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A Revisit Study on Violations and their Countermeasures to Four Major Nuclear Accidents

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1. INTRODUCTION

The safety of nuclear power systems, born from the best science, was secured in advance with a variety of pre-designed safety functions. Unlike general industrial safety, it was fundamentally different from the empirical safety approach through accident accidents. However, the importance of retrospective analysis emphasized in general industrial safety has been highlighted by experiencing a variety of unexpected events and accidents in the process of operating as a commercial system. In particular, four major nuclear accidents have been used as common tasks in the global nuclear sector.

One important feature in learning nuclear accident is that it is analyzed from the perspective of human error. Human error appears to be one of the strategic and effective perspectives in interpreting and learning the real problems of safety experienced by people (1992 Rasmussen, 2015 Lee). However, the human error perspective naturally leads to the responsibility of the parties, requiring careful or pre-designed methodologies in practice. In particular, human error is likely to be interpreted as a violation. Controversy over violations has become frequent at a time when the sensitivity to safety has increased due to the increased hyper-connectivity and vulnerability of new technologies. Therefore, it is urgent to overcome the controversy over responsibility for violations and come up with more effective technical measures.

In the process of developing an effective analysis method for violation errors, this paper presents the results of the re-analysis in terms of violation of human error in major domestic and foreign nuclear accidents.

2. CONCEPT OF HUMAN ERROR 3.0

I reviewed most traditional approaches and methods for human error investigation and analysis in theory and practice, and found one curiosity about the basic concept applied to them. Human error analysis has been misunderstood as an investigation on human error itself rather than on an (or failure) factors related to human error. Causal analysis needs to be focused to the human factors as well as human himself. Human error was highlighted at the center of system safety, which led to the start of the era of mass production due to the Industrial Revolution. At that time, not only did we increase productivity by studying the time and operation of the workers, but we also made efforts to ensure the safety of the workers themselves. The goal of system safety was also the physical safety of ordinary workers, and physical safety efforts from an injury prevention perspective were the primary concern of safety. The main body of physical safety was not only the worker himself, but also the responsibility for not securing physical safety was basically on the worker. In this era of human error 1.0, the investigation of workers' abilities and defects was key in retrospective analysis of safety accidents. Most of the results of retrospective analysis were educational training and monitoring supervision management due to strengthening requirements to prevent workers' abilities and defects.

However, a realistic perception has begun that ensuring the safety of the operator is a crucial factor not only for the operator himself but also for the performance and performance of the system as a whole. As mechanical functions have developed and stabilized, the role of workers has been highlighted as an uncertainty factor throughout the system. Therefore, the operator's mistakes cannot be simply left to the operator's individual. At the same time, however, due to the characteristics and limitations of the worker, the limitations that could be improved on the worker's ability were evident. Therefore, it was found that fitting the system to the human being was reasonable rather than improving the worker. This human error 2.0 perspective resulted in the optimization and rapid interface development of a worker-centered system. The accident investigation analysis in the 2.0 era of human error was aimed at capturing various human factors that needed improvement, starting from the perspective of human error. As a result, innovative safety has been achieved in the high reliability sector thanks to advances in the hardware and software technologies of computers.

However, the human error 2.0 perspective also showed its limitations. The TMI nuclear accident revealed the possibility of numerous improvements due to traditional human error 2.0 perspective. As a result of the accident analysis, vast safety tasks related to human error prevention were highlighted, such as additional installation of ERF/SPDS, reinforcement of emergency operation procedures centered on symptom-based and safety function recovery, and complete improvement of the control room interface. However, the effectiveness of traditional retrospective research and analysis has been questioned due to the nature of the large-scale

high-reliability system. There were many measures that seemed to be a "hindsight effect" enough to be interpreted as a "normal accident." Therefore, a new perspective on human error 3.0 was proposed for the safety of the large reliability system. Human error 3.0 does not necessarily assume a particular defect or failure. Therefore, it is a proactive view that finds room for additional possible or necessary measures for the safety of the system rather than for the cause of the accident.
- Non-faulty/Non-faulty normal accident: human resources and human resources
- The ultimate/infinite responsibility premise of a dangerous society: the common destiny of future safety
- Possibility of countermeasures independent of causes: Field safety based on practical reality
- Trust-based human factors safety: mutual trust-based discovery among stakeholders
- Infinite responsibility safety based on participation: Continuous expansion of safety value through active participation
- Safety of future-oriented creative measures: Focus on future measures at a new level

