Review of Emergency Operating Guidelines from Nuclear Safety Culture Perspectives

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Abstract: The term “Safety Culture” first appeared after the Chernobyl accident in the IAEA safety series No. 75-INSAG-1 in 1986. Even though the concept of “safety culture” was born after the severe accident, the safety cultural mind had been diluted with efficiency of NPPs and nearly forgotten until another one, the Fukushima accident, come in 2011. Nuclear Safety Culture (NSC) seems to be more strong connection to plant operation organizations because NSC focuses on prevention of damages and impacts on people and the environment caused by nuclear accidents. However, so evidently, NSC has influence on plan, design, and construction of NPPs, and NPP safety is finally maintained by operating companies. Emergency Operating Guidelines (EOGs) are license documents developed by a design company in Korea. Thus, through examination of EOGs from the NSC perspective is worthwhile since EOGs are the basis documents to handle NPP accidents. Even though EOGs do not mention NSC, EOGs contain key item and philosophy of NSC.
Keyword: Safety Culture, Emergency Operating Guidelines

1 Introduction

The term “Safety Culture” first appeared after the Chernobyl accident in the IAEA safety series No. 75-INSAG-1[1] in 1986. Even though the concept of “safety culture” was born after the severe accident, the safety cultural mind had been diluted with efficiency of NPPs and nearly forgotten until another one, the Fukushima accident, come in 2011. Nuclear specific features have been added to the term “safety culture”, and the updated term “nuclear safety culture (NSC)” has been being used broadly in the nuclear industry ever since. All utilities, research institutes, regulatory bodies, governmental/non-governmental organizations and other nuclear related companies are now considering NSC in their work procedures. NSC is strongly connected to utilities because, even with the same NPP design, NPPs can experience all the different events with different operation organizations. Korea Hydro & Nuclear Power Co., Ltd. (KHNP), the only nuclear power utility in Korea, has put enormous efforts to check and refurbish its NSC since the Fukushima accident occurred. However, NSC of NPPs or of one country cannot be maintained by the sole company because the word “culture” implies complex, comprehensive, and time-taking processes. Manufacturing, engineering, and construction companies are undoubtedly related to NSC, but these companies have paid less attention to NSC than the utility has in Korea. The life of NPPs starts from designing them when only considering the technical aspect. All the design documents produced in the stagnated period of safety culture, between the late 90’s and 2010, recommended to be reviewed from the perspective of NSC if time allows.

Emergency Operating Procedures (EOPs) are core frameworks to handle the situation which requires NSC most. Thus, producing Emergency Operating Guidelines (EOGs) , which are produced by the NPP system design company, based on NSC principles is important for EOPs as the final product containing the NSC basis because EOGs are the fundamental backgrounds of EOPs. Therefore, for the start, EOGs were reviewed whether they are considering NSC in their contents in this paper.

The general descriptions and philosophy of NSC are explained in chapter 2, and those of EOGs are described in chapter3. Chapter 4 discusses and summarizes the review results, and conclusion is presented in Chapter 5.

2 Safety Culture in Nuclear Industry

2.1 Nuclear Safety Culture

Even though the certain gap between industries exists, safety is the fundamental ground where every industry stands on, and this safety ground is enlarged when the industry prospers and knowledge is built up. The concept of safety in the modern industry shows interwoven expansion of its influence with other areas of the industry, such as quality, productivity, etc., where there were visible borders in the past and considered as different fields. For example, the relationship between safety and productivity was conventionally considered to be negatively proportional to each other, but, in fact, observing laws and regulations is a driving force to keep producing useful products and services nowadays. In the nuclear industry, slight violation of laws and regulations would cost millions of dollars by holding NPP operations. Moreover, whatever the root causes are, a single nuclear accident can cause immense harm to surrounding people and the environment. Due to the immeasurable consequence, the nuclear industry started to adopt nuclear specific features to safety culture and evolved to NSC. US NPP utilities started to develop safety culture evaluation methods because the US Nuclear Regulatory Commission (US NRC) had revised the Reactor Oversight Process (ROP), and related inspection procedures and guidelines to include safety culture in regulatory inspections. Especially, Institute of Nuclear Power Operations (INPO) established the definition, principles, and attributes for NSC from the view point of NPP operators. Three internationally accepted NSC frameworks are introduced in the next chapter. Three framework use the similar structure and all of them consist of three tiers as shown in Table 1.

