

Approach and Procedure to Develop LILW Transport System - Lessons Learned from Korean Transport System Development Project - 11258

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ABSTRACT

Hyundai Engineering Company (HEC) signed a new contract with Korea Radioactive Waste Management Corporation (KRMC) to develop Low and Intermediate Level Radioactive Waste (LILW) transport system applicable to regular transportation of LILW from each Korean Nuclear Power Station to LILW disposal facility located in Gyeongju-si. The project scope includes developing transport principles & procedures, deriving transport scenarios (on road and sea), appraising transport routes, and verifying the overall transport system. At first a design guide was established for a proper development of transport system. The guide considers not only applicable laws, rules and codes & standards, but also engineering principles so as to develop and verify the transport system. The technical requirements are derived from the guide to set up reasonable system elements and activities. System elements are classified into hardware and software. Hardware features are characterized by waste drums, containers, vehicles, vessels, cranes, forklifts, cargo loading & unloading units, roads, wharfs, and Silos. Software characteristics depend on the plans, procedures, and scenarios. The transport system in this project means the complex of the various hardware and software measures. This paper introduces the approach and procedure how to develop the transport system.

INTRODUCTION

Transport is the movement of energy, material, or information between elements of a system. Transport is associated with the event of an interaction between system elements as shown in Figure 1. Transport system consists of system elements. In Korea, twenty (20) nuclear power plants including PWR and CANDU 6 types are in operation and additional eight (8) PWR type plants are under construction as of December, 2010. These plants have only limited interim storage facilities for LILW (hereinafter called "waste"), which are expected to be saturated in a few years. Disposal facility for waste is currently under construction to accommodate all wastes generated in Korea. KRMC has charge of transporting the wastes from nuclear power plant (NPP). Thus, it is essential to establish the transport system in order to facilitate waste transport on time.

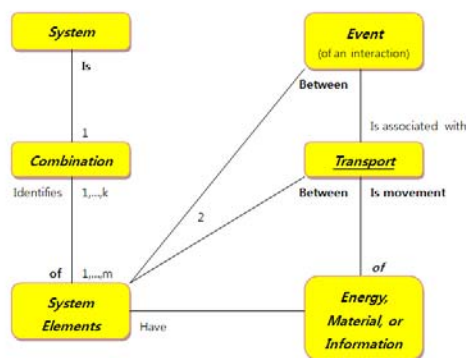


Figure 1. Schematic diagram of the term "transport"

Now it is planned to carry out the transportation of wastes from the interim storages in NPP sites to the disposal facility in Gyeongju-si. Both sea and land carriage will be performed. The disposal capacity reaches about 100,000 waste units in first stage with final goal of 800,000 units by extension.

The transport system includes not only hardware (ship, vehicle, drum, crane, etc), but also software (plan, procedure, scenario, etc). The system should be so designed as to provide the proper integration of hardware and software based on the operation plan. Thus, transport system refers to disposal plan, interim storage capacities in NPP sites, characteristics of carriage infrastructure, and reflects following survey and analysis in order to make the interface smooth between NPP operation and waste disposal.

- Waste generation status and characteristic analysis
- Long term waste quantity estimation
- Waste storage arrangement in underground disposal storage (Silo)
- Transport related laws, codes & standards
- Operation status and feature analysis of interim waste storage facility in NPP sites
- Transport route status survey and analysis
- Transport means characteristic analysis
- Transport procedure, work unit and time analysis
- Transport scenario and alternative analysis
- Verification of transport system

SYSTEMATIC APPROACH

Transport system is composed of hardware and software as indicated in Figure 2. Hardware, which is built from elements, needs proper software for efficient operation. Thus, system elements such as container should function and link with other elements according to appropriate plan, procedure and scenario.

