Extracting HEPs from Event Reports of Domestic Nuclear Power Plants – Case Study

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1. Introduction

One of the traditional definitions on the human error is any kind of unintended human actions resulting in the dysfunction of a target system [1]. This means that, once human errors have occurred, it is unavoidable to experience a wide spectrum of casualties and financial losses due to the dysfunctions of systems. For this reason, it is very important to soundly estimate the human error probability (HEP) of required tasks that could degrade the operational safety of systems. To this end, it is necessary to provide the HRA practitioners with the reliable catalog of HEPs.

Unfortunately, one of the common issues raised by HRA practitioners is a lack of HRA data including HEPs [2]. Therefore, many researchers are trying to provide reliable HRA data from diverse sources, such as (1) event reports reflecting the operational experience of domestic nuclear power plants (NPPs), and (2) human performance data observed from full- and/or partial-scope simulator exercises [3].

2. Event reports as a source of HRA data

For many decades, at least in the nuclear industry, full-scope simulators have been regarded as the most promising source of HRA data because they allows us to observe the response of human operators to cope with rare events that occurs with a very low frequency (e.g., loss of coolant accident or steam generator tube rupture). At the same time, however, it should be emphasized that the collection of HRA data from event reports is indispensable because the use of the full-scope simulators is one of the alternative solutions. In other words, since human operators frequently show different behaviors comparing to those being observed from simulated conditions, it is still careful to directly use HRA data collected from the full-scope simulators [4].

In this regard, several researchers have tried to extract HEPs from event reports. Typical HRA databases based on the analysis of event reports are CAHR (Connectionism Assessment of Human Reliability) and CORE (Computerized Operator Reliability and Error) [5, 6]. More recently, Preischl and Hellmich proposed the catalog of HEPs that are extracted from the event reports of German NPPs [7].

Basically, the HEP of the above-mentioned studies can be quantified by using the following equation [8].

$$\text{HEP of the } i^{th} \text{ task } (\text{HEP}_\text{i}) = \frac{m_i}{n_i} \qquad Eq. (1)$$

Here, Here, m_i and n_i denote the number of human errors observed from the performance of the i^{th} task and the number of opportunities for the performance of the i^{th} task, respectively. From Eq. (1), the number of human errors can be easily identified from event reports meanwhile the number of task opportunities (i.e., n_i) cannot be directly counted from event reports. Accordingly, it is necessary to estimate the number of task opportunities. Table 1 shows an example for estimating the number of task opportunities.

Table I: An example for estimating task opportunity; reproduced from Ref. [8]

Item	Contents
Error description	During an in-cave operation to load active material into waste flasks, a piece of highly active waste was places in the wrong flask.
Operating history	4 years
Task frequency	Twenty loading operations per week, for 26 weeks a year
HEP	4.81E-4 (= 1/2080)

From Table 1, the number of human errors is one because a human operator put radioactive materials into a wrong waste flask. In addition, according to an operating history, it is known that there was no such human error for four years of operation. This implies that the number of task opportunities for the given human error is 2080 because of: 20 (loading tasks/week) ×26 (weeks/year)×4 (years). Therefore, it is promising to calculate that the HEP of the loading task is 4.81E-4.

3. Technical challenge

Although the above-mentioned approach seems to be obvious and ease to follow, there is a big technical challenge in extracting HEPs from event reports. For example, from Table I, it is expected that human operators who have to put something (e.g., a cask) to a specific place are likely to make a mistake with the probability of 4.81E-4. This result is really helpful for HRA practitioners who have to calculate the HEP of the identical (or similar) task. In contrast, this HEP is less meaningful for HRA practitioners who have to calculate HEPs for other types of tasks (e.g., control the level of a reservoir). In other words, the types of tasks being identified from event reports are too specific to be generally applicable.

In order to address this issue, the KAERI (Korea Atomic Energy Research Institute) proposed a framework that can be used to estimate the number of task opportunities for generic task types [9]. Figure 1 depicts the overall process to estimate the number of task opportunities from event reports.

