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Human Error Prediction and Countermeasures based on CREAM in Loading and Storage Phase of Spent Nuclear Fuel (SNF)

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1. Introduction

With the steady demands for nuclear power energy in Korea, the amount of accumulated SNF has inevitably increased year by year. Thus far, SNF has been on-site transported from one unit to a nearby unit or an on-site dry storage facility. In the near future, as the amount of SNF generated approaches the capacity of these facilities, a percentage of it will be transported to another SNF storage facility. In the process of transporting SNF, human interactions involve inspecting and preparing the cask and spent fuel, loading the cask, transferring the cask and storage or monitoring the cask, etc. So, human actions play a significant role in SNF transportation. In analyzing incidents that have occurred during transport operations, several recent studies have indicated that "human error" is a primary cause [1].

Therefore, the objectives of this study are to predict and identify possible human errors during the loading and storage of SNF. Furthermore, after evaluating human error for each process, countermeasures to minimize human error are deduced.

2. Human Error Prediction in SNF Transportation

2.1 The Key Process in Transporting SNF

The SNF transport operations are as follows: At a nuclear power plant, SNF is loaded into a dedicated cask. After the casks were confirmed to comply with the regulatory requirements, they are transferred to the on-site private port or to a nearby public port. The SNF casks are loaded into the dedicated SNF transport ship using a wharf crane. The ship carries the SNF casks to the private port. At the port, SNF casks are unloaded from the ship by a wharf crane and loaded onto a dedicated SNF transport truck-trailer. After safety inspection and radiation measurement of the casks, they are transported to the storage facility [2] [3].

Consequently, the life cycle of the transporting SNF is divided into three distinct phases. These phases are cask loading, transfer, and storage. Among these three phases, the highest parts of occurring human error are loading and storage phase. Because complicated human actions are needed in these phases.

2.2 The Method of Human Error Prediction

This study is approached for performance prediction based on the Cognitive Reliability and Error Analysis Method (CREAM) [4]. This method can consider the human cognition and context factors of the SNF transportation task. The predictions of possible erroneous actions were made for the specific process of transporting SNF.

2.2.1 Simple Model of Cognitive (SMoC)

The CREAM classification scheme makes use of a simplified model of cognition termed SMoC. SMoC contains the essential elements of cognition. It attempts to organize these elements in a way that is generally applicable. The SMoC is to describe the basic features of human cognition. And although it implies a typical path from observation over interpretation and planning to execution, the pathways in the model are not limited to only this [4].

2.2.2 Describe Actions and Assign Cognitive Activity

For the purpose of the performance prediction, a uniform level of description can be achieved by describing each action using a set of standard categories, referred to as the cognitive activity list. This list is derived from accumulated experience from operator performance studies rather than from an analytical basis. The starting point is the descriptions of the actions that it results from, for example, the task analysis. Each action is characterized in terms of the corresponding cognitive activity, using a table of generic cognitive activities [4] [5].

2.2.3 Determine Cognitive Function

This can be used to define the generic mapping of the dominant cognitive function for each of the cognitive activity. The first step in determining the likely error mode is to assign the cognitive function that corresponds to a cognitive activity [5]. If a cognitive activity involves more than one cognitive function, it is necessary to choose that which is most important given the conditions. This choice requires a good understanding of the working conditions and the tasks.

2.2.4 Determine Possible Error Mode

This step involves the determination of the possible error mode for the cognitive activity/cognitive function. This is achieved by using a table of the possible cognitive function failures or error modes for each of the basic cognitive functions [4].

For each cognitive function, several possible error modes are defined. The analyst must select from among these the one that best matched the description of the scenario and the performance condition.

2.2.5 Determine Cognitive Failure Probability

Once the likely cognitive function failures have been assigned for each task element in the task description, it is possible to assess the probability of failure for each cognitive failure type. This can be termed the Cognitive Failure Probability (CFP) in accordance with the traditional Human Error Probability (HEP). The quantification stage therefore comprises the following steps [4]:

1) Determine the nominal error mode probability
2) Assess the effects of the Common Performance Condition (CPC) in SNF transportation: Surveyed by four experts (persons from KAERI, NETEC, and Kori-site workers).
3) Incorporate the adjusted CFP values: the nominal error mode probability multiplied by the total influence of the CPC.