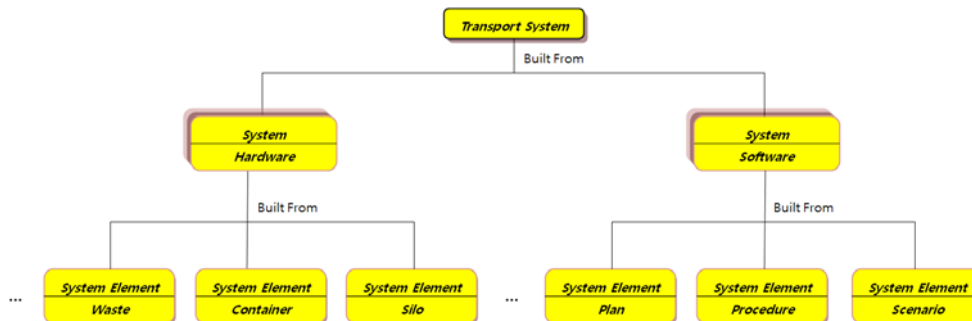


Figure 2. Transport system structure

For developing transport system, it is essential to set up the principles and criteria, derive scenarios, formulate procedures, analyze possible routes, set up transporting plan, and verify the transport system as shown in Figure 3. It is necessary to analyze target waste quantity and transport sequence, to estimate the amount of required containers and handling equipments, and to perform the required time analysis by process in order to acquire most adequate scenario. Setting up transport procedures includes work process analysis, countermeasure plan and emergency procedure against accidents.

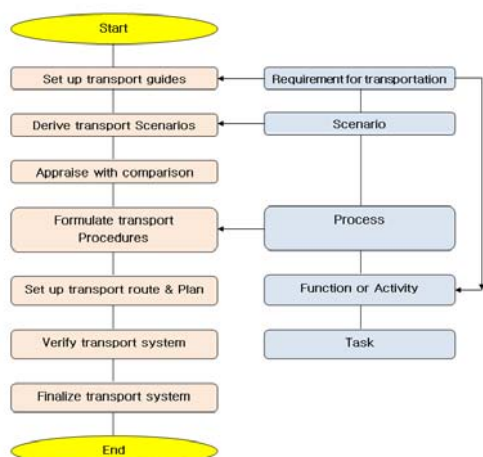


Figure 3. Project implementation based on systems engineering approach

Transport system has been developed reflecting System Engineering Approach shown in Figure 3. Radioactive material transport requirements are based on source documents. Source documents may be classified into regulatory, internal and external documents, which include applicable laws (domestic and international), codes & standards, industrial practices and contract documents, etc. Source documents were reviewed to prepare for main design principles and criteria. Four (4) scenarios have been defined to cover all possible transport options. Each scenario is composed of several processes. In each process, the functions/activities for transport (sea and land) are described based on transport procedures. Then each function/activity shall be allocated to system element such as vessel and container.

HARDWARE ELEMENTS

Most of wastes are generated and piled up from NPP operation. The most wastes from NPP, which are classified into miscellaneous solid waste, concentrated liquid waste, spent resin and spent filter according to their type of contents, have been packed in drums and stored in the NPP storage. The appraisal was performed about waste contents, radioactive source distribution, radiation dose rate distribution, and waste characteristic including density and composition, average radioactivity, allowable radioactivity loaded in drums.

The followings were analyzed with appraisal in order to estimate the waste quantity to be transported into disposal facility, and the waste quantity per container necessary to set up transport scenario.

- NPP-generating waste characteristic & quantity
- Waste quantity loadable in underground disposal facility (Silo)
- Waste quantity estimation according to waste type and container type for each NPP
- Estimation of the expected quantity of transport containers

The essential elements to facilitate the transport include the transport purpose containers, handling equipments, related space and structure. With feasibility study, the handling equipments can be used without modification or innovated. Forklifts, drum loading units and cranes are mainly used for handling waste. Drum loading unit is composed of gripper, up-down unit, travelling unit, traversing unit.

