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Current Status and Issues of Nuclear Safety Culture[1]

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Objective: The aim of this paper is to discuss the nuclear safety culture in Korea.

Background: Recently, Korean nuclear field has met a strong anti-nuclear trend after a few happenings, as well as Fukushima accident, which are turned out to be caused by organizational pitfalls and safety culture defects in general.

Method: We review the concepts and constructs of safety culture based on the brief history of the nuclear safety culture that IAEA mainly raised after the Chernobyl accident in 1986. Additionally, we give a comparative discussion on the approach to the safety culture with U.S.

Results: Finally, we discuss the three technical domains and propose six selected domestic issues related to the nuclear safety culture for coping with the demanding requests on nuclear safety in Korea.

Conclusion and Application: We suggest several recommendations and a research direction in the form of a re-start line for the nuclear safety culture in Korea.

Keywords: Safety culture, Nuclear power plants, Concept, Issue, Fukushima, IAEA

1. A Challenging Issue of Nuclear Safety Culture

Perception on safety culture has steadily been disseminated internationally and domestically. There are almost no people who do not know the term of safety culture now, and there seem to be almost no people who cannot mention the definition of safety culture, and their own opinions in brief. Nuclear organizations appear to think that they implement training or assessment of safety culture well for their workers. There has been a tendency thinking that maintaining excellent performance without big accidents in Korea's nuclear power facilities is likely to be derived from the mature safety culture of nuclear power plant licensees (Choi, 2008; Lee, 2015).

Looking at the current situation, horizontal diffusion of perception on safety culture for the past 30 years can be said to be conducted domestically and internationally to some degree, since safety culture was raised in the nuclear field (IAEA, 2003, 2016). However, whether the vertical understanding of workers on safety culture in each field has also been developed is questionable. Whether safety culture level of top

[1]This manuscript has revised "What Should We Do about Nuclear Safety Culture?" (Choi G.S., Nuclear Industry, February Issue, 2008).

management of a licensee affecting the nuclear power plant's safety the most is satisfactory is actually questionable. Whenever huge accident cases and in nuclear power plants abroad, and the analysis results of the causes to those accidents were reported, and the lack or decline of safety culture in most cases was the main cause was pointed out, resulting anxiety was not just an unfounded fear. Despite efforts in diverse ways including educating nuclear safety culture at site, holding a symposium and dealing it in a subcommittee in an academic association, people could not be adequately confident to cope with nuclear accidents with all those efforts. A concern that an incident or an accident similar to the cases occurring abroad and causing national anxiety and public criticism may occur in Korea one day emerged gradually, due to the lack of safety culture.

Anxiety and questions on safety culture in Korea were discussed in several aspects. Although domestic licensees are proud of having high operational performance including operation rate, paradoxically it becomes complacency on safety, and there has been a concern that the foundation of safety culture of the licensees was been gradually eroded. Although the licensees raised a question on whether safety culture was sufficiently understood and safety culture programs were implemented well, they seem to be vaguely confident of safety culture in that high operational performance was shown.

Looking at the regulatory aspect, Korea's regulatory bodies have knowledge and perception on safety culture to some degree, but there is a question on whether they cope with safety culture issues adequately. It is concerned that the currently implemented safety regulation scope does not include safety culture officially (Choi, 2008). The safety culture of a regulatory body is very important to the entire safety culture in the nuclear field. Compared to interest in nuclear power plant's safety culture, how the safety culture of the nuclear design, manufacture, supply and service organizations should be dealt with, as well as other nuclear facilities such as reactor for research, isotope, accelerator and waste facilities, and nuclear fuels.

Conceptually, the nuclear field easily concludes that safety culture is part of corporate culture or part of organizational culture associated with the safety of the licensees or regulatory bodies, and tends to think they sufficiently understand and execute safety culture in many cases. Safety culture, however, needs to be reviewed on what correlation it has with organizational culture, and on whether it is adequate to limit the safety culture as a subculture, the part of organizational culture. Above all, the part that needs verification essentially is the correlation with performance and safety of nuclear power facilities. Generally, people believe that a nuclear power plant with good operational performance or good use rate is a safe one; however, it is difficult to accept the correlation or causal relationship conceptually.

At the time when nuclear power plant export was achieved, it was the Renaissance era of nuclear power according to Framework Convention of Climate Change, and all seemed to be in light excitement. In view of the basic concept of safety, lots of voices that cautions are needed have been raised at home and abroad (Choi, 2008; IAEA, 2003). A concern that an unexpected accident can occur under such a good atmosphere was presented, due to Fukushima Nuclear Power Plant accident and Korean nuclear power industry's concealment/irregularity events (Lee, 2013, 2015).

At this time, there is a need to ponder over what we should do about safety culture beyond discussion on nuclear safety culture at the level of reviewing the definition and detailed factors of the INSAG-4 presented by IAEA. In February 2016, IAEA held a large scale international conference to conclude discussions on safety culture and human factors for the past 30 years. This was to conclude leadership on safety culture over five years on the part of IAEA since the Fukushima accident, and to decide the future direction. The background is described well in the report on the Fukushima accident published by IAEA. Even before the Fukushima accident, IAEA held an international co-workshop in May 2007 under the topic of "Regulatory body's Oversight on Licensees' Safety Culture" together with OECD/NEA. Thus, the following were discussed: major issues on regulatory body's oversight in relation with safety culture, namely, what and when the aspects of safety culture need to be reviewed, how safety culture data should be collected and interpreted, and how they can be utilized for regulatory programs (Choi, 2008).

Despite the standing out of safety culture issues in the Chernobyl Nuclear Power Plant accident, an insistence that safety culture should be left to licensee's autonomy was dominant, since the safety culture can be negatively affected by control and intervention. Although huge accidents such as core fusion or radiation leakage did not occur, whenever incidents with social sensation including Monju fast breeder reactor fire, US Davis-Besse reactor vessel head degradation event, Japan JCO's criticality accident and Japan TEPCO's inspection report falsification event occurred, people paid attention to the lack of safety culture as a main cause, and the climax can be the Fukushima Nuclear Power Plant accident. The most important thing is that perception change into intervention in safety culture and concrete countermeasures are needed anyhow in order to prevent such accidents.