Table 1. NSC Terms used in Each Organizations[2][3][4]

Orgs. / Tiers	NRC	IAEA	INPO
1st	Definition	Definition	Definition
2nd	Traits	Characteristics	Traits
3rd	Applications	Attributes	Attributes

2.1.1 The US NRC Nuclear Safety Culture

The US NRC defines NSC 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.” The US NRC used 13 components from the ROP for the second tier until Feb. 2009, and changed them to 13 characteristics. This tier revised again through the public meeting in 2010 to 9 traits. 9 traits are as follows;

1. Leadership Safety Values and Actions: Leaders demonstrate a commitment to safety in their decision and behaviors.
2. Problem Identification and Resolution: Issues potentially impacting safety are promptly identified, fully evaluated, and promptly addressed and corrected commensurate with their significance.
3. Personal Accountability: All individuals take personal responsibility for safety.
4. Work Process: The process of planning and controlling work activities is implemented so that safety is maintained.
5. Continuous Learning: Opportunities to learn about ways to ensure safety are sought out and implemented.
6. Environment for Raising Concerns: A safety conscious work environment is maintained where personnel feel free to raise safety concerns without fear of retaliation, intimidation, harassment or discrimination.
7. Effective Safety Communications: Communications maintain a focus on safety
8. Respectful Work Environment: Trusts and respect permeate the organization.
9. Questioning Attitude: Individuals avoid complacency and continually challenge existing conditions and activities in order to identify discrepancies that might result in error or inappropriate action.

The US NRC had used “Aspects” for third tier, but also changed the term to “Applications” to emphasize practicality since.

2.1.2 IAEA Nuclear Safety Culture

IAEA defines nuclear safety culture as "Assembly of characteristics and attitudes in organizations and individuals which establishes that, as an overriding priority, nuclear plant safety issues receive the attention warranted by their significance." in the IAEA safety series No. 75-INSAG-4[5], 1991. IAEA also published IAEA-TECDOC-743[6], "ASCOT Guidelines" to self-evaluate safety culture in organizations and teams. IAEA developed 5 steps to assess safety culture in INSAG-15[7], "Key Practical Issues in Strengthening Safety Culture" in 2002, and published Service Series 16, "SCART Guidelines" in 2008 to determine 5 characteristics and 37 attributes.

1. Safety is a clearly recognized value.
2. Leadership for safety is clear.
3. Accountability for safety is clear
4. Safety is integrated into all activities.
5. Safety is learning driven.

IAEA tend to use safety culture rather than NSC. Broad use of the concept of safety culture is clearly notified in some attributes. For example, attribute D.2 states that "Consideration for all types of safety, including industrial and environmental safety and security, is evident." Therefore, the framework developed by IAEA is more likely adoptable to other industries no matter how those industries are closely relevant to the nuclear field.

2.1.3 INPO/WANO Nuclear Safety Culture

INPO is supported by NPP utilities, so the safety culture framework is more oriented to NSC. INPO developed 8 principles and 56 attributes in "Principles of a Strong Nuclear Safety Culture"[8] in 2004, and revised them to 10 traits and 40 attributes to align with the US NRC's NSC framework. Thus, INPO's definition of NSC is the same as the NU NRC's. Actually the definition was first appeared in 12-012 "Traits of a Healthy Nuclear Safety Culture"[4], 2012 and the US NRC updated its definition in Aug. 2013. INPO's NSC 10 traits are as follows;