Containers are classified by the purpose of the usage, such as storage, transport and disposal. Candidate contents for the transport container include drum (200/320 liter), High Integrity Container (HIC) and several types of concrete vessel. Various transport containers including Industrial Package (IP) 2, A and B types should be used. Only IP-2 (Figure 4) type containers are currently available for 200/320 liter drums, in which most wastes are in a state of solidification. Total weight of IP-2 type container with eight (8) drums is about 6.5 tons. Maximum allowable dose rate at container surface is 2 mSv/hr and 0.1mSv/hr at

2 meter away from container surface. Other nonstandard types of transport containers are under development.

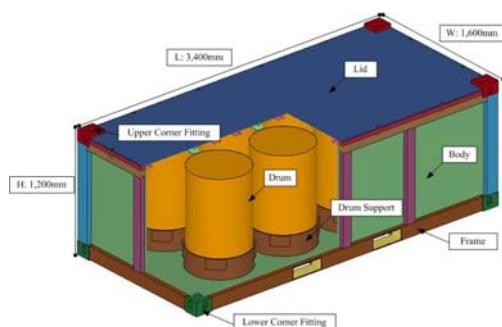


Figure 4. IP-2 type container shape

Exclusive trucks are prepared to transport containers to the wharf in NPP site where ship crane is operated to load containers into ship cargo sections. The truck affords maximum loading capacity of 15 tons. Radiation shielding is installed to prevent driver from being exposed above dose rate of 0.02 mSv/hr. Trucks with net capacity more than 15 tons should be acquired to transport the nonstandard containers except the IP-2 type containers.

One INF-2 grade ship with tonnage of 2,600 tons is reserved exclusively for sea transport between NPP sites and disposal facility. The compartment for containers in ship is partitioned into four sections, three of which are same size and one is a little small. The partitions, which are designed mainly appropriate for IP-2 containers, need to be remodeled to load nonstandard containers. The ship provides the loading capability of one hundred ninety (190) IP-2 type containers.

Six silos in disposal facility can accommodate 100,000 waste units such as 200/320 liter drums. All wastes packages except for concrete packages are put into concrete disposal containers before being loaded in Silos. The concrete packages, as nonstandard, are used for both purposes of transport and disposal. The packages are so layered to achieve optimal space efficiency in Silo. Figure 5 shows Silo layout with layered containers.

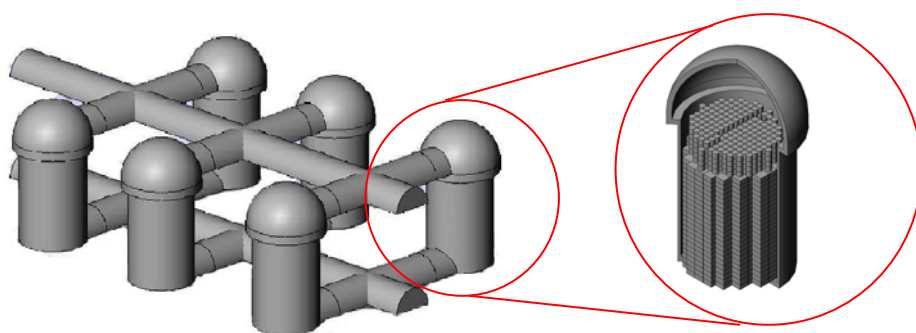


Figure 5. Layout of Silo in the disposal facility

TRANSPORT SCENARIO

The regular transport scenario should be established to reflect NPP storage status (stored waste quantity, saturation year), first applied transport scenario, transport process and procedure (Figure 6 for sea transport), transport cycle, required time for work and sail, disposal facility operation, waste quantities for transport, remodeling of ship cargo sections, and handling equipments. Then every transport system

element is allocated to scenario. First applied scenario (sea transport for initial one thousand (1,000) drums is planned both to resolve the interim waste storage capacity shortage in Ulchin NPP before first stage disposal facility construction is finished and to enhance the reliability on safety of disposal facility operation and waste transport. These wastes (1,000 drums) are stored in the Reception Building in disposal site.