3. A REVISIT TO MAJOR ACCIDENT CASES

3.1 Fundamental characteristics of nuclear safety

In terms of safety, nuclear power systems have several prominent findings:
- *High reliability large system*
- *Complex interdisciplinary process*
- *Non-injury system-loss safety*
- *Segmented and out-of-the-loop system*
- *Tightly-coupled functional closed system*

In nuclear systems with high reliability system characteristics for high safety levels, accidents exhibit very low frequency characteristics of rare accidents. Therefore, there is a difficulty in retrospective analysis for experience learning-based learning. First, it is difficult to obtain statistical significance in statistical analyses based on accumulation of case data. Statistical analyses based on a very small number of defect case information in a large system of more than 3 million components each for a variety of road types cannot be sufficient to reinforce with international cooperation. Second, the conclusion of the cause-result combination approach obtained by estimating the cause for a particular defect has no clear guarantee of future safety.

This is because it is impossible to discuss securing safety of the entire system with fragmented work experience due to the nature of the large system. Third, it is difficult to track and confirm the effectiveness of the implementation results of the measures. This is inevitable as a result of statistics based on the characteristics of very few rare accidents. The latent nature and inhibition of defects, most of which consist of various multiple protections are not detected as safety problems, is serious. At the same time, due to the nature of the adherence system, very minor defects in tasks or functions may threaten overall safety, but the conditions of the numerous other systematic elements required are difficult to track and manage, which act as a fundamental limitation of safety management.

3.2 Overview of violations of human error incidents

In this study, several accident cases were re-analyzed to examine more effectively analyzing recent highlighted violations in relation to human error. Among the major nuclear accidents, the following four cases were selected as subjects of research, with human error issues of the nature of violation highlighted at the core.
- *Former Soviet: Chernobyl nuclear accident (1986)*
- *Japan JCO: nuclear re-criticality accident (1999)*
- *Kor#1: Station Black Out and concealment (2012)*
- *Hanbit#1: power increase/delayed manual trip (2018)*

The Chernobyl accident was the latest nuclear power plant built by the Soviet Union at that time. Human error was involved in conducting new experiments using turbines as part of various technological developments has been reported as the main cause. Although the relevant human error was a clear violation, it was seen as unintended consequences by experimental performers who did not have sufficient prior knowledge. Therefore, the vulnerable safety culture of the Soviet Union, which forms the background of the violation, was attributed to the vulnerability of the safety culture, which was significantly lacking in the concept of nuclear power plant design.

Nuclear re-critical accidents at JCO, a Japanese reprocessing facility, have been reported to be the main cause of customary violations. As far as safety is concerned, the lack of expertise in the organization and team responsible for reprocessing operations in Japan, as well as the long-standing practice violations, has led to rare loss of life. It is clear that Japan's hubris over safety as well as nuclear power has contributed to a flaw in safety culture.

The SBO and concealment case of Kori #1 was a serious issue due to succeeded by Fukushima natural disaster, which occurred shortly after a minor test failure in Korea. However, internal concealment and subsequent violations of sensitive power loss events rather than the loss of power itself were revealed postmortem, bringing a decisive collapse in the reliability of the domestic nuclear power sector. This is because the methods and contents of concealment and subsequent violations gave fundamental anxiety about nuclear safety.

Hanbit #1 case of minor power increase and delayed manual shutdown events are the most recent human error events among the cases subject to reanalysis. It was investigated that human error during the critical testing process related to core power not only resulted in poorly managed power increases, but also a deliberate delay in the promised manual shutdown due to the increase in power. Excessive power growth is managed by engineering safety functions, but the importance of violations has been seriously raised in that the human in the final role did not engage in a hull-blocking of power growth.

3.3 Re-visit and Review of Human Error Cases

Human error at Chernobyl case reveals optimizing violations that occurred in delayed test situations. It starts with the planning of an experiment that is clearly out of scope of operation to utilize the inertia of turbine stops. Thus, situational violations of workers in situational circumstances, as well as poor experimental planning itself, were rather natural consequences. This is interpreted as an unfair and inappropriate transfer of risk, as well as an Expert Violation by experts who planned, pushed, planned and directed experiments, not by practitioners at the implementation stage.

