Development of Behavioral Indicators of Competences for Safety Culture of Nuclear Power Plants: A Preliminary Study

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1. Introduction

Safety culture is no longer a strange term in the safety research area. The nuclear power industry has been recognized the importance of safety culture after Chernobyl accident [1], and has encouraged operators to assess and improve the safety culture of their plants [2].

Although, safety culture has been defined differently by various researchers, safety culture mentions to the ways that safety issues are addressed in a work place. It open reflects "the attitude, beliefs, perceptions and values that employees share in relation to safety" [3]. Nuclear safety culture is defined by practitioners as "the core values and behaviors resulting from a collective commitment by leaders and individuals to emphasize safety over competing goals to ensure protection of people and the environment from the radiation" [4].

Low level of safety culture has been presented one of the main causes of "serious accident" [5], [6]. For the establishment of robust safety culture, in this study, we present a "*safety culture competency*". The term of safety competency in nuclear field was presented in the OECD/NEA workshop held in 1999 [7]. A model of the safety culture competencies in nuclear power plants was developed by KAERI (Korea Atomic Energy Research Institute) [8], [9].

In general, a competency (competence) is defined as "cluster of employee's attribute, knowledge, skill, ability or other characteristic that contributes to successful job performance" [10]. We also defined *safety culture competency* as "cluster of various internal characteristics (e.g., knowledge, skill, ability, motive, attitude and etc.) of employee that contribute to perform job safely and shape a healthy and strong safety culture." By this definition, the safety culture competency is the broader construct including job competency. An employee having high level of safety culture competency shows extra discretionary effort to improve safety of peer, team and organization in addition to the individual's successful and safe job accomplishment.

Safety culture competency can be exposed by the individual behavior and it must be written in measurable safety behaviors specifically to be observed for systematic management and enhancement of the competency. If employees do not show the safety behaviors related the safety culture competence, it can be assumed that the safety culture is not fully-established.

High risk organizations such as nuclear power plants (NPPs), value of safety is more important than economic benefits and productivity. This value of safety in organization is established not when the value is just declared to the employees from the management but the behaviors related the value across each position should be practiced by all members in the organization.

Safety culture competencies of employees are an essential part of the safety performance agreement. The behavioral indicators for each of the competencies are focal points of conversations on progress and are monitored continuously by self-assessment and managers or supervisors' intervention.

Deficiencies in any of these indicators can point to coaching, training or other learning opportunities that employees may be required in order to improve. That is, it is necessary to appropriately correct the behavior of employee for the formation of robust safety culture. It is necessary to develop the criteria or standards of behavior related with each safety competence for significant change of behavior.

The purpose of this study was to derive a model of safety competencies for improving safety culture of NPPs and develop a set of behavioral indicators of each competency. In addition, the method of measuring behavioral indicators was suggested

2. Method

The safety culture competencies and behavioral indicators were derived from the five steps consisted of literature review, content analysis, interview, examination of content validity and decision of final indicators.

2.1 Literature review

On the basis of safety culture competency modeling (knowledge, skill, attitude, motivation, belief, confidence, inclination, responsibility, values, ethics), various literature associated with safety culture (high reliability organizations such as railway, aviation, safety culture, IAEA, INPO, KINS, and safety culture theory in general industry) was reviewed. Through the review, we derived 125 preliminary competency items.

2.2 Content Analysis

After literature review, content analysis was conducted. Based on the key word and subject of description of competency items, we classified similar items to same category. Through the content analysis, the 16 competencies and 85 behavioral indicators were derived.

2.3 Interviews applied

After content analysis, FGI (Focus Group Interview) and BEI (Behavioral Event Interview) [11] [12] were carried out. BEI is one method of developing competencies and most flexible way to discover differences between two types of employees (Outstanding vs. Typical). The object of BEI is to get very detailed behavior descriptions of how an employee goes about doing his or her work. The interviewer's job is to elicit complete stories that describe the interviewee's specific behavior, thoughts, and action in specific situation. Because past performance predicts future performance, valuable information from experiential response can be collected.

Four retired employees having career with operation and two architect clerical workers in the nuclear power plant participated this interview.