Intervention in the organizational culture related with safety in the relevant organizations, as well as the licensees in any form including regulations, is a clear trend domestically and internationally. The reason is because a perception that responsibility of nuclear safety cannot be delegated to the engineering area, and only ensuring of safety by just reviews, documents and witness check of safety design and performance is not enough and is a serious problem has been diffused socially. The following are predicted to be the key matters to be discussed domestically and internationally in the future: Discussion on how much regulations contributed to nuclear safety, discussion on how to ensure national relief on nuclear safety as a goal of safety regulation, and what policy should unfold on safety culture and organizational elements.

2. A Brief Review on the Concept and Construct of Safety Culture

Safety culture has become a familiar term in the nuclear field. Many nuclear institutions have continuously emphasized and educated safety culture, and thus the concept seems to be diffused a lot and understood well. However, this paper examined the concept and evolvement of safety culture in brief for in-depth discussion on the nuclear safety culture.

2.1 What is safety culture?

The term of safety culture emerged in the process of investigating the Chernobyl Nuclear Power Plant accident in 1986 and discussing the issues by international experts, centered on IAEA, for the first time. This actually emphasized the importance of organization and workers' overall attitudes on safety, and became the starting point of official discussion on safety culture, irrelevant of nuclear power industry. The INSAG-3 "Basic Safety Rules of Nuclear Power Plant" published by IAEA in 1989 presented safety culture as the most preferential safety principle. The INSAG-3 defined safety culture as "Cultural climate in which an open attitude that all individuals and organizations engaged in all activities related to nuclear power can freely exchange all information on safety, frank acknowledgement on mistakes, thorough perception on and responsible for safety are shared". Since then, the concept of safety culture has been more clearly established, and concrete assessment indicators were presented, as IAEA published the INSAG-4 in 1991. That is, nuclear safety culture is that the combination of the attitude and character of individuals and organizations resolving safety issue is the top priority interest (INSAG-4). The definition of safety culture by IAEA through the INSAG-4 can be the most widely used definition nowadays (IAEA, 1997).

The association of the U.S. nuclear power plant operators, INPO (Institute of Power Operations), defined safety culture as "An organization's values and behaviors-modeled by its leaders and internalized that serve to make nuclear safety the overriding priority". This appears to be presented in almost the same context with the definition of IAEA.

In the occupational safety and health field, safety culture is actively discussed, centered on the railway, aviation and medical fields closely related with safety management. The British government's upper level organization on health and safety at policy level, the Health and Safety Commission, defines safety culture of an organization as "Integration made by individuals and groups in the contribution to a health and safety program, and the things determining the type and effectiveness of the program, namely value, attitude, skillfulness and behavior type". In the occupational safety area putting priority on worker's injury prevention, safety culture

is defined as follows recently: A comprehensive concept of individual and organizational attitudes on basic value, safety institution's operation and quality, occupational consciousness and continuously learning improvement process of the institution concerned, and atmosphere in which workers can raise problems on concern of safety without fear of being reprimanded, beyond the safety climate of workplace.

2.2 Conceptual evolution of safety culture

Although the definitions of scholars' safety culture are not raised, there is quite a huge deviation in the concrete concept of safety culture. Although the understanding level of the relevant countries on safety culture concept was low at the early stage, as perception that expected level of safety is not achieved with just ensuring of facility or equipment's safety was diffused, the understanding and interest in safety culture became higher in the latter part of the 1990s. The safety culture scope was gradually was expanded, and the concrete factors of safety culture newly stood out, as the ensuring of safety including the hardware aspect such as safety facilities, software aspect like operation procedures or quality activities, and organizational factors including workers' attitude are perceived to be essential. The following safety culture factors have been presented: Personal perception that safety is important, knowledge and ability acquired through self-learning, the superior's initiative putting the highest priority on safety, individual attitude accepting a common goal of safety, motivation through leadership, setting up reward/punishment system, the formal division of duties and indication of duties, and sense of responsibility through each individual's understanding of work. Safety culture has been explained with various factors according to safety issues raised in practical work.

Many international conferences, technology consultations, workshops and training were held to synthesize individual discussions on safety culture, centered on IAEA and OECD/NEA. The results and relevant reports were published, and perception on safety culture factors of many countries with nuclear power plants increased, they implement the relevant activities. In the nuclear field, research and onsite application of safety culture are carried out, and the contents to implement safety culture concept developed, as understanding of safety culture increased. That is, the elements, hierarchical model and development stage concept of safety culture were developed, and discussions of safety culture's requirements, assessment criteria and activities for safety culture's improvement or establishment are being carried out recently.

Each country shows different positions on how to intervene in or support safety culture, and the reason is because the quantification and objectification of a qualitative, internal and comprehensive concept of specialization is fundamentally limited. Discussions on which part needs to be valued more among the elements of safety culture, and whether active intervention in safety culture is necessary for safety culture improvement are still conducted. Actual actions of each country in each technical field are different on whether precise assessment is possible on the sub-hierarchy of safety culture, what can be voluntary effects on safety culture development, what level of regulatory intervention is good, and whether there are no negative effects upon intervention. Although safety culture has been raised as an issue since the Chernobyl Nuclear Power Plant accident, the need for active intervention was questioned at first. However, the problems in the incidents, such as the US Davis-Besse reactor vessel head degradation event, German Brunsbuttel and Philippsburg nuclear power plants' violations of safety management, and French Demperier nuclear power plant's management negligence, and Japan TEPCO's inspection report falsification event were presented in the 2000s, according to the lack of safety culture. Therefore, safety culture began to be discussed within the regulatory scope from the trend of leaving the safety culture in the external area of regulations. Especially, the scope of safety culture consideration was not only expanded widely to long time academic trend and social perception, as well as regulatory bodies and governments, but sufficient bond of sympathy on the need for active activities including assessment and enhancement in various directions was formed.