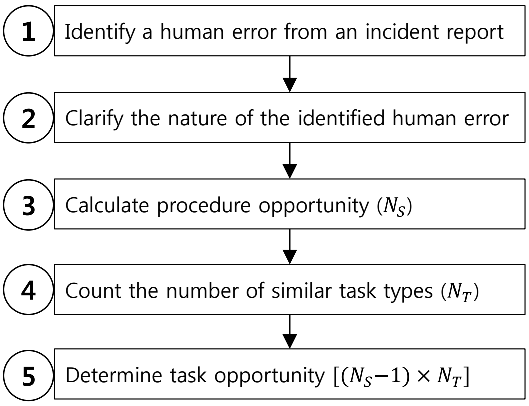

Fig. 1. Overall process to estimate the number of task opportunities from event reports; adopted from Ref. [9].

From Fig. 1, the first step is to identify a human error from an event report. After that, it is necessary to identify the nature of the corresponding human error. To this end, the KAERI developed the taxonomy of generic task types with the associated human error modes. Table 2 summarizes a part of the taxonomy.

Table II: Task types and error modes; modified from Ref. [9]

Task type	Error mode
Verifying alarm occurrence	EOO, EOC
Verifying state of indicator	EOO, EOC
Synthetically verifying information	EOO, EOC
Reading simple value	EOO, EOC
Comparing parameter	EOO, EOC
Comparing in graph constraint	EOO, EOC
Comparing for abnormality	EOO, EOC
Evaluating trend	EOO, EOC
Entering step in procedure	EOO
Transferring procedure	EOO, EOC
Transferring step in procedure	EOO, EOC
Directing information gathering	EOO, EOC
Directing manipulation	EOO, EOC
Directing notification	EOO, EOC
Diagnosing	EOO, EOC
Identifying overall status	EOO, EOC
Predicting	EOO, EOC
Manipulating simple control	EOO, EOC
Manipulating dynamically	EOO, EOC

The third step is to calculate how many times a specific procedure has carried out. For example, let us assume that an unexpected reactor trip has occurred because a human operator pushed a wrong button in the course of conducting a periodic test procedure for *EDG (Emergency Diesel Generator) fast start-up*, of which test period is 15 days. This means that it is possible to estimate how many times the *EDG fast start-up* procedure was performed without a human error (i.e., N_s). At the same time, the profile of task types can be determined with respect to *the EDG fast start-up* procedure (i.e., N_T for each task type). Once the N_s and N_T are determined, the HEP of each task type can be calculated by using Eq. (1).

4. Case study

In order to clarify the process of the HEP estimation from event reports, let us consider an unexpected reactor trip event occurred in December in Wolsong unit 2. According to a NEED (Nuclear Event Evaluation Database) managed by the nuclear regulatory body of the Republic of Korea (KINS, Korea Institute of Nuclear Safety), the primary cause of this unexpected reactor trip is that a local operator open a wrong valve in the course of conducting the periodic test procedure of *Shutdown system no. 1 gadolinium injection tank sampling* [10]. As a result of manipulating the wrong valve, the reactor was tripped due to the creation of an injection path from a gadolinium tank. This test procedure is supposed to be conducted in the period of 7 days, and it is revealed that this test procedure has been accomplished in total 335 times without a human error (i.e., N_s). Figure 2 shows a piece of the periodic test procedure.

