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Improvement of Corrective Action Program (CAP) in Decommissioning Plant

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ABSTRACT

In a previous research [1], a proposal was made to change the importance of maintenance by rationalization of facilities in decommissioning plants. Here, we analyze CAP management data before and after the transition to decommissioning, then verify the validity of the previous paper confirming the impact of facility rationalization on facility performance by utilizing the Reactor Oversight Process (ROP) perspective and other factors. Another aspect of CAP management is the impact on human performance, and we verify the human error (HE) model setting and prediction in the initial phase of decommissioning by analyzing HE caused by environmental changes during decommissioning.

Based on the results obtained from these verifications, we propose an effective conservation approach after the transition to decommissioning.

KEYWORDS

Decommissioning, Corrective Action Program, Reactor Oversight Process (ROP), Condition-Based Maintenance (CBM), Human Performance

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1. Introduction

Corrective action program (CAP) is an important management tool that contributes to quality assurance of nuclear power plants and is legally required for quality assurance activities stipulated in the safety regulations based on the "Regulations Concerning Standards of Systems Required for Quality Control of Operations for Safety of Nuclear Facilities" introduced in 2020. Together with the inspection via the reactor oversight process (ROP), it is considered an effective system for operators to improve their own performance autonomously. The operator defines the individual importance levels of findings that include all problems or potential events less than defect in the CAP management and by classifying the importance levels of management, the appropriate level of response to them, progress management, and other measures are taken based on the unitary defined standards.

In a plant that has been transferred to decommissioning, the required functions of the equipment have been changed compared with those of the operating plant, and many of the facilities that have been multiplexed or reduce to rationalize the equipment. It is useful to tabulate and analyze the events that occur in such changes in facilities and the environment and findings that affect quality, and to examine defects found in CAP management, which enhances rationality and safety in decommissioning plants. CAP management in Japan has been in operation for only a few years [2], and the effects of trend analysis and utilization of the results have not yet become evident. In addition, few studies have been focused on CAP management of decommissioning and it can improve the effectiveness of prevention through effective utilization of CAP management.

2. Purpose

Here, we analyze CAP management data by the following two perspectives to verify assumptions inferred from previous studies and the HE models.

(1) Equipment aspect: Verify the validity of rationalization of equipment and change of

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importance in decommissioning plants as discussed in a previous paper [1].

(2) Human aspect: To set up and verify an estimation model for the occurrence of HE in the initial phase of decommissioning by analyzing human errors (HE) due to environmental changes that occur during the transition to decommissioning.
The estimated model for the occurrence of HE in the initial phase of decommissioning is a model that demonstrates an increasing trend of HE, which assumes that the changes in organization and facilities due to the transition to decommissioning and the accompanying changes in the environment and operational management will cause frequent initial troubles due to misidentification, operational errors, and other factors.

The above two perspectives have been proposed in a previous paper as one of the measures to classify the causes of nonconformity classification that occur in nuclear power plants [3].

We utilize the results of this study to identify the optimum maintenance method that can reduce the degradation trend of equipment and the characteristics of HE in the initial phase of decommissioning.

3. Scope

CAP management at nuclear power plants is systematically managed through a process of reporting, screening (importance), analysis, implementation, and monitoring of all findings including all problems or potential events less than defect that occur at the power plant. This is intended to improve safety by reporting them without omission from all perspectives in the plant, classifying the severity in the screening process to understand the state of the power plant, and analyzing the data from various perspectives such as severity, target equipment, and HE.

Here, the analysis of CAP management data will focus on manifested defects. As Illustrated in Figure. 1, nonconformance events are considered to be important cases because they are part of many predictive signs that have become apparent. Therefore, the data is considered the most accurate data for identifying the latest trends in the management of equipment and personnel at power plants, because the details of the event and the equipment involved are accurately understood, and measures to prevent recurrence are also mentioned.