1. Personal Accountability: All individuals take personal responsibility for safety.
2. Questioning Attitude: Individuals avoid complacency and continuously challenge existing conditions and activities in order to identify discrepancies that might result in error or inappropriate action.
3. Effective Safety Communication: Communications maintain a focus on safety.
4. Leadership Safety Values and Actions: Leaders demonstrate a commitment to safety in their decisions and behaviors.
5. Decision-Making: Decisions that support or affect nuclear safety are systematic, rigorous, and thorough.
6. Respectful Work Environment: Trust and respect permeate the organization.
7. Continuous Learning: Opportunities to learn about ways to ensure safety are sought out and implemented.
8. Problem Identification and Resolution: Issues potentially impacting safety are promptly identified, fully evaluated, and promptly addressed and corrected commensurate with their significance.
9. Environment for Raising Concerns: A safety-conscious work environment (SCWE) is maintained where personnel feel free to raise safety concerns without fear of retaliation, intimidation, harassment, or discrimination.
10. Work Processes: The process of planning and controlling work activities is implemented so that safety is maintained.

2.2 Nuclear Safety Culture Philosophy

Generally, "industrial safety" comes in mind when first encountering the term "safety culture". In fact, many interviewees who attended NSC evaluation sessions had the stereotype that NSC is similar with industrial safety culture. Consequently, scores of self-assessment were always higher than those by evaluators in Korea because interviewees unconsciously thought that all the rules for industrial safety had been well kept, such as wearing a safety helmet or a harness, during the tasks. However, the core idea of NSC is well expressed in the INPO's NSC definition, "to emphasize safety over competing goals to ensure protection of people and the environment."

3 Emergency Operating Guidelines

3.1 EOG generals

The US NRC established requirements addressing the objective to improve quality of operational information to deal with emergency events following the Three Mile Island Unit 2 (TMI-2) incident. Such documents include IE Bulletin 79-06C, "Nuclear Incident at Three Mile Island - Supplement,"[9] NUREG-0578, "TMI-2 Lessons Learned Task Force Status Report and Short Term Recommendations,"[10] NUREG-0660, "NRC Action Plan Developed as a Result of the TMI-2 Accident,"[11] and NUREG-0737, "Clarification of TMI Action Plan Requirements."[12] Item I.C.1 of NUREG-0737 states that the Office of Nuclear Reactor Regulation has required licensees of operating plants, applicants for operating licenses, and licensees of plants under construction to:

- Perform analyses of transients and accidents including multiple failures
- Prepare EOG
- Upgrade emergency procedures, including procedures for operating with natural circulation conditions
- Conduct operator retraining

According to NUREG-0899[13], the Procedure Generation Package (PGP) should be submitted to the NRC for the plant licensing at least 3 months prior to initial operator training on the new or upgraded EOPs. "Plant-Specific Technical Guidelines" are one of the items in PGP, and NUREG-0899 describes that plant-specific technical guidelines could be one of the following:

- Technical guidelines prepared by plants not using generic technical guidelines, or
- A description of the planned method for developing plant-specific Emergency Operating Procedures (EOPs) from the generic guidelines including plant-specific information, where a plant is using generic technical guidelines.

The goal of the EOG is to provide the best available and up-to-date technical information to be used for writing plant specific EOPs. These technical guidelines provide the actions necessary for mitigation of plant events that a reactor trip is either activated automatically or required to be manually initiated to mitigate the event, or that initiated in Mode 3 or 4.[14]

EOGs in Korea, especially for APR-1400 type plants, contain the improved guidance and the essential elements; the EOG system structure, major event strategy, safety function concept, safety function status check and success paths. A set of typical APR-1400 EOGs consists of:

- Standard Post Trip Actions (SPTAs
- Diagnostic Actions (DAs)
- Optimal Recovery Guidelines (ORGs)
- Functional Recovery Guideline (FRG)