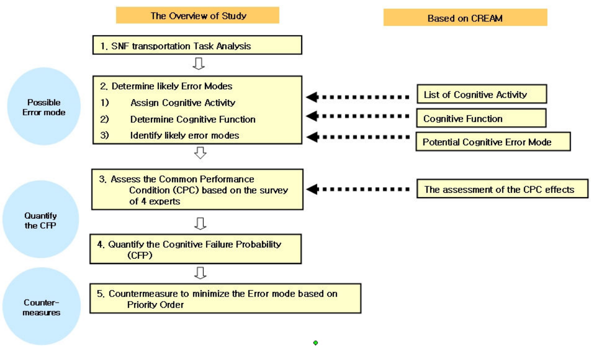

Figure 1. Basic steps of a performance prediction

2.3 Case Study

The human error modes are deduced by using the performance prediction method. After analyzing the human error in each process, the primary human errors are prioritized by the list. The primary human error can be deduced by calculating the adjusted cognitive failure probability (CFP). In the cask loading and storage phases, the highest CFP error is Fault diagnosis or interpretation error and the lowest CFP errors are decision error or delayed interpretation. The results of determining the error priority are illustrated by Table 1.

3. Countermeasures to Prevent Human Error

The primary human errors in SNF transportation are derived as in the following priority order.

1) Fault diagnosis or interpretation error
2) Missed action error
3) Inadequately formulated plan or priority error
4) Decision error or delayed interpretation

	Task step or activity	Cognitive activity	Error mode	Nominal CFP	Weighting factor	Adjusted CFP
1	1. Checking the existing regulation.	Evaluate	Fault diagnosis or interpretation	2.0E-1	0.8	1.6E-1
	Checking the back gate open.					
	Checking the state of connect.					
	Checking surface pollution level.					
	Inspecting safe arrival state.					
2	2. Requesting the back gate open.	Communicate	Action missed, not performed, (i.e., omission)	3.0E-2	0.64	1.92E-2
	Worker signals to driver and stop the vehicle.					
	Communicate the signal between the worker and head worker.					
	Receiving the sign from the head worker and take down the fuel in the package.					
	Vehicle stops the front of designated space when worker signals to driver.					
	Constructing the landing leg in each side of vehicle.	Execute				
	Moving the vehicle to the outside of the fuel building.					
	Wash spouting desalted water on cask and decontaminate.					
	Removing the water on the cask lid using the inhalation tube.					
	Removing the water on the whole cask and dry the cask.					
	Drain the water in the cask.					
	Installing the impact absorbing device to the cask and connecting the bolt.					
	When working on trailer, must put certainly clean shoes or shoes cover.	Regulate				
3	3. Vehicle is going back slowly before fuel building entry and stopping the vehicle when it enters in the building .	Co-ordinate	Inadequate plan formulated, (the plan is either incomplete or directly wrong).	1.0E-2	1.25	1.25E-2
	Prevent pollution on the cask surface and prepare the decontamination work well.					
	Establishing the hood to the trailer and designated space of ship .					
	Checking the radiation dose rate : cask lid, the bottom of cask	evaluate	Priority error.			
4	4. Re-checking the fuel number and specific location of storage pool.	Evaluate	Decision error	1.0E-2	0.8	8.0E-3
	Enforcing leakage test using helium.		Delayed interpretation			
	Checking the radiation dose rate in every part of cask.					

Table 1. Primary human errors in cask loading

The human error can be directly attributed to the system design, operational environment and personal factors [6]. In order to minimize human error in SNF transportation, the system design should be improved by a proper labeling of all devices, and warning message or voice, automatic system. The operational environment should be changed for the better by using a hand-held communication device, a real time worker support device, accurate and standard procedures. And human ability can be elevated by the creation of a special team for SNF transportation. This team must be managed by training, adjustment of fatigue, and distributed work for each worker.

4. Conclusion

In SNF transportation, human error is commonly indicated as a primary accident causation factor. The human errors in SNF transportation were analyzed using Hollnagel's Cognitive Reliability and Error Analysis Method (CREAM). After evaluating the error modes in the transport process, countermeasures to minimize human error were deduced based on the CFPs (Cognitive Failure Probabilities) and survey from SNF transport experts (CPC, Common Performance Condition). Thus far, not all aspects of SNF transportation (e.g., a special procedure device) have been established. When SNF transportation work starts in the near future, this research will be more useful.

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