2.3 Elements of safety culture

IAEA presented the elements of safety culture in the nuclear field through the INSAG-4. It presented two elements, namely

"framework and management responsibility" and "attitude of staff". The framework and management responsibility was divided into policy dimension and manager dimension, and three elements were presented. The INSAG-4 segmented the elements so that they can be used when the safety culture of a nuclear operation organization is assessed, and It presented the elements into 13 areas, and presented detailed checklist: Safety practices, responsibility regulations, training, manager selection, safety performance review, safety emphasis, workload, relationship with regulator, manager's attitude, personal attitude, onsite practical work and onsite oversight at licensee level. The ASCOT (Assessment of Safety Culture in Organizations Team) organized by IAEA to support safety culture assessment presented 268 items as the purpose of safety culture assessment. As IAEA published ASCOT Guidelines in 1994, IAEA built a safety culture assessment team, and started to offer a service proposing the safety culture assessment and effective establishment experience and method to member countries through the team. IAEA's safety culture elements are currently included in the review items of the safety review team (OSART) assessing each country's nuclear facilities during the nuclear facility operation. Actually, those elements are applied to comprehensive safety assessment and improvement.

Meanwhile, OECD/NEA presented 11 items: Organization important to the safety of nuclear power plants, goal and strategy as management elements, management function and review, manpower management, resources allocation, training and communication. OECD/NEA hosts safety culture conferences jointly with IAEA, however, OECD/NEA presented the factors of safety culture that need to be dealt with in regulations through documents including the role of the nuclear regulator in promoting and evaluating safety culture (1999), and regulatory response strategies for culture problems (2000) by focusing on defining a method to cope with and the role on the part of regulators early.

North America such as the U.S. and Canada present safety culture principles, traits and good practices, centered on INPO/NEI and licensee associations, according to the change of regulation policy. They presented 17 factors such as organization, management, goal setting and performance for assessment, staff selection, resources management, training and communication, and developed many detailed questions or assessment items for practical work assessment of those items, and currently apply them.

Because safety culture needs to be identified with numerous assessment items and various methods reflecting a variety of perspectives, it is a common sense that investigating all those, and analyzing not only statistically significant values on one organization's safety culture, but concrete issues are difficult. Nonetheless, the safety culture issues were urgently raised, after the Fukushima accident, and therefore the licensees are burdened to prove safety culture level internally and externally by developing the elements and assessment criteria/framework of safety culture on their own. In Korea, a licensee, Korea Hydro & Nuclear Power, set up six principles and 30 items of assessment criteria, based on INPO's principles and NEI's assessment items, and assess periodically. Although, the assessment is mainly questionnaire-based assessment, it has a trait to present safety culture level of each nuclear power office. As for the reactor for research, peculiar safety culture factors were defined by using IAEA's proposals, and safety culture issues are tackled through periodic assessment and activities of safety culture.

2.4 Hierarchical structure of safety culture

Edgar Schein, an organizational psychologist who proposed a hierarchical model of organizational culture, applied the model to safety culture equally, and proposed the hierarchical structure composed of three layers as shown in the following Figure 1.

In the model, artifacts mean visible factors such as rules, behavior types and structures. Espoused value refers to the value that organization members selected or supported. Basis assumption is the fundamental belief that an organization accepts unconsciously, and it is on the depth of culture, and forms the basis. Artifacts can be grasped through observation and inquiry on members and organization, and espoused value can be grasped through interviews and questionnaires. But, basis assumption is generally inferred or estimated through organizational psychology and socio-metric methodology. Although artifacts or espoused value can be intervened through relatively concrete things on members and organization, a change or an impact is impossible for basis

assumption. Since safety culture is difficult to intervene and properly identify with a single method, due to such a hierarchical structure, an approach comprehensively applying the methods suitable for each hierarchy by harnessing them by each hierarchy in the process of assessment and enhancement is essential.

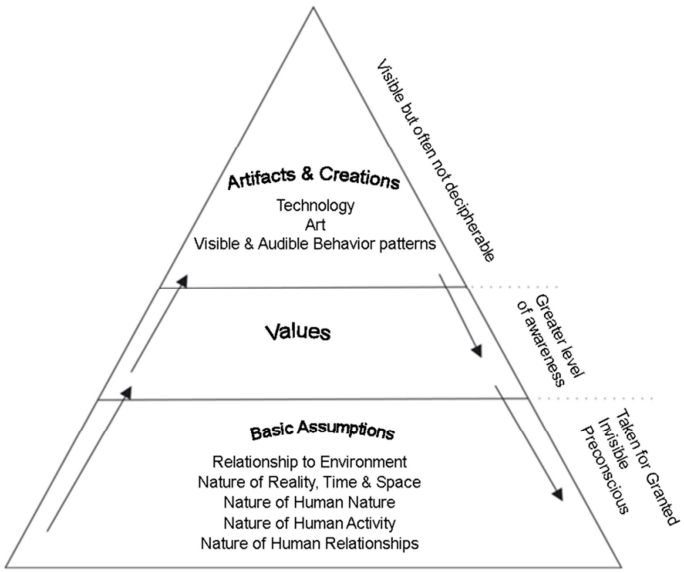

Figure 1. A hierarchical model of organizational culture by E. Schein in 1985

2.5 Stages of safety culture

Culture has a trait to continuously change, and therefore safety culture is analyzed to show three development stages in general. Identifying what stage is an organization's safety culture lies in terms of safety culture's development stages is required in order to establish an enhancement plan to the next stage through which safety culture can be changed into better one.

