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Development of Nuclear Safety Culture evaluation method for an operation team based on the probabilistic approach

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ABSTRACT

The aim of this study is to propose a new quantitative evaluation method for Nuclear Safety Culture (NSC) in Nuclear Power Plant (NPP) operation teams based on the probabilistic approach. Various NSC evaluation methods have been developed, and the Korea NPP utility company has conducted the NSC assessment according to international practice. However, most of methods are conducted by interviews, observations, and the self-assessment. Consequently, the results are often qualitative, subjective, and mainly dependent on evaluator's judgement, so the assessment results can be interpreted from different perspectives. To resolve limitations of present evaluation methods, the concept of Safety Culture Healthiness was suggested to produce quantitative results and provide faster evaluation process.

This paper presents Probabilistic Safety Culture Healthiness Evaluation Method (Pro-SCHEMe) to generate quantitative inputs for Human Reliability Assessment (HRA) in Probabilistic Safety Assessment (PSA). Evaluation items which correspond to a basic event in PSA are derived in the first part of the paper through the literature survey; mostly from nuclear-related organizations such as the International Atomic Energy Agency (IAEA), the United States Nuclear Regulatory Commission (U.S.NRC), and the Institute of Nuclear Power Operations (INPO). Event trees (ETs) and fault trees (FTs) are devised to apply evaluation items to PSA based on the relationships among such items. The Modeling Guidelines are also suggested to classify and calculate NSC characteristics of respective NPPs. Probability of the fault tree top event, namely safety culture healthiness, is automatically calculated to determine the state of NSC healthiness of operation teams. Validation of the suggested method performed by case studies using training video of NPP operators.

According to the validation results, a positive relationship between 'success' states of safety culture and human performance was found, the safety culture state probability profile of each team represents the team characteristic, and the cut-set analysis of the proposed method provides not only the root causes but also the latent causes of failure. Pro-SCHEMe showed possibility to apply NSC to NPP system safety analysis judging by the results of the case study. Further case studies will be conducted to meet the statistical requirement of the results.

1. Introduction

Safety was first recognized in the nuclear industry after the Three Mile Island (TMI) accident in 1979. But people in the nuclear industry were merely aware of the Safety Culture, and the Safety Culture had been, in general, recognized as "Industrial Safety Culture". For example, personnel protection from the harmful and hazardous working environment or a personal health management to keep up the best physical condition for reducing the latent risk of facing dangers. The concept of Nuclear Safety Culture (NSC) was first appeared after the nuclear industry specific situation; the Chernobyl accident in 1986, while the professionals in newly organized group called the International Nuclear Safety Advisory Group (INSAG) under the auspice of International Atomic Energy Agency (IAEA) investigated and discussed about the accident (IAEA, 1991).

The concept of NSC is well defined in the IAEA Safety Report Series No.75, INSAG-4: "Safety culture is that the assembly of characteristics and attitudes in organizations and individuals which establishes that, as an overriding priority, protection and safety

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issues receive the attention warranted by their significance" Thus, the meaning of NSC is totally different from the normally conceived Safety Culture. The nuclear industry worldwide had paid attention to NSC since. Institute of Nuclear Power Operations (INPO) and Nuclear Energy Institute (NEI) published methods and guidelines to strengthen NSC for respective Nuclear Power Plants (NPPs) (INPO, 2004, 2012; NEI, 2014). However, the nuclear industry realized to pay more attention to NSC after the Fukushima accident which proved to be strongly related to NSC, happened again. The United States Nuclear Regulatory Commission (U.S.NRC) announced Safety Culture Policy Statement in 2015, (U.S.NRC, 2015a) and the leading organizations' effort to remind every nuclear related entity of NSC. Korea also suffered pains caused by weak NSC, the concealment of a station blackout (SBO) at the Kori NPP unit 1 and equipment quality document forgery in 2012.

One field of efforts to strengthen NSC was to develop NSC assessment methods. Although there exist different assessment methods, the target of each NSC assessment is all to manage and improve characteristics and attitudes of individuals and organizations. Independent Safety Culture Self-Assessment (ISCA) (IAEA, 2014) developed by the IAEA, Independent NRC Safety Culture Assessment (U.S.NRC, 2014a) from the U.S.NRC, and the Nuclear Safety Culture Assessment (NSCA) survey process (NEI, 2009a,b) developed by the NEI are mostly adopted NSC assessment methods throughout the world. These methods commonly contains the survey, interview, and observation modules with different items of assessment. Since all methods have the similar frameworks, result forms are more or less the same; qualitative and subjective. In addition, the reliabilities of results are often dependent on respondents, and the analysis process takes several days to weeks to provide results including preparation and schedule arrangement.

