections</li> <li>- Documentations</li> </ul>
<b>10CFR72, 74, and 75 (U.S.)</b>	<ul style="list-style-type: none"> <li>- Record keeping</li> <li>- Inventory check</li> <li>- Retaining records</li> <li>- MC&amp;A plan</li> </ul>	<ul style="list-style-type: none"> <li>- General provisions</li> <li>- Facility and location information</li> <li>- Material accounting and control for facilities</li> <li>- Reports</li> <li>- Advanced notification and expenses</li> <li>- Enforcement</li> </ul>
<b>Safeguards Manual (IAEA)</b>	N/A	<ul style="list-style-type: none"> <li>- Record and reporting</li> <li>- Physical inventory verification</li> <li>- Transfer verification</li> <li>- Inventory change verification</li> <li>- Special criteria for difficult-to-access items</li> </ul>

Table III compares the discussed provisions in the NSA and the 10CFRs in comparison with the criteria in the IAEA safeguards manual based on the categories used in Section 3.1. Although the NSA merely broadly states each items defined in the 10CFRs and the IAEA manual, the Act, sub-enforcement decree, and sub-enforcement regulations well provide the legal supports for safeguards activities in the Republic of Korea. The Act, however, does not embody the criteria to the difficult-to-access items, which is exclusively stated in the manual. It is crucial that provisions tackle the concept of the difficult-to-access items so that relevant legislations can be facilitated.

Although there have been different perspectives on roles and responsibilities of the IAEA and a domestic regulator, the IAEA's verification regime under the comprehensive safeguards agreement incorporates each member state's effort on the SSAC. The intention is to allow domestic nuclear safeguarding to cooperate with the IAEA safeguards system. The legal framework for safeguards, therefore, can well be established while combining each requirement from the IAEA agreement and from domestic regulators. It is expected that this strategy can construct legal grounds for safeguards with better consistency and efficiency.

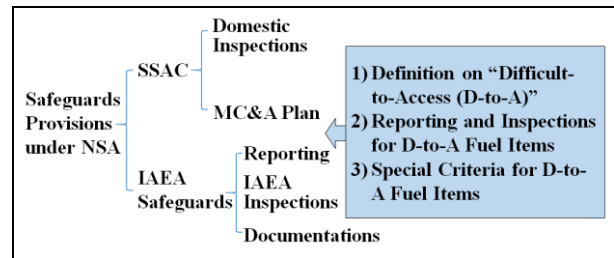


Fig. 1. Structured Overview of Discussed Categories (SSAC and IAEA Safeguards) under Nuclear Safety Act and Proposed Amendments

As illustrated in Figure 1, three amendments were suggested to the current NSA. The first involves a new provision as a paragraph defining the terminology, 'difficult-to-access'. The paragraph aims to cope with legislations on the 'difficult-to-access' items because the dry storage for PWR fuels poses a change of inspection conditions that constrain the access to the fuel items. In addition, an article covering reporting and inspections procedures needs to be expanded. The legal boundary should explicitly include a series of safeguards activities on difficult-to-access items so that a legal ground can be established for the activities that can function as a preventive measure in case of the loss of the CoK. As defined in the IAEA safeguards manual, the Act also needs to provide special safeguards requirements for items being designated difficult to access. This is because the statutory requirements can better assure regulators and operators of regulatory guidelines on safeguarding the items.

## 4. Conclusions and Future Works

The initiative on interim dry storage for PWR spent nuclear fuels in the Republic of Korea has raised concerns regarding the implementation of safeguards at dry storage facilities. Their unique characteristics give rise to the fuel items under a state that is difficult to access. Not only conventional technical methodologies but legal frames, thus, necessitate the improvement and revision of existing system. This study first aimed to examine safeguarding measures at dry storage facilities in the Republic of Korea, Kazakhstan, and Ukraine. The study analyzed and compared provisions that provide

legal grounds for safeguards in the Republic of Korea and the United States in comparison with criteria in the IAEA safeguards manual. We then derived a suggestion on amendments to the current Nuclear Safety Act.

The investigation on the safeguarding measures in the Republic of Korea, Kazakhstan, and Ukraine showed that similar approaches have been used for safeguarding the spent fuels in dry storage facilities regardless of reactor types, which were CANDU-type PHWRs, sodium-cooled FBRs, and LWRs with VVER-1000 fuels. It implies that dry storage facilities for typical PWRs in the Republic of Korea necessitate the same approaches implemented in those facilities.

To the extent of the comprehensive safeguards agreement, new provisions should embrace and yield effective safeguards implementations by the IAEA as well as domestic safeguards activities on difficult-to-access items. Along with this approach, the comparison analysis between the provisions in Nuclear Safety Act and 10CFRs and the IAEA criteria suggested amendments to the existing Nuclear Safety Act. We concluded that it is required to include paragraphs defining the terminology, 'Difficult-to-Access', and incorporating difficult-to-access items in the scope of reporting and inspection procedures. In addition, provisions embodying special requirements for the items designated difficult to access were suggested for a legal preparedness to the dry storage facilities planned to be installed in the Republic of Korea.

The future work includes discussions with stakeholders and consolidation of their opinions to enhance the reliability and applicability of the suggestion.

## **ACKNOWLEDGMENTS**

This work was supported by the Nuclear Safety Research Program through the Korea Foundation Of Nuclear Safety (KoFONS) using the financial resource granted by the Nuclear Safety and Security Commission (NSSC) of the Republic of Korea (No.1803025).

## **REFERENCES**

- [1] Initiatives on the management of highly-radioactive waste, the Ministry of Trade, Industry and Energy, the Republic of Korea, 2016
- [2] International Safeguards Aspects of Spent-fuel Storage, IAEA Bulletin, Spring, 1986
- [3] Research and Development Plan, January 2018 (STR-385)
- [4] M.T. Swinhoe at al., The High Energy Neutron Mapping System In-field Measurements in 2008, LANL, 2009 (LA-UR-09-01938)
- [5] C. Jayson Wharton at al., Summary Report: INL Compton Dry-Cask Imaging Scanner Testing at Doel, Belgium, 2013 (INL/EXT-13-28809)
- [6] Safeguards Approached for Very Long-Term Storage of Spent Nuclear Fuel, ANL, 2013 (ANL/NE-13/5)

[7] Park, WAN-GU at al., Development of Consolidated Spent Fuel Dry Storage System, KHNP, 2010

[8] Won-Woo Na at al., New Approach for Safeguarding Spent Fuel Transfer to Dry Storage at OLR, KINAC, 2005 KNS Spring Meeting

[9] Kyung Ho Lee at al., Design Requirements of A Consolidating Dry Storage Module for CANDU Spent Fuels, KHNP, 2003 KNS Spring Meeting

[10] Santi, Peter A., Michael C. Browne, Attended Safeguards for the BN-350 Dry Storage Facility, Transactions of the American Nuclear Society 95:44-45, 2006

[11] Herrera at al., IAEA Safeguards Implementation at Dry Spent Fuel Storage at Zaporozhe Nuclear Power Plant, International Safeguards Symposium on Addressing Verification Challenges, Vienna, Austria, 2006

[12] Ministry of Government Legislation, "Nuclear Safety Act, Decree, Regulation and Nuclear Safety and Security Notices"

[13] US Government Publishing Office, NRC Regulations Title 10 Code of Federal Regulations