Stage 1 is a situation in which the ensuring of safety depends on the rules and regulations, and stage 2 is the stage where the ensuring of safety is shared as organization's goal, and performance and performance management are carried out. Stage 3 is the stage where persistent safety improvement is adopted as a belief, and organization members try to improve behaviors or attitudes related with safety.

Such development stages can be useful to effectively set up the role of intervention of an external institution (regulatory body). In the stage 1, the role of regulations work importantly, but organization's voluntary efforts are regarded as important by minimizing regulations in the stage 3. For the assessment and enhancement of safety culture, the development of an optimized method based on spontaneity is necessary in consideration of reverse effects that can be brought about by external intervention.

3. Assessment of Safety Culture

Although 30 years has passed since INSAG advocated safety culture, a perception that safety culture is difficult to grasp, is not concrete and is abstract, and cannot understand easily is strong. Part of the reason is that the systematic and reliable criteria and assessment method of safety culture have yet to be developed. The Convention on Nuclear Safety led by IAEA repeatedly pointed

out that more efforts for assessment method's development and verification should be made, in comparison with the importance of safety culture, although each country promised periodical assessment including safety culture on the safety of nuclear power plants currently under operation (IAEA 3rd review meeting in 2005). IAEA presents the specific characteristics of safety culture and requirements, develops an assessment method, and presents it with the requirements document (GSR-R-3.1) and guidelines (safety culture self-assessment guide). After the Fukushima accident, training on practical improvement means of safety culture on leadership has recently been implemented actively, centered on superiors. However, the fact that there is no arranged method for consistent assessment and identification, as well as safety culture's improvement, is still a pending issue.

As examined above, safety culture has various aspects including elements, hierarchical structure and development stage. Therefore, the level of specific factors (element aspect), hierarchical traits (hierarchical structure aspect) that an organization has, and the status on which development stage has been arrived (development stage aspect) should be identified at least in the safety culture assessment. As such, there is a huge barrier fundamentally in the development of safety culture assessment methodology, since safety culture needs to represent various aspects implicitly. Even though, there are areas, where applied sciences including engineering or sociology methodology are possible, there is a need to systematically establish through humanities methodology such as literature and psychology.

Due to differences in vision on culture, different opinions on the part to notice in safety culture assessment are presented, and thus the utilization of assessment results is not enhanced. For example, culture is viewed as the pattern of behaviors of members, and focus is on tangible safety management type, if a logic of a concretist camp asserting, "Behaviors form perception", is based. Meanwhile, if a logic of the cognitive mentalistic camp, "Perception decides behaviors", is based, culture is viewed as the pattern for behaviors of the members, and focus is on the intangible consciousness and attitude. If the concepts, assessment methods and roles of safety culture are arranged, they can be schematized separately (Choi, 2008). Safety culture assessment can be divided into objective and quantitative assessment (concretist approach) on framework and management, and subjective and relative assessment (cognitive mentalistic approach) on staff's attitude. Because assessment focused on confirmation is possible in framework and management responsibility, objectivity and quantitative digitalization are easy, but assessment and metrification of staff's attitude is difficult, and should depend on interviews and questionnaires. However, in such a case, the development of a mechanism inducing respondent's frank responses and a technique enhancing accuracy of survey is required.

4. Discussions on the Selected Issues for Safety Culture in Nuclear Field

This section comparatively reviewed nuclear safety culture trends, centered on the U.S., to draw safety culture issues in the Korean nuclear field. This study presents preferential items to cope with in Korea regarding nuclear safety culture issues by arranging the raised major issues of safety culture.

4.1 A comparison with U.S. in nuclear safety culture

The U.S., a leading country in the nuclear field, has promoted many studies and improvements in relation with facilities' man-machine interface to cope with nuclear human error issues, since the TMI accident in 1979. NRC (Nuclear Regulatory Commission) has continuously studied not only traditional regulatory types since the early 1980s, but the impacts on nuclear stability in the human performance and organizational management, while promoting SALP (Systematic Assessment Licensees' Performance). However, NRC concentrated its competence on the new conceptual development of risk-informed regulations using risk information in order to improve the predictability and objectivity of safety regulations, due to the constraint of immense cost required for R&D in the human performance and organizational management field, and thus NRC suspended the support for the relevant research.

The U.S. NRC, a regulatory body, maintained a policy not to directly intervene in licensee's safety culture from the perspectives of

the subjectivity of safety culture assessment, assessment method uncertainty, concern on licensee's managerial right infringement and the importance of licensee's effort. Until the US Davis-Besse reactor vessel head degradation event took place in 2002, there was no performance indicator for safety culture assessment and regularly performed test. However, since the occurrence of the Davis-Besse event, NRC concluded the root cause as the lack of safety culture through various investigations, researches and public hearings, and therefore a change on regulation position on safety culture took place.

NRC instructed to prepare for the measures for improvement so as to more sincerely deal with safety culture in ROP (Reactor Oversight Process), conduct training for inspector's safety culture understanding enhancement, and develop safety culture assessment procedure on nuclear power plants with reduced performance. NRC carried out improvement work to deal with safety culture in ROP for one and a half years, developed a regulatory test performing system linked with ROP's cross-cutting area through opinion convergence of licensees and stakeholders, and diffused the results to the entire nuclear power plants through pilot implementation for 18 months from July 2006.