Recently, some regulatory guides and research papers started mentioning that NSC should be considered in Human Reliability Assessment (HRA), which requires quantitative values to draw a result, for more accurate safety assessment of NPPs (Phillips et al., 1983; KAERI, 2001; Kroger, 2012; INL, 2004; Williams, 2015). But, these documents only pointed out the necessity of NSC consideration in HRA or suggested a simple way to address NSC to HRA, such as inclusion of NSC into one of the Performance Shaping Factors (PSFs) for HRA. This paper considered that NSC of operation teams was the most important aspect when first introducing NSC to HRA, because the core organization of the operating NPP is the operation team. So this paper only focused on NSC of operation teams out of many NSC perspectives.

A new method to address NSC to HRA, Probabilistic Safety Culture Healthiness Evaluation Method (Pro-SCHEMe) was proposed, especially from the operation team's point of view, to resolve problems and limitations mentioned above. The main purpose of Pro-SCHEMe is a provision of objective and quantitative results for HRA, thus, the NSC of operation team was modeled using the FTA method. The proposed method was validated by conducting case studies by recording and analyzing the training data of NPPs operation teams on the full scope simulator.

2. Probabilistic Safety Culture Healthiness Evaluation Method (Pro-SCHEMe)

2.1. Concept of safety culture healthiness

Healthiness contains the idea of integrity and completeness of systems and organisms which consist of numerous sub-part. Likewise, nuclear power plants are run by teams of operation, maintenance and so on. Thus, the purpose of introducing the term "safety culture healthiness" in this paper is to see the NSC integrity and completeness in operation teams.

NSC integrity and completeness of operation teams can be enhanced by achieving the following 3 sub-goals:

1. Reducing occurrence frequency of incidents and accidents by building a safety conscious working environment (SCWE) (Turner et al., 1989).
2. Managing and mitigating occurred incidents and accidents appropriately (IAEA, 1991).
3. Re-examining so that preventing the recurrence of incidents or accidents (Booth and Lee, 1995).

If any one or more of these 3 sub-goals is not achieved, NSC is not in a desirable state (Cooper, 2000). Fig. 1 shows the flow of sub-goals in the desirable NSC state.

Therefore, safety culture healthiness in this paper is deeply related to maintaining and enhancing this circulation of sub-goals. Development of the method how to quantify NSC of operation teams will be explained from the next section.

2.2. Team safety culture evaluation items selection and categorization

For the first stage, safety culture assessment items from various organizations were re-classified and sorted out for the purpose of this research, namely operation team, because the definition, structure and contents of the assessment items in one nuclear related organization differ from those of others. Eight reports below published by 4 major nuclear-related organizations were reviewed.

- *"Safety Culture"* (IAEA, 1991).
- *"Safety Culture Assessment Review Team (SCART) guidelines"* (IAEA, 2008).
- *"Principles for a Strong Nuclear Safety Culture"* (INPO, 2004).
- *"Traits of a Healthy Nuclear Safety Culture"* (INPO, 2012).
- *"Safety Culture Policy Statement"* (U.S.NRC, 2015a).
- *"Safety Culture Common Language"* (U.S.NRC, 2014b).
- *"Nuclear Safety Culture Assessment"* (NEI, 2009a,b).
- *"Fostering a Healthy Nuclear Safety Culture"* (NEI, 2014).

Each document uses its own terms, such as attributes, characteristics, traits and principles and so on, thus the extent, coverage, and scope of some terms have disparities. Therefore, assessment items with the same or similar meaning were combined first. Then, the 36 items, which are normally considered as the basic work units in a nuclear plant, suitable for assessing NSC of the operation team were selected and divided into 8 categories. The 8 categories and their acronyms and detailed description of 36 assessment items in according categories are shown in Tables 1 and 2 respectively.

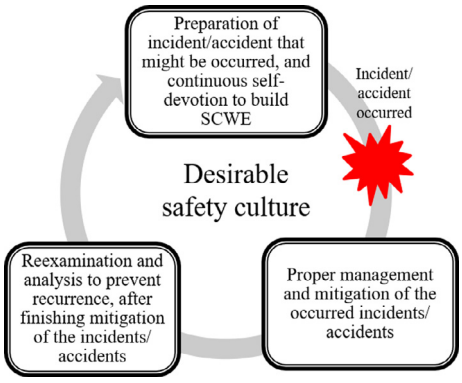

Fig. 1. Goals of desirable safety culture.