The purpose of this interview was to refine of description and confirm of application level of each competence and behavior indicators. In addition, inappropriate behavior indicator in each competence was removed and similar competence was integrated based on the interview participants' agreement based on their field experience. By using this process, the 16 categories decreased to 15 and 68 indicators extracted from 85 behavior indicators.

After the interview, reevaluation on the each competency and behavior indicator was performed with the following six criteria. Each criteria evaluated by 3 point scale (high, middle, and low) and each one is decided to maintain when at least four or more criteria was evaluated as middle. As the results of re-evaluation, 14 of category 48 indicators were derived.

- Is the each competency and indicator to be has in common nuclear power plant employees?
- Is the each competency and indicator has a high possibility of change and development through education, training and feedback?
- Is it sensitive competency and indicator to change the safety culture?
- Is the each behavioral indicator possible to observe and measure?
- Is the behavioral indicator representative of each competency?
- Is the each competency and indicator exclusive with other ones?

2.4 Examination of content validity

It has been known that the appropriate number of experts for reasonable content validation was from three to ten [13]. Therefore, in the present study, a total of eight subject-matter experts (3 retirement workers, 2 architect clerical workers who participated in the interview earlier and 3 researcher of this study) were participating in the content validity verification.

Each behavioral indicator evaluated by 4 -point scale, 4 points (which is very reasonable), 3 points (which is reasonable), 2 point (not appropriate), 1 points (not a very reasonable). After evaluation, 4 point scale was divided into two 1-2 points and 3-4 points, we calculates the percentage of 3-4 points (Index of Content Validation: ICV) for the total experts. When IVC score of behavioral indicator was above 80 %, it was selected as a significant indicator [14] [15].

2.5 Decision of final indicators

Based on the above processes, total 13 competencies and 35 behavioral indicators were confirmed.

3. Results

Table 1 shows the result of development of safety culture competences and behavioral indicators of each competence.

Table 1. The result of development of safety culture competences and behavioral indicators

Competencies/Definition	Behavioral Indicators
Safety Communication: Creates an atmosphere in which timely and high quality information flows smoothly both up the plant and down, inside and outside the plant; encourages open expression of safety related ideas and opinions.	- Expresses one's own opinion, knowledge, and experience freely in the safety-related meetings and conversations. - Refrains from immediate judgment and criticism of others' ideas, delivering criticism in a way that demonstrates sensitivity to the feelings of others. - Asks open-ended questions that encourage others to give their points of view. - Cooperate with other departments, external organization and relevant institutions and open or provide safety-related documents and information.
Reporting Safety-Related Issues: Report the safety-related issues promptly to the peers and supervisors without hesitation and anxiety of blame.	- Stop work and report promptly when unexpected situation or plant response occurred and a procedure or work document is unclear or cannot be performed as written. - Report promptly on small questions about safety, violation, and near-miss.
Questioning Attitude: Employees avoid complacency and continuously challenge existing conditions and activities in order to identify discrepancies that might result in error or inappropriate action. Employees are watchful for assumptions, anomalies, values, conditions, or activities	- Give a question during pre-job briefings and job-site reviews to identify and resolve unexpected conditions (e. g., Is right method to work safely?; Which human error can arise?). - When other employee have raised the question for the safety, didn't show negative reaction to the question (denial, neglect, threats, etc.). - Check that activities that