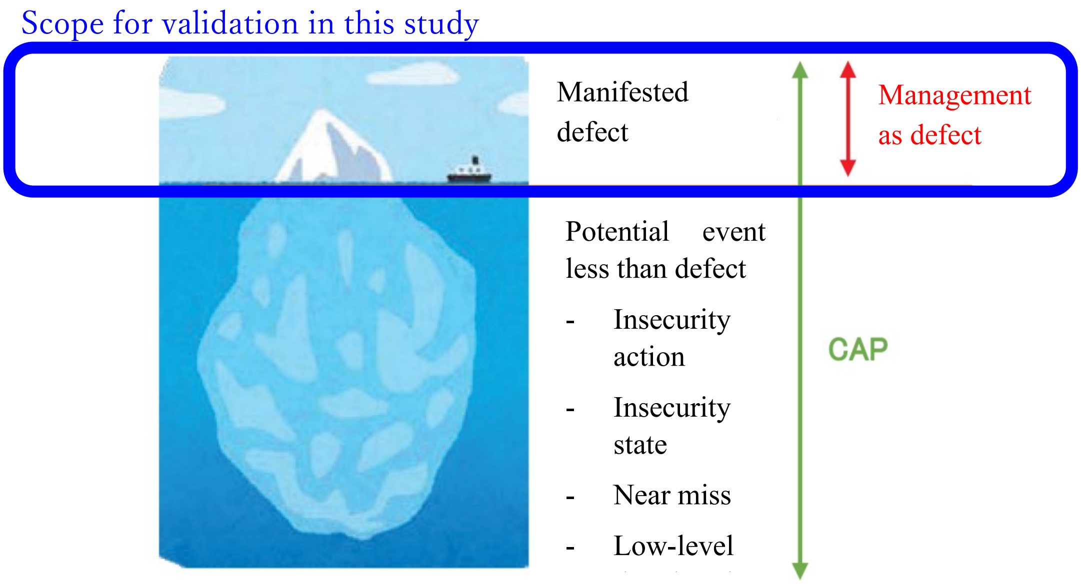

Fig.1 Relationship between CAP and the scope of this study

4. CAP analysis methods

4.1. Perspectives of Reactor Oversight Process

The CAP data analysis of facilities in this study is conducted while utilizing the perspective of ROP. This statutory inspection that incorporates an evaluation of the performance of nuclear operators in their safety activities. This legal inspection method is implemented at nuclear power plants in the US, and has been legislated and introduced in Japan since 2020. Performance here refers to the status of security activities related to the ROP's monitoring area and actions taken to further improve safety. In the U.S. CAP, the Nuclear Energy Institute (NEI) has established a document NEI 16-07 [4], which defines the judgment and importance of the Condition Adverse to Quality (CAQ) according to the presence or absence of performance deficiencies and the degree of influence on the monitored area from the ROP perspective. By analyzing CAP data from this perspective, we believe that we can conduct an analysis from a viewpoint equivalent to the nuclear safety perspective required by regulations and the U.S. standards, and thus meet the basic safety level requirements. However, because no monitoring area specifies a specific ROP implementation method or function/facility in a decommissioning plant [5], events in the ROP monitoring area that are related to facilities with equipment attributes that correspond to the current facility status of the decommissioning plant will be the subject of analysis.

As a reference, the following is the track record of safety improvement through the introduction of ROPs and CAPs in the United States.

In the US, the utilization of risk information has been promoted since around 1990, and regulatory inspections have been conducted as performance-oriented ROPs. In line with this, US operators promoted the utilization of risk-informed decision-making, RIDM. And they introduced CAP management to link performance improvement to safety improvement.

As demonstrated in Figure 2[3], these performance improvement measures contributed significantly to the improvement of plant equipment utilization and the reduction of core damage frequency (CDF). This is considered to be one of the cases where the quality improvement measures by CAP management and ROPs are numerically expressed in terms of safety improvement.

Previous study on CAP management in Japan [6] have also proposed a method that can reasonably reduce CDF through effective CAP management.