The process of NRC's oversighting safety culture through ROP is as follows: The U.S. reconstructed safety culture factors. After investigating and analyzing the cases of IAEA, NEA and each country, NRC integrated safety culture factors into 13 factors, and re-defined cross-cutting areas, and linked them as shown in Table 1. As for implementation method, NRC let an inspector assess, and write down in the inspection report, if there are inspection findings, such as performance reduction and regulation violations in ROP. As an implementation method, NRC applied a graded approach. By analyzing half yearly inspection reports, NRC assessed each nuclear power plant on whether any problems exist in relation with safety culture. If there is any problem, NRC notified the licensee concerned of the result, and induced voluntary actions (IP95001 applied). If green or higher performance reduction continues for 18 months, and association with safety culture exists, NRC instructed licensee' own assessment or a third party assessment of safety culture, (IP95002 applied). If ROP's action matrix column 4 is needed, due to continuous performance reduction, NRC implements its special inspection of safety culture (IP95003 applied). If safety culture vulnerability is judged to seriously affect the safety of a nuclear power plant, NRC orders the suspension of its operation, based on the judgment. Through devising relevant basis, NRC revised the inspection manuals and procedures, and presented concrete guidelines on the assessment of safety culture. In the manuals (IMC0305, IMC0612) and procedures (IP71152, IP93800, IP93812, IP95001~3), various cases and formats, such as things to observe by an inspector, assessment method and report writing method, are presented. Also, training for inspectors is conducted, and a special inspection team of safety culture is organized. As a result of safety culture inspection, a report is open to the public through the NRC homepage. During the 18-month pilot implementation in 2007, the first safety culture special inspection on the Palo Verde Nuclear Power Plant was carried out in 2007, based which NRC expanded and applied the safety culture inspection method on other nuclear power plants.

The U.S. confirmed SCPC (Safety Culture Policy Statement) including nine basic requirements recently by completely shifting from the early stage regulatory body's non-intervention policy on safety culture. Also, the U.S. developed and has been applying a licensee safety culture oversight program, based on site-stationed inspector's observation and assessment, and the special inspection of safety culture of headquarters inspector. Many relevant countries are forecast to benchmark such an approach of the U.S in the future.

The early review result on safety culture approach showed various trends of many countries (Choi, 2008; IAEA, 2003, 2016). The vision on safety culture regulation and oversight has changed worldwide, and the opinion that regulatory body's intervention causes a reverse effect has changed. Therefore the need for active intervention in safety culture by the graded approach is a clear trend nowadays. In some countries, regulatory bodies have extensively intervened in licensees' safety culture; however, most countries take a method reviewing licensee's own assessment method and result. Most countries implements regulatory activities from the safety management aspect, and they seem to seek more sophisticated assessment method development and R&D strategies.

4.2 Three technical domains for nuclear safety culture

Various discussions are conducted for concrete activities on safety culture. Although R&D of safety culture's models, criteria and basic principles are actively carried out in the safety culture-related academia, an in-depth analysis on specific phenomena and issues cannot be ignored. The representative R&D is about the interpretation of leadership effect, and practical methods, focused by IAEA. From the practical work aspect, the issues of licensees and regulators are contrasted in terms of role, but, they have close association. The practical work issues of safety culture can be classified into three domains: Which aspect of safety culture should be examined when and how, how safety culture data should be acquired and interpreted, and how safety culture data should be utilized for enhancement of safety culture.

As a result of discussing safety culture issues among the experts of nuclear countries including the U.S., the U.K., Japan, France, Germany and Russia, and international organizations such as IAEA, OECD/NEA and EU, the discussion details and the results drawn so far on the methodology and approach related to safety culture oversight are as follows (Figure 2, Choi, 2008):

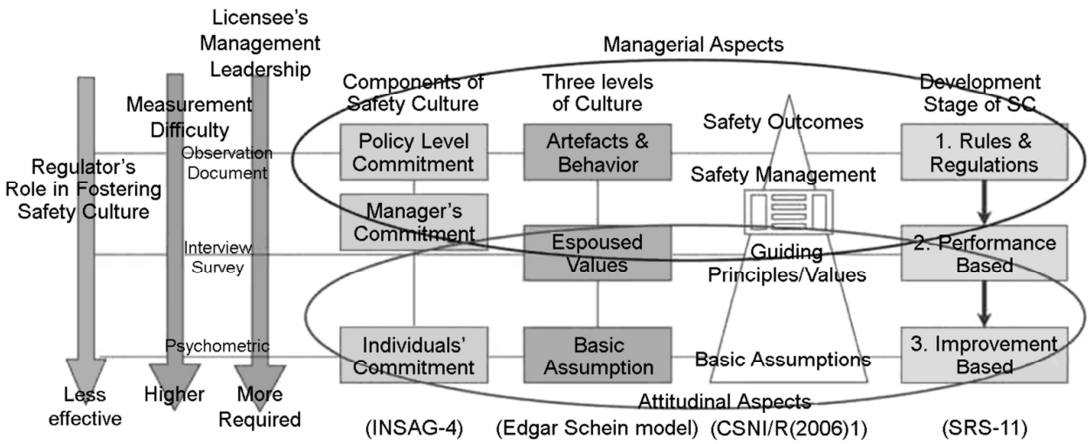

Figure 2. Two Basic Dimensions for safety culture: Managerial and Attitudinal Aspects (Choi, 2008)

4.2.1 Target and time for safety culture works

Above all, the core factors of safety culture should be examined first. It is urgent to set up peculiar items by the field and body concerned using the five traits of safety culture presented by IAEA as basic factors, and the detailed questions presented as self-assessment items. Although, assessment starts based on other factors, not based on the theoretical factors presented by IAEA, the development results of concrete sub-factors will not be greatly different. The foundation to construct concrete assessment indicators targeting detailed factors, and assess entire safety culture systemically can be laid.

The consideration of not only safety culture factors, but identification and assessment methods, is an important issue. Even though there are many indicators that can be viewed from various aspects, the results can vary according to assessment methods. Currently, the assessment methods include just questionnaire survey, interview, document review, observation and FGI (focused group interview), the establishment of an assessment system, through which balanced decisions can be made by applying and synthesizing the assessment method suitable to multi hierarchies and detailed factors of safety culture, is important. Discussion on whether licensee's attitude, values and behaviors should be assessed, in addition to the framework, procedures and documents

related with safety, and on what method is needed to enhance the accuracy of such an assessment is necessary.

Besides, overall cultural characteristics can be identified by paying attention to high level management's style and leadership. Especially, Canada needs to pay attention to those, as the country wants to include the safety items for the selection of licensee's management.