The SPTAs are guidelines for evaluating the status of each safety function along with contingency actions which can be quickly and easily performed to improve the status of safety functions in jeopardy. DAs assists the operators to determine the type of event occurred. Depending on the operators' ability to diagnose, operators will then select either one of ORGs or the FRG. ORGs provide an event-specific guidance and contain all possible actions necessary for recovery of the plant from the event. APR-1400 EOGs consist of:

- Reactor Trip Recovery Guideline (RT)
- Loss of Coolant Accident Recovery Guideline (LOCA)
- Steam Generator Tube Rupture Recovery Guideline (SGTR)
- Excess Steam Demand Event Recovery Guideline (ESDE)
- Loss of All Feedwater Recovery Guideline (LOAF)
- Loss of Offsite Power/Loss of Forced Circulation Recovery Guideline (LOOP/ LOFC)
- Station Blackout Recovery Guideline (SBO)

The FRG is a guideline implemented when operators cannot diagnose the event, or the initially identified ORG does not properly mitigate the event. The FRG verifies the satisfactory control or restoration of all critical safety functions and provides actions to restore and maintain those safety functions in jeopardy. Table 2 shows the status of EOG/EOP of Korea.

Table 2. EOG/EOP status

Plant Type (vendor)	EOG Supplier	EOG Structure	EOP Developer	EOG/EOP Format	Characteristics
PWR (W.H.)	W.H.	ORG (24) FRG (25)	KHNP	2-column	• Complex • Easy to use
PWR (Framatome)	Framatome (KHNP)	Event-Oriented (40) Symptom-Oriented (3)	KHNP	Flowchart	• Broad Coverage • Complex • Easy to use
PHWR (AECL)	KOPEC	Event-Oriented (13) Symptom-Oriented (2)	KHNP	Flowchart	• Simple & Large • Flexibility • Need more knowledge to use
PWR (ABB-CE & KOPEC)	KOPEC	ORG (9) FRG (1)	KHNP	2-column	• Simple & Large • Flexibility • Need more knowledge to use

3.2 EOG Philosophy

One of the core concepts of EOGs is to keep plants in a safe condition. Thus, the concept of safety functions introduces a systematic approach to plant operations based on a hierarchy of protective actions. The protective actions are directed at mitigating the consequences of an event and, once fulfilled, ensure proper control of the event in progress. A safety function is defined as a condition or action that prevents core damage or minimizes radiation release to the public. A complete set of safety functions needs to be fulfilled to ensure proper operator control of the event and public safety. The overview of APR-1400 EOG system is shown in Fig. 1. The operator does not have to know what event has occurred but does have to know what success paths are being utilized and what acceptance criteria must be satisfied. All safety functions are directed at mitigating an event and containing and/or controlling radioactivity releases. These safety functions can be grouped into four major classes as follows:

- Anti-core melt safety functions: Reactivity Control, Inventory Control, Pressure Control, Core Heat Removal, RCS Heat Removal
- Containment integrity safety functions: Containment Isolation, Containment Temperature/Pressure Control, Combustible Gas Control
- Indirect radiation release safety functions (not included in EOGs due to outside the containment)
- Maintenance of vital auxiliaries needed to support the other safety functions: Electric power, Instrumentation air, Component cooling, Ultimate heat sink