Four (4) scenarios in this study are defined as followings.

- Scenario#1: All the wastes of NPPs to be accommodated by the standard IP-2 type containers are by priority transported without remodeling of ship cargo sections. After that, the remaining wastes are transported by nonstandard containers which require remodeling of ship cargo sections.
- Scenario#2: From early stage of transport, remodeling of ship cargo sections is optimized to allow standard and nonstandard containers to be transported by way of all nuclear power plants according to planned sequence.
- Scenario#3: Considering the saturation year and the remaining storage space in each plant, transport sequences are decided and transport works are performed accordingly.
- Scenario#4: Special conditions (dredge, near surface disposal) reflected

The transport numbers per NPP, cycles, container quantities and Silo arranging sequences are analyzed and compared as well as plant interim storage capacity and cargo section capability. In addition, the required time and transport distances are analyzed to select an efficient scenario. The following preconditions are considered.

- NPP storages should not be saturated during transport period.
- Transport sequence reflects preferentially waste arrangement in Silo not to interfere in disposal facility operation.
- Sea transport is only for wastes generated from NPPs not adjacent to disposal site.
- Land transport is for NPP wastes generated from Wolsong sites adjacent to disposal facility
- One (1) exclusive ship with cargo sections is operated.
- Cargo sections are remodeled to load nonstandard containers.
- Total weight of containers and wastes loaded in ship cargo sections should not exceed the deadweight capacity.
- Sea route around Younggwang NPP needs to be dredged considering topographic and geological features

In scenario#1, some containers of each NPP are transported to disposal site in one shipping cycle as shown in Figure 7 and after remodeling ship cargo sections, one departure covers the carriage through several NPP sites. Scenario#1 is most advantageous in safety and efficiency in the terms of transport distances and required time. Scenario#1 may allow containers to be received and stored efficiently. In case of near surface disposal being operated together, the transport may be performed much more flexibly. Scenario#1, however, is not economical in the aspect of required container quantities because nonstandard containers should be transported within a short period.

In scenario#2, after loading some containers from a NPP site, the ship moves to other NPP to load other containers into remaining sections. Scenario#2 may be considered most economical in the viewpoint of remodeled cargo sections and numbers, and the quantities of required containers. But there is not enough time left to mobilize all the required auxiliary facilities including port and handling equipments such as cranes up to remodeling of ship cargo sections. Scenario#2 is estimated to be disadvantageous in transport efficiency in that containers should be loaded and transported via several NPPs per one shipping cycle.

In scenario#3, more cargo sections should be remodeled than scenario#1/#2 and more transport containers are needed than scenario#2. It is estimated that scenario#3 does not have more merits compared to scenario#1/#2. In this case it should be considered to shorten remodeling time not in order to impact on transport work schedule.

In scenario#4, the near surface disposal is additionally deployed as other special option with Silo

operation, which may make transport operation less influenced by disposal sequences. This case may result in more efficient usage of disposal spaces.