Because an engineering approach cannot guarantee nuclear safety culture, attention needs to be paid to all parts. However, a caution is required in that external intervention can have a negative impact. Also, it is desirable for a licensee to investigate in terms of investigation from the worker's attitude perspective. It will be difficult to demand the exertion of non-technical competence with knowledge on operators' psychology, culture and values to an inspector with just engineering knowledge such as machine, material and core.

There are many opinions that separation of safety culture from safety management is difficult on whether safety culture should be considered as a separate activity. Therefore it will be desirable to approach from one perspective. Some countries adopt a method to approach safety culture with safety & health and quality control in an integrated way. As a result, huge effects can be expected to make staff perceive the importance of safety culture with periodic assessment alone. The method to manage and oversight safety culture from the integrated perspective should be established through peculiar development process, respectively. Towards this end, a method to expand the certification system including ISO, OHSAS for existing environmental safety & health and sustainability management can be considered.

4.2.2 Acquisition of data and information of safety culture

As for the acquisition of objective data on safety culture, the independent observation of safety culture-related things during everyday life activities of an inspector (stationed inspector or supervisor), and the management of those as separate items will be desirable. To do so, proper understanding on how the main players of the data acquisition acquire what information is a basic condition, and therefore training of the relevant staff is needed. Since available resources are limited, a decision on how many resources should be inputted to safety culture data acquisition under the risk-informed environment, in which more efforts are focused on relatively more important parts on safety, is a task to be prudently achieved in priority. Although the separately assigned staff for safety culture is not set up in Korea's nuclear power plants, burden has been on the rise with only normal staff, since the Fukushima accident and the nuclear power plant's quality warranty incident.

The safety culture data acquisition at site is an important regulatory activity not to cause an accident like the TMI accident or Chernobyl accident. Consequently, periodic information acquisition from regular inspection, and intensive assessment through root cause investigation upon nuclear power plant performance reduction and accident investigation are required. In the U.S., most onsite staff's activities are related with safety culture factors, and thus it is judged that there is not much input of regulatory staff. The inspection procedures and manuals developed by NRC with much effort describe the methods such as interview, questionnaire and behavior observation as the techniques related to licensee's safety culture in detail, and the merits and demerits are specified. For this reason, it is good to refer to them. However, non-engineering methods need to be realistic and coordinated to be suitable for the Korean conditions and environment.

It is required to set up the qualities, knowledge and skills that the relevant people need to be equipped with in order to intervene in safety culture. There is a need to refer to the U.S. case that the qualification of safety culture assessors is classified into level 1 and level 2. A level 1 assessor needs to have Ph.D. degree in psychology or sociology, and also communication ability and nuclear experience. A level 2 assessor needs to have master's degree at least as an expert of statistics and questionnaire survey. However, the mindset, "Trust but verify with critical eyes", is essential, and above all, an attitude not overreacting and that can

shape trust should be equipped with. Since an ability like a detective Colombo who can identify various clues and internal characteristics at a glance is not possible in reality, it is needed to develop formal training course acquiring and interpreting safety culture data in accident analysis, root cause investigation and classification by accident type for practical work of safety culture. In safety culture observation, there is a need to find a suitable person, who can immediately identify a problem at the closest distance, and to actively utilize the person. When intensively investigating safety culture, it is impossible without knowing technical matters. Therefore, it is needed to organize an interdisciplinary team, since an assessor should know psychology or praxeology, which is not easy.

It is important to make it a habit to acquire safety culture data, rather than requiring an effort. It is required to establish safety data acquisition as one of the basic activities in the nuclear field, which is a burdensome area to regulatory inspectors, as well as licensees. Currently, it is supported with relevant institution head's will and policy, the solution to it is urgent. If ERP (enterprise resource planning), BPM (business process management) and computerized programs that rapidly developed in the industrial and system management fields are used, various detailed operation information including safety culture can be acquired (Lee, 2013, 2015). If a new function meeting IAEA's IMS (Integrated Management System) requirements is developed in a nuclear power plant, global technology leading role can be fulfilled. The big data technique recently emerging will open a new possibility acquiring the objective data of safety culture and interpreting the information that offers the basis of safety culture activities.

An effort not only assessing and judging safety culture, but reviewing the suitability of safety culture procedure (assessment and improvement) conducted by a licensee is necessary. For example, it will be effective to examine whether licensee procedure or plan is adequate in the review of an assessment report related with safety like PSR. Because how to associate the operation information items of safety culture is a peculiar area of each country or field, the arrangement of it is also urgent.

4.2.3 Interpretation and utilization of safety culture data

Concerning indicators and criteria for overall judgment of safety culture, people need to depend upon expert's judgment mostly, but the leading indicator currently developed by IAEA can be partially utilized. The indicators are meaningful, only if they are strictly used for change according to specific topic's information time and statistical use, rather than working as absolute numeric value. From the safety management aspect of a nuclear power plant, Japan, Germany and the U.K. construct indicators in 14, eight and four fields, respectively, and information from the organizational operation and cultural aspects can be drawn through them. Although several attempts of developing major indicators related with safety culture were made in Korea, it is uncertain whether safety culture data production is continuously carried out. A development process to set up beforehand is necessary, so that the interpretation result of safety culture data and information can form a close relationship with concrete action means and methods that can be actually operated. The reason is that assessment result in existing safety culture assessment is very vulnerable to linking interpretation with concrete actions, which can work as a cause to make safety culture-related efforts obscure or non-persistent, as a result of uncertain feedback mechanism.