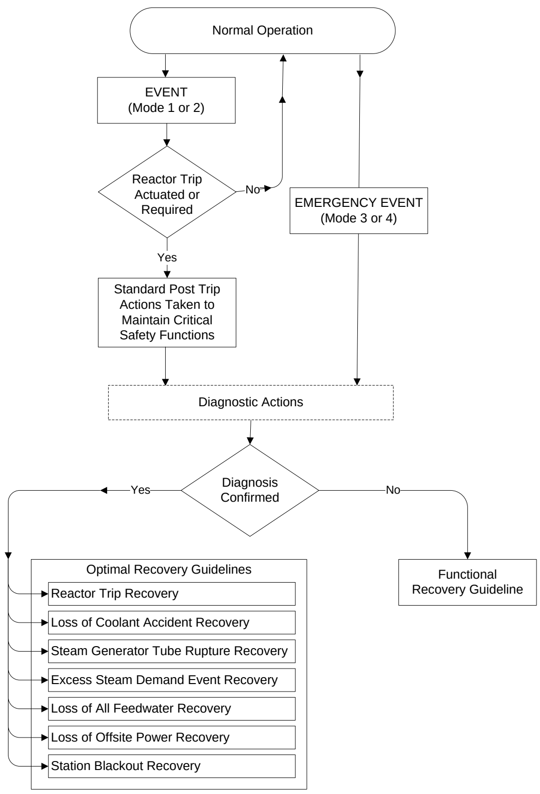

Fig. 1 Overview of the EOG system

4 Discussions

NSC seems to be more strong connection to plant operation organizations because NSC focuses on prevention of damages and impacts on people and the environment caused by nuclear accidents. However, so evidently, NSC has influence on plan, design, and construction of NPPs, and NPP safety is finally maintained by operating companies. EOGs are license documents developed by a design company in Korea. Finding NSC items in EOGs is rather difficult, because the majority of contents EOGs address is technical and quantitative matters and NSC itself is descriptive and qualitative. However, through examination of EOGs from the NSC perspective is worthwhile since EOGs are the basis documents to handle NPP accidents.

Based on reasons above, INPO's utility focused "NSC 10 traits and 40 attributes" framework was referred to review EOGs.

Four traits were closely related to EOG development and contents: Questioning Attitude (QA), Decision-Making (DM), Problem Identification and Resolutions (PI), and Work Process (WP).

Within those traits, following four attributes in PI and WP were related to EOG development:

- PI.1 Identification: The organization implements a corrective action program with a low threshold for identifying issues. Individuals identify issues completely, accurately, and in a timely manner in accordance with the program.
- PI.2 Evaluation: The organization thoroughly evaluates problems to ensure that resolutions address causes and extents of conditions commensurate with their safety significance.
- PI.3 Resolution: The organization takes effective corrective actions to address issues in a timely manner commensurate with their safety significance.
- WP.3 Documentation: The organization creates and maintains complete, accurate, and up-to-date documentation.

All the design documents including EOGs generated and updated by KEPCO-E&C must observe Engineering Procedure (EP) as a part of quality assurance processes. When an issue happens, changes for the initial issue are identified. For the identified changes, change requests are made if necessary, and the statement of revision is registered when resolved. Reviews of the technical adequacy include 4 items below;

1. Appropriateness of selection and use of design inputs
2. Applicability of project design requirements
3. Application of design interface
4. Mutual consistency with Safety Analysis Report (SAR)

Attributes which envelopes EOG contents were:

- QA.1 Nuclear is Recognized as Special and Unique: Individuals understand that complex technologies can fail in unpredictable ways.
- QA.2 Challenge the Unknown: Individuals stop when faced with uncertain conditions. Risks are evaluated and managed before proceeding.
- DM.1 Consistent Process: Individuals use a consistent, systematic approach to make decisions. Risk insights are incorporated as appropriate.
- DM.2 Conservative Bias: Individuals use decision-making practices that emphasize prudent choices over those that are simply allowable. A proposed action is determined to be safe in order to proceed, rather than unsafe in order to stop.
- WP.3 Documentation: The organization creates and maintains complete, accurate, and up-to-date documentation.
- WP.2 Design Margins: The organization operates and maintains equipment within design margins. Margins are carefully guarded and changed only through a systematic and rigorous process. Special attention is placed on maintaining fission product barriers, defense-in-depth, and safety-related equipment.