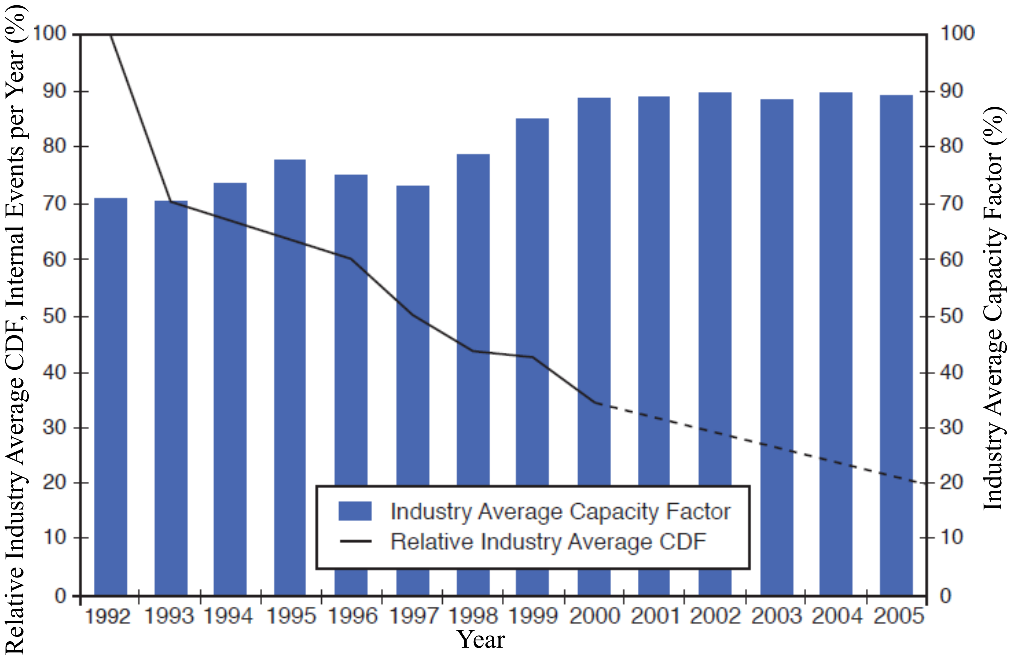

Fig.2 Facility Utilization and Core Damage Frequency (CDF) of U.S. Nuclear Power Plants [7]

4.2. Analysis of CAP data

We collected CAP data from multiple BWR plants of the same type in Japan and analyzed trends based on average values. For comparison with operating plants, CAP data were collected and analyzed from multiple plants under long-term shutdown whose facility operation conditions are similar to those of decommissioning plants, and adopted as comparative data. In Japan, PWR and BWR types of reactors are mainly operated. However, the relationship between equipment nonconformity and maintenance management is independent of plant type, Hence the BWR CAP data analysis results are considered representative of the results that occur in both types of reactors.

In addition, CAP data of HE before and after the transition to decommissioning in decommissioning plants were collected to analyze human aspects, and HE cases before and after the transition to decommissioning were analyzed utilizing the HE analysis tool TWIN [3]. It was developed by INPO and DOE, and TWIN is utilized mainly as a quantitative method to assess HE and evaluate the system's reliability and safety, employs observed data to detect human errors, and evaluates errors utilizing predefined risk assessment criteria. Hence, TWIN is employed to evaluate errors utilizing more quantitative methods than other HE analysis tools. Specific analysis is conducted in Chapter 5.

5. Results

5.1 Results of CAP analysis of equipment aspects

For the CAP data of decommissioning plants, Figure 3 illustrates the changes in the average number of defects for six years from four years before to two years after the transition to decommissioning for several plants that have recently been decommissioning. In addition, for comparison with operating plants, Figure 4 indicates the average number of defects for six years, the same period as Figure 3, in the CAP data of several long-term outage plants.

This comparison confirms the equivalence of CAP management, because the data are averaged over the same year for multiple plants in the decommissioning transition plant and the long-term outage plant, and the CAP management method, etc., is managed based on the same method.