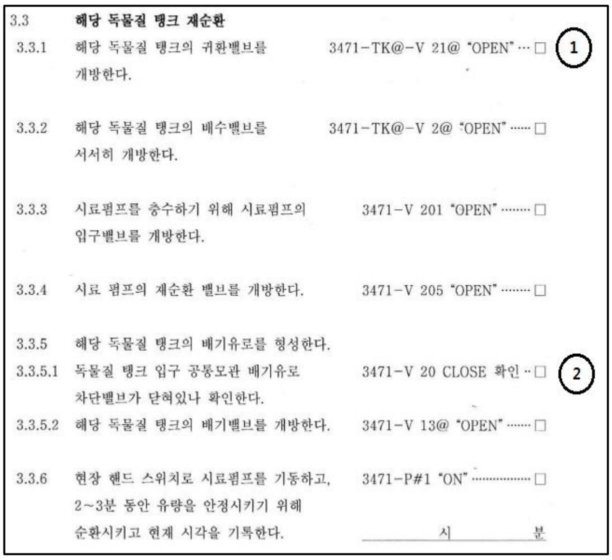
3.3 **해당 독물질 탱크 재순환**
3.3.1 해당 독물질 탱크의 귀환밸브를 개방한다. 3471-TK@-V 21@ "OPEN" … □ (1)
3.3.2 해당 독물질 탱크의 배수밸브를 서서히 개방한다. 3471-TK@-V 2@ "OPEN" …… □
3.3.3 시료펌프를 충수하기 위해 시료펌프의 입구밸브를 개방한다. 3471-V 201 "OPEN" ……… □
3.3.4 시료 펌프의 재순환 밸브를 개방한다. 3471-V 205 "OPEN" ……… □
3.3.5 해당 독물질 탱크의 배기유로를 형성한다.
3.3.5.1 독물질 탱크 입구 공통모관 배기유로 차단밸브가 닫혀있나 확인한다. 3471-V 20 CLOSE 확인 ·· □ (2)
3.3.5.2 해당 독물질 탱크의 배기밸브를 개방한다. 3471-V 13@ "OPEN" …… □
3.3.6 현장 핸드 스위치로 시료펌프를 기동하고, 2~3분 동안 유량을 안정시키기 위해 순환시키고 현재 시각을 기록한다. 3471-P#1 "ON" ……………… □
_____ 시 _____ 분

Fig. 2. A piece of the periodic test procedure of *Shutdown system no. 1 gadolinium injection tank sampling*; modified from Ref. [10].

From the above-mentioned event, the result of the first step is obvious because a local operator open a wrong valve. In addition, the nature of this human error and the associated error mode is *Manipulating simple control (EOC)* because the required control of the corresponding valve is dichotomous (i.e., *Open* and *Close*).

The most difficult step is to determine the profile of task types with respect to the periodic test procedure because each and every task being described in it should be counted. For example, task types of two tasks marked as ① and ② in Fig. 2 correspond to *Manipulating simple control* and *Verifying state of indicator*, respectively. Table III summarizes the profile of task types included in the periodic test procedure.

Table III: Profile of each task type and the associated task opportunity

Task type	N_T	n_i^*
Verifying alarm occurrence	29	9700
Verifying state of indicator	5	1673
Synthetically verifying information	3	1005
Reading simple value	44	14717
Comparing parameter	2	334
Comparing in graph constraint	0	
Comparing for abnormality	0	
Evaluating trend	0	
Entering step in procedure	0	
Transferring procedure	0	
Transferring step in procedure	0	
Directing information gathering	0	
Directing manipulation	0	
Directing notification	0	
Diagnosing	0	
Identifying overall status	0	
Predicting	0	
Manipulating simple control	26	8688
Manipulating dynamically	3	1002

*Task opportunity

Accordingly, the number of task opportunities for each task type can be calculated by multiplying the profile of each task type with 335 (refer to the third column of Table III). In addition, since a human error was observed from the task of *Manipulating simple control*, its HEP can be calculated as 1.151E-4 (1/8688).

5. General conclusions

It is evident that the contribution of human errors to the safety of socio-technical systems is very critical. For this reason, it is important for HRA practitioners to provide reliable HRA data including HEPs. Although a full-scope simulator can be used to collect valuable HRA data, it is still necessary to extract HRA data from the review of operational experience data. If so, it is possible to expect several benefits, such as the use of HRA data gathered from the operational experience of domestic NPPs as reference information to clarify the appropriateness of those collected from full-scope simulators. In this light, the results of this study seem to be meaningful because we are able to take the first step in securing a set of HEPs from operational experience data.

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