The design of the EOGs recognizes that eventually in the course of an emergency it will become necessary for the operator to specify what resources are available to continue to satisfy safety functions. This is necessary because the operators must know what systems and equipment are available for use either in continued operation or for taking the plant to cold shutdown conditions. Standard Post Trip Actions (SPTAs) in EOGs are organized around those critical safety functions which must be satisfied when a reactor trip is actuated or required, in order to ensure that the plant is placed in a stable, safe condition or that the plant is configured to further respond to a continuing casualty. In order to provide for this, the operator is given specific, unambiguous acceptance criteria which can be evaluated without interpolation directly from the control room instruments. Also, Following the SPTA, Diagnostic Actions (DAs) are performed to determine the symptom set corresponding to the type of event in progress. Reactor Trip (RT) bases section provides the operators with information which will enable them to understand the reasons for, and the consequences of, the actions they take during an RT. The EOGs are designed to be used independently and cross referencing is minimized. Cross referencing is appropriate only when the other guideline entry conditions are achieved during the course of operation (e.g., when Shutdown Cooling System entry conditions are established, then initiate it per operating instructions). Each plant already has an extensive network of procedures. Emergency operating procedures must be coordinated with all other plant procedures. The contents and scope of the emergency operating procedures developed from EOGs should be designed to interface with, but neither overlap nor duplicate, other plant procedures (other than the emergency procedures they are intended to replace). When acceptance criteria are not met, then this serves as a cue to perform the appropriate instructions located under the heading of "CONTINGENCY ACTIONS". With regard to "CONTINGENCY ACTIONS", a generic list of these was prepared from operator interviews, review of existing emergency procedures, and simulator validation efforts. Guidance is provided for operating equipment which is closely associated with but not part of the NSSS (e.g., the turbine generator). This is in recognition of the existence of vital non-NSSS equipment and systems at each plant (i.e., balance of plant) which are important to overall plant control. Each ORG contains a section which requires the operator to confirm the diagnosis and continually review the status of safety functions by use of the SFSC. The system of EOGs also recognizes the possibility of a misdiagnosis by the operators and makes provisions for detecting and recovering from such misdiagnoses. If the operators have selected the FRG because they cannot diagnose the event, the FRG provides action steps to bring the plant to a safe, stable condition. Once the FRG has been implemented, the operator will continue within the FRG until the exit conditions have been met. Once entered to the guideline, the operator uses the Safety Function Status Check to confirm that the guideline is providing the appropriate instructions for maintaining safety functions and mitigating the event. The FRG directs the operator to ensure that the event is classified and placekeeping is implemented. It also includes specific actions that apply to all success paths which will enhance the operators' ability to monitor plant status and maintain the plant in a safe condition. The FRG directs the operator to verify all safety functions and to prioritize operator actions to address jeopardized safety functions first, challenged safety functions and finally all other safety functions.

5 Conclusion

International organizations, regulatory bodies, and NPP utilities became aware of the importance of enhancing safety culture after the Chernobyl accident in 1986. However, NSC had not been a major issue in the nuclear industry until the Fukushima accident in 2011 even the term "safety culture" has been used more than two decades. Stunning event may need to wake up the complacent industry as the huge driving force is required to move forward a big ship.

The idea of this paper started from where safety or safe operation related documents, such as EOGs, need to be revised from the view point of NSC, especially those generated before the Fukushima Accident. Fortunately, Even though EOGs do not mention NSC, EOGs contain key item and philosophy of NSC. There exist two rough reasons to explain outcomes. One is the trigger event of EOGs was the TMI-2 accident which is also the cause of a safety culture concept development. The other is significant changes and improvement of work processes in recent 10 years in the Korea nuclear industry.

Key NSC attributes, which are likely to be included in design documents, were all considered in current EOGs in Korea. If accountability of the actions taken by operation personnel in the team was defined, NSC would be more permeated through the operating organizations of NPPs. Moreover, as the attribute "WP.3 Documentation: The organization creates and maintains complete, accurate, and up-to-date documentation." indicates, the very important issue of the EOG system in Korea is to maintain and keep EOGs updated. EOGs are maintained and updated individually at the moment, though the comprehensive management efforts are needed for further improvement of EOGs.

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