that can have an undesirable effect on plant safety.	could affect reactivity are conducted with particular care, caution, and oversight.
Checking Effects of Improvement: Employees shows extra discretionary effort to improve plant safety related objects such as material, tools, work document and equipment and so on.	- Check, consider and improve the position and tags of material, tools, equipment, work document and etc. - Make sure that there is any effect after improvement and report the effect verbally or through document.
Decision Making Considering Safety as Top Priority: Always consider safety as top priority in all decision making situation	- Always mention that safety is a top priority to all of the business. - To ensure safety, conservatively access and carefully determine work procedure rather than traditional decision making - Check the possibility of human error before job performance and applied human error prevention technique suitable for the job
Appropriate Application of Resource: Check, classify and apply personnel, equipment, tool and time necessary for the safe work performance.	- Check sufficient qualified personnel are available to maintain work hours within working hour guidelines during all modes of operation. - Check tools, equipment, procedures, and other resource materials are available to support successful work performance, including risk management tools and emergency equipment. - Check staffing levels are consistent with the demands related to maintaining safety and reliability.
Considering Effects on Whole Plants: Consider effect of individual job performance on the safety of other system and whole plant.	- Consider potential undesired consequences of their actions prior to performing work and implement appropriate error reduction tools. - Prior to authorizing work, verify procedure prerequisites are met rather than assuming they are met based on general plant conditions. In addition, cooperate related other team. - Aware that latent conditions can exist, addresses them as they are discovered, and considers the extents of the conditions and their causes.
Suggestion/Advice/ Support: provide actively care for all member's safety and accept other's care with sincerity	- Presenting the advice and suggestion when the peers and boss presented opinion contrary to safety, or doing unsafe behavior. - Presenting the advice and help when the peer, supervisor and manager did not fulfill their safety responsibility.
Safety Training/Education: Believe that continuous learning about safety prevent accident and participate training and education actively.	- Participate in regular safety education and training voluntarily. - Provide for necessary education and training content required for his/her team.
Respecting Others' Opinion: Listen courteously others' opinion and accept it as much as possible	- Listen courteously others' (boss, subordinates, colleagues, partners) opinion in safety-related conversations and meetings. - Recommend suggestion of various safety related concern, question posed and accommodate this.
Management of Stress and Fatigue: Maintain the body and mind in a healthy state and practice fatigue/stress management action voluntarily	- In order to maintain the body and mind in a healthy state, practice fatigue/stress management action (nondrinking, nonsmoking, exercise, etc.). - The measurement index of physical and psychological fatigue and stress exist within the normal range.
Preparing Crisis Situation: Prepare the possible crisis situation in their job performance and participate related education and training	- To respond calmly in the event of a crisis situation, participate in relevant training (e. g., severe accident, harsh environments). - Know and can explain the coping guideline about crisis situation - Excessive tension in unexpected situations such as sudden stop is not appeared.
Accountability: demonstrates an understanding of the link between one's own job responsibilities and overall plant safety and goals, and performs one's job with the broader goals in mind. Demonstrates a high level of dependability in all aspects of the job.	- Performs assigned work in accordance with safety standards and Complies with all safety policies and procedures. - Strives to achieve the highest level of performance and takes responsibility for own actions and decisions. - Helps and supports fellow employees in their work to contribute to the plant's overall success and safety. - Looks beyond the requirements of one's own job to offer suggestions for improvements.

4. Discussions and Conclusions

For the application of developed safety culture competences and behavioral indicators, the most suitable measuring method for behavioral indicators must be developed. In the case of behavioral observations, behavioral dimensions (frequency, persistence and latency), observation possibility, occurrence basis of

behavior (daily job performance, situational dependent) are considered to determine the method of measurement.

Mainly used tools for behavior observations are Critical Behavior Checklist (CBC), Behaviorally Anchored Rating Scale (BARS), Behavior Observation Scale (BOS), and Mixed Standard Scale (MSS) [16] [17] [18] [19]. Each measure is used differently depending on the occurrence likelihood and dimension of behavior. Therefore, further study is needed in order to determine the most appropriate technique for effective and efficient measuring behavioral indicators in practice.

In the future study, there are additional considerations to apply the suggested set of safety culture competences to any specific NPP. In general, five to seven core competences are recommended for efficient competence management, it is required to prioritize the importance of each competence among all competences through the field validation including actual behavior observation and discussion with incumbents. Moreover, it is better to select core competences across various types of jobs (operator, maintenance/repair, experiment and so on) because the priority of each competence may be different across job types.

In addition, only the safety culture competence for field employees was proposed in this study. It needs to develop the safety culture competences and the behavioral indicators for supervisor, manager, executive and management. Also, it is necessary to consider the optimal measurement method in terms of the measurement period, the scale (3 point, 5 point) of behavioral indicators for monitoring of safety culture competences, and the feedback of monitoring information.

Acknowledgement:

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