It is impossible and undesirable to extrapolate entire safety culture with observation and interview on the part of an organization frequently used for safety culture assessment. Since one of the essential traits of culture is diversity, it is impossible to represent entire and a variety of safety culture with part of it, which is improper thing to do as much as indicating safety with a single numeric value. Therefore, the acquisition and interpretation of safety culture data should be carried out totally and continuously according to the set up goal, and should be limited to selective identification of the change and relative weakness of the status. Especially, the use of color is said to be desirable in that it does not distort its meaning, rather than number, regarding the indication of safety culture status with a number. In this regard, a human factors engineering study on proper method to indicate safety culture status will be necessary. When expressed with numeric value, ill effect is unavoidable, regardless of good or bad score in terms of the risk of improper, unnecessary and relative comparison. If a score is relatively higher one, arrogance can be induced,

and if the score is bad, a serious distort of resources can be caused through concentration on a specific field.

A framework to decide what and how should interpret is very important to actually reflect safety culture information. If technical assessment and safety culture activities are treated separately, they just stay in separate areas, and thus an interpretation and decision making process should be developed so that the actions drawn as a result of safety culture interpretation can be properly combined with technical area.

Although how a licensee will react to the findings of a regulatory body can be an indicator revealing the safety culture level, an interpretation process presenting improvements for the worried parts, rather than pointing out faults, needs to be prepared in order to elevate the acceptance of safety culture interpretation result. If the need for change is not agreed, or interests are conflicted, a method to seek compromise by looking at the importance needs to be offered, or a method to induce adequate decision making is required by effectively presenting management with what such a thing means.

Since autonomous selection and effort of the person concerned are necessary in response to the findings on safety culture, the person concerned should be responsible for safety culture, and maintain an attitude to decide autonomously. This, however, should be preconditioned of safety culture's development stages, and checking management's will and commitment, according to change of each stage, and also a method to follow up for the long term are needed. If infrastructure information system is built with a form of IMS for the acquisition and interpretation of safety culture data, flexible support can be offered according to each person's autonomy in terms of safety culture information's composition and utilization. In the continuous improvement field, centered on the U.S., a dash board type of information indication function, through which a person can check and manage necessary information by sector and position in the nuclear power plant's operation process, is offered. In a company, where a method is globalized by which various items and information are autonomously built by top management, middle management and site staff, and thus safety culture's practical work can be supported nowadays, such a function is already familiarized.

Looking into the regulations on safety culture, Europe considers that minimization of regulations on safety culture, centered on continuous discussions with licenses, and interventions from the narrow perspective are possible. However, there is an opinion in the U.S. and Germany that some efforts (Enactment of regulations, a method to add or extend from the existing regulations) for compatibility from the attitude perspective in a situation that clear regulation criteria are not established are required. In Korea, it is limited to applicability verification of safety culture assessment items from the regulation aspect, therefore a study on how safety culture information should be interpreted and utilized as regulatory purpose is urgently required.

Because general open discussion on safety culture of licensees is a critical factor to the acceptance of nuclear power plants, and it is the area to be ultimately achieved. However, simple open discussion may cause more complex impact relationship and trial and error, rather than regulatory intervention, and thus prudent preparation and gradual approach are necessary. Because safety is not guaranteed with only regulations or technical criteria, and strict regulatory initiatives are not always desirable, adequate balance and a well-coordinated and rational strategy is required for the interpretation and utilization of safety culture information.

4.3 Selected items for nuclear safety culture in Korea

Safety culture for nuclear safety needs to have different concepts and requirements from general industry's safety culture, because many unique aspects of the nuclear field exist (Lee, 2013, 2015; Kim and Lee, 2012). If the goal area of safety is segmented, there is safety to cope with injuries of the staff, and to cope with the losses of facilities and capital. However, the goal of public safety responsible for environmental and community safety also exists in nuclear safety. To achieve multidimensional nuclear safety culture, a prudent approach including the identification and assessment of and intervention in safety culture is necessary. The top two levels of safety culture hierarchy are known to be easy to grasp, but adequate mode in the nuclear field has yet to be established.

As you can see from the Fukushima accident report (IAEA, 2013, 2016), the traits of base hierarchy of safety culture in the "fundamental surprise" conditions of an "unexpected situation" may work as a critical factor (Figure 3). However, the intangible aspect of base hierarchy such as attitude and values on safety cannot be easily grasped, despite the existence of a problem, and it should be carefully estimated, and change needs to be sought through an indirect method.

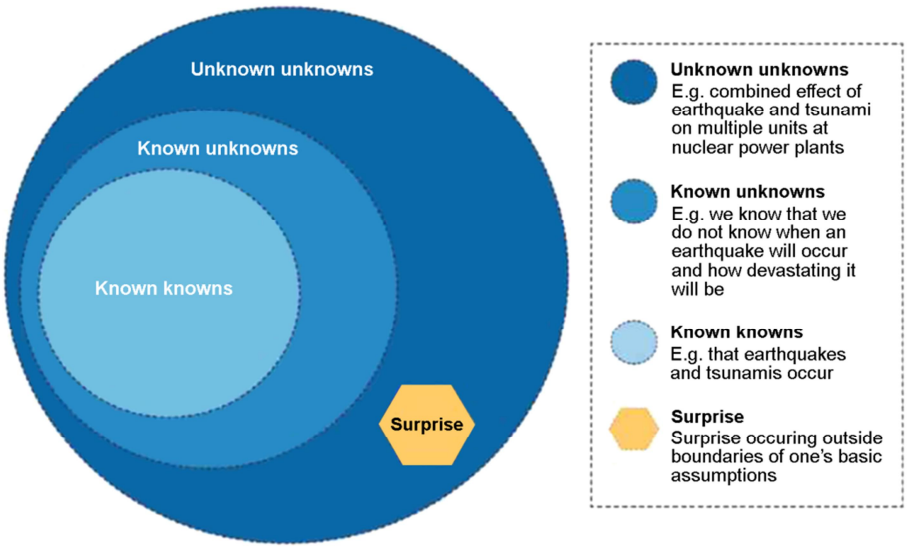

Figure 3. *Known Knowns, Known Unknowns, and Unknown Unknowns* (adopted from Fig. 2.6-1 Impact of Unknown Unknowns, Fukushima Diichi Accident Report, IAEA, 2015)

Safety culture should be approached with safety management in an integrated way, rather than being separated. Although proactive efforts on safety culture are desirable, a method to provide teamwork between the experts understanding technical background in the nuclear field and psychology and behavioral science experts is necessary. A method to assess overall safety culture with numeric values does not exist, and therefore assessment needs to depend upon the data acquired by individual issue and field, and experts' judgment. Since comprehensively grasping safety culture is difficult, it is needed to build a safety culture framework prepared in advance to enhance reliability by using various methods by hierarchy, level and field. Although safety culture indicators are not sufficiently developed, the detailed items and discussions on concrete measured values by the institutions concerned or field can be constructed by using basic indicators offered by IAEA, INPO/NEI, WANO and OECD/NEA. Through this, meaningful result can be drawn via the trend analysis and statistical analysis.