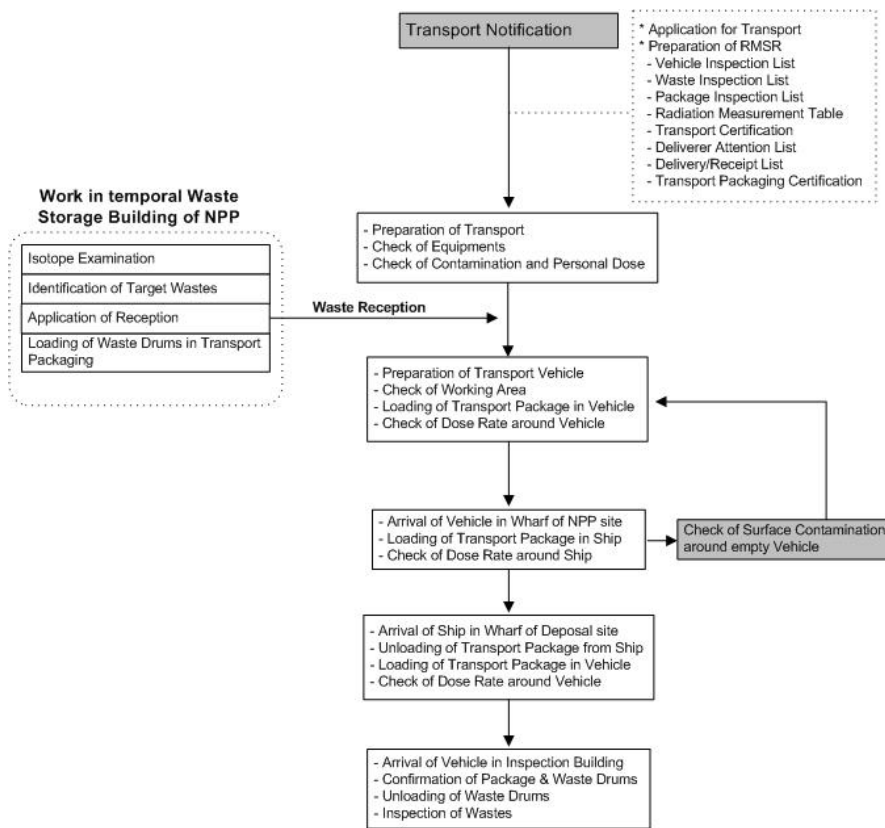


Figure 6. Sea transport process

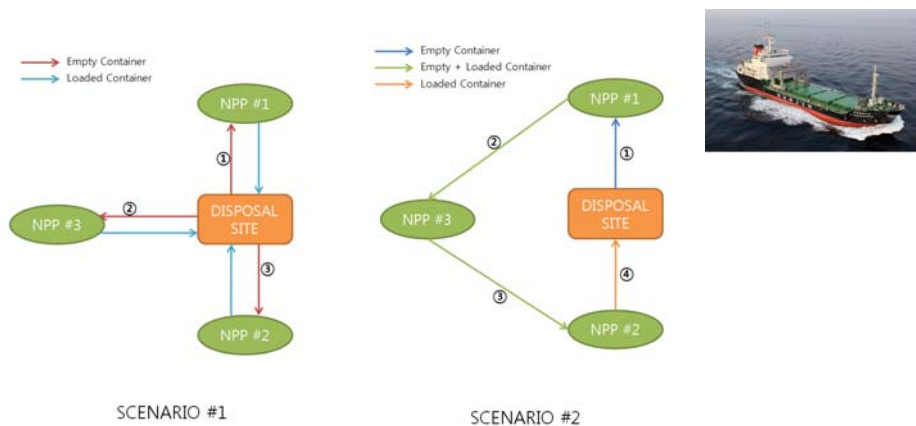


Figure 7. Transport scenario alternatives

CONCLUSION

With sufficient consideration of the geological conditions for Korea NPPs, several evaluations were performed to obtain proper transport (sea and land) system. Waste quantity and characteristic for transport have been analyzed with appraisal as well as transport features and scenarios in order to establish efficient transport system. To achieve this purpose, the influential factors on transport scenario need to be

appraised. Thus, arranging sequences in Silo, characteristic of NPP interim waste storage and transport route have been analyzed as well as transport procedures, processes and required time.

As a result of the comparison, scenario#1 is recommended relatively advantageous in the viewpoint of transport efficiency meanwhile scenario#2 is selected to be more economical in the aspect of required quantities of containers. It is efficient that after remodeling cargo sections, one cycle of transport covers the containers from several nuclear power plants in that waste quantity distribution for nonstandard containers varies with NPP. If the near surface disposal is deployed in addition to Silos, the receptivity of wastes in disposal facility may be enhanced.

The result of the project will be used as basic information for operating disposal facility efficiently as well as procuring the containers and handling equipments, remodeling cargo sections, and operating transport ship.

ACKNOWLEDGEMENTS

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