It is reasonable to view the Chernobyl accident as a violation of human error caused by a flaw in the safety culture. However, pointing to the IAEA as the main cause of safety culture is unduly comprehensive, and it is not enough to deal with violations at all. After the Chernobyl accident, there is a tendency to emphasize safety culture as the cause of accidents or human error. However, the following attribution issues under the pretext of safety culture must be checked in order to deal effectively with violations:

- *The obvious problem of safety culture that is always right as a cause. Triviality of casual intervention.*
- *Convenience of cause analysis by termination criteria*
- *Arbitrary-ness on countermeasures by virtue of the vagueness of safety culture*

Violations included in JCO case are the most typical permitted routine violations. However, the safety management process has been poorly managed over a long period of time, as the violators are not even aware of the possibility of human casualties. Shortly after the accident, discussions on the cause were active not only internationally but also internationally, but it was still obscured by a comprehensive safety culture. As a result, the safety culture attribution phenomenon worsened in Japan's nuclear power sector, resulting in no responsible improvement in safety culture until Tokyo Electric Power Co.'s cover-up of test corruption in 2002 as well as the 2011 Fukushima nuclear accident. It is one of the most representative examples of the dangers of safety culture attribution methods.

The loss of all members of Gori-1 and the cover-up incident were violations in Korea immediately after the Fukushima accident. Violations in the case of Gori-1 are included in the background of the lack of independence of the organization's authority and make-up, and poor safety decision-making systems. However, it was an event that occurred at a time when the seriousness of safety culture was sharply highlighted due to the Fukushima accident, which easily led to the emphasis on the management perspective as the cause of safety culture. However, the domestic safety culture, which had remained relatively distant and faced the safety culture highlighted in the Chernobyl accident, was subject to uncertainty not only its substance but also its concrete intervention. Although the evaluation and improvement of safety culture has been implemented from various perspectives through the Gori # 1 event, it is not clear whether the actual improvement has been made or not. Rather, public opinion-based distrust of the parties involved and the entire domestic nuclear system has continued to rise, and negative controversy has intensified due to confirmation bias in all subsequent domestic nuclear incidents.

Violations in the Hanbit #1 incident are highly organized and constantly reinforced violations. By systematically insisting on unintended human error, which can be relatively simple, it has been turned into a violation. However, the violation of Hanbit-1 showed a new aspect as it led to an investigation that dealt with legal responsibilities in terms of regulation. While countermeasures against human error could generally remain in the technical area, the core of the countermeasures such as CCTV surveillance functions is analyzed as a case of concern for derivative problems.

4. CONCLUSION AND DISCUSSIONS

Discussions on common findings in reanalyzed examples include:

First, the effectiveness of the discussion of individual responsibilities relating to violations is uncertain. As pointed out in human error 3.0 or the paradigm of normal thinking, the actual risk of accidents stems from the fundamental limitations of the system itself. Even if the person involved in the violation violated it, it is because the possibility of human error (risk) caused by the fundamental limitation is only realized in a situation. In addition, individuals' pursuit of responsibility does not seem to help compensate/recovery for future past losses at all, and does not seem to have much meaning in improving safety. The justification for the culpability of violations as well as the effectiveness of the reprimand in terms of efficiency should be carefully considered.

Second, it is reasonable to view violations as a matter of safety culture, and it is clear that they are in a critical influence relationship. However, due to the excessive inclusiveness of safety culture terms, efforts to improve the actual violation problem are not clearly revealed in the countermeasures. Measures for violations derived by over-expanding representation (or over-expanding and generalization errors) can be hindered in tracking whether effective learning has been achieved from the problem of violations actually revealed.

Third, there is an urgent need for practical safety measures to address the burden of violations for workers.

The employee performs his/her duties on the basis of the role defined by the operator by the contractual relationship with the nuclear operator. However, the current law requires the state to hold the individual responsible for so many job violations and stipulates punishment. This is excessive beyond the principles of the contracting party, as it goes beyond the job requirements required by the operator or at least through the operator. Legal demands for job requirements that are not within the scope of social and ordinary obligations beyond the obligations of nuclear operators and the way of punishment for violations are feared to have a negative ripple effect. This is because it could worsen into a more difficult type of human error in the 21st century, such as avoidance, neglect, responsibility disputes, and arbitrary interpretation. In addition, the irresponsibility structure could worsen by simply dismissing these issues as a comprehensive safety culture.

Fourth, among human errors, a new approach to violations is urgently needed. The post-improvement-oriented approach based on individual factors, which has developed from a human error 2.0 perspective, was an important point of view to achieve many innovative high reliability systems as well as nuclear power systems. However, it seems that effective measures for the future cannot be accessed only from the perspective of human error 2.0 that specifies and improves specific factors. The key measures selected for re-analysis include dozens of back-fitting and require resource inputs ranging from tens of billions to 1 trillion won, as tracking and verification of their effectiveness is virtually impossible. The concept of human error 3,0 should be considered as a way to overcome component-based approaches, and the complementary introduction of Safety-II and Resilience perspectives centered on the ability to maintain safety beyond fault/failure-driven limits.

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