To systematically cope with such conflicting factors, it is urgent to build safety culture infrastructure as the foundation of safety culture enabling intensive safety culture analysis. Actually, the basis of information acquisition and processing, through which concrete true nature of safety culture can be grasped, should be built in priority.

Even though a method to encourage licensee's own efforts is unavoidable in terms of safety culture, since safety culture has yet to be built as a regulatory factor, a long-term and continuous effort ranging from making own assessment procedure and top management's commitment to regulation's improvement is required. There is a need to pay attention to the method to ensure practical linkage of a program for proactive leadership and leadership. Upon nuclear power plant's own safety culture assessment, the utilization of a third party professional body, and the participation of labor union can also be considered. The exchange of

regulatory experience on safety culture is necessary, and towards this end, each country's inspector exchange program can be useful. According to the emergence of a global company, a united team can be utilized including the non-nuclear field. Based on the discussion on international trends and technical areas, the items that have been proposed for nuclear safety culture in Korea can be summarized as follows:

First, enabling a licensee to conduct its own assessment by the already developed safety culture assessment method, and the licensee and a regulator to consult and assess with the assessment method and result, and to focus on improving safety culture based on the result.

Second, enabling to continuously conduct HuPI, and build up regulation experience and relevant data, expand the scope for the long-term, and link with the general safety assessment system combining with safety culture in the current regulation and inspection.

Third, enabling to effectively carry out safety culture inspection in the daily life activity in the nuclear site. To this end, the enhancement of safety culture perception and the diffusion of knowledge on safety culture are necessary, and safety culture curriculum or workshop tour needs to be held at site.

Fourth, conduct intensive inspection, when safety culture intervention is detected. To this end, develop a program inspecting the safety culture correlation upon investigation the incident. The licensees and regulators continue to conduct R&D activities for a Korean style safety culture model, and verify and improve the own nuclear power plant's assessment means/method, and implement safety culture model improvement.

Fifth, training should be carried out for regulator, stationed inspector, licensee's headquarters and office staff through safety culture-specialized courses. Since the effects of top management's safety consciousness are huge, apply a special training program for top management's safety culture [i.e. SCART (Safety Culture Enhancement Program) offered by SCART (Safety Culture Assessment Review Team)].

Sixth, implement a safety culture oversight program, enact the safety culture basic guidelines, draw up a comprehensive safety culture improvement plan that concretely identifies Korea's position on safety culture, and promote institutionalization, if data enough to ensure effectiveness are acquired.

5. Closing

At the heightened time of the Renaissances era of nuclear power, the confidence of the management of a Korean nuclear power plant office on safety, based on the excellence of the nuclear power plant, was pointed out as a concern to foreign visitors. Some middle manager participants in a safety culture training course showed a response on the Davis-Besse nuclear power plant accident, saying, "We would have taken a corrective action by removing those things all". He showed confidence that such a thing cannot occur in Korea. It was encouraging in that our staff showed pride and competence on our nuclear facilities' safety. However, such a remark was connected to the arrogance of licensee's management or the organization. Therefore a concern that we should extremely be on the alert in terms of safety culture was unavoidable.

After several years since then, Fukushima accident occurred that reversed the Renaissance of nuclear power, and Kori Unit 1 Station Black Out (SBO) Concealment Event and quality assurance (QA) document forgery and medication event in the nuclear parts supply chain took place subsequently. All these discourage the heightened atmosphere, derived from Korea's nuclear technology export. As worried early, safety culture has become a big obstacle in the nuclear field. Is it too late to discuss the

nuclear safety culture issues? However, when one thinks it is too late, it will be early. This paper urges to consider how we should think and practice in nuclear safety culture in order not to repeat such a failure due to safety culture problems.

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References

Choi, G.S., What Should We Do about Nuclear Safety Culture?, *Periodicals of Nuclear Industry*, vol. 2008(2), 2008.

IAEA, Developing Safety Culture in Nuclear Activities (safety report series No.11), 1997.

IAEA, IAEA Technical Meeting on the Role of Governments and Regulators in Fostering a Strong Safety Culture, IAEA Vienna, 2003.

IAEA, Human and Organizational Factors in Nuclear Safety in the Light of the Accident at the Fukushima Daiichi Nuclear Power Plant: IAEA Report on International Experts Meeting, 2013.

IAEA, IAEA Report on Fukushima Diichi Accident: Technical Vol. 2, section 2.5 HOF (Human and Organizational Factors), 2015.

IAEA, International Conference on Human and Organizational Aspects of Assuring Nuclear Safety - Exploring 30 years of safety culture, 2016.

Kim, S.K. and Lee, Y.H., Nuclear Safety Resource Management: an approach toward Strengthening Safety Culture through the Integrated Management System in Korea, *IAEA meeting on Safety Culture during Pre-operational Phases*, 2012.

Lee, Y.H., A Strategic Enhancement of the Personnel Competences for the Safety Culture of Nuclear Power Plants, *Proceedings of ESK 2013 Spring Conference*, 2013.

Lee, Y.H., A Study on the Human Factors Engineering Approach to Safety Culture, *Proceedings of ESK 2015 Fall Conference*, 2015.

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