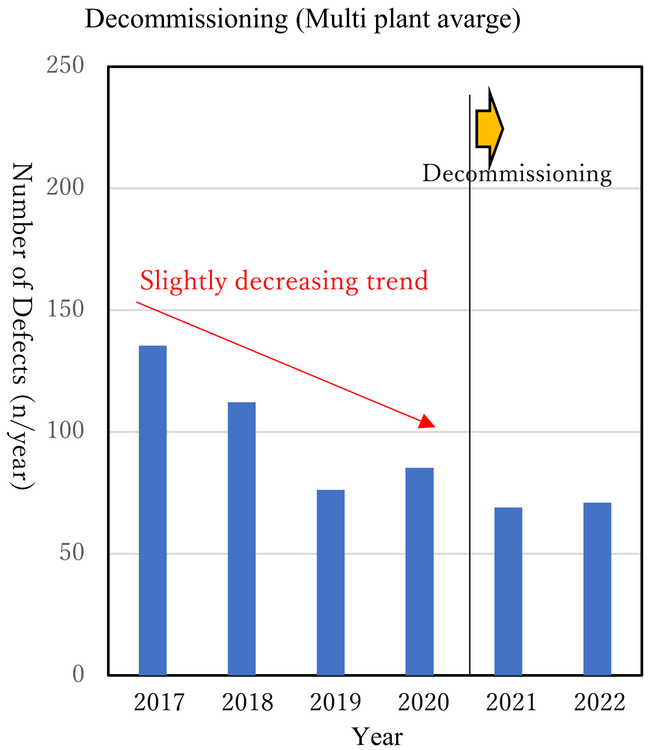

Fig.3 Number of defects near decommissioning

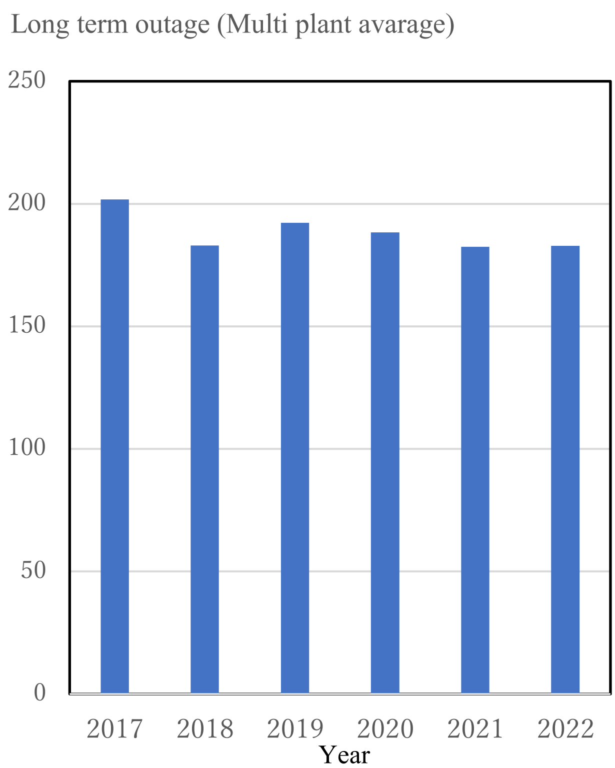

Fig.4 Number of defects of long term outage plants

Figure 3 demonstrates that the number of defects has been slightly decreasing since before the transition to decommissioning. This is assumed to be due to the rationalization of maintenance as a preparatory step for decreasing the amount of equipment to be maintained and managed following the transition to decommissioning. After the transition to decommissioning, the number of occurrences has remained constant at approximately 60% of that of four years ago. For BWR plants, the number of systems to be maintained is approximately 200 for operating plants and approximately 110 for decommissioning plants, indicating that the number of defects is decreasing in proportion to the number of devices to be maintained.

Figure 4 demonstrates that the number of defects in operating plants (long term shutdown) is higher than that in plants that have been decommissioning, but the number of defects remains constant.

Figures 3 and 4 demonstrate that the number of defects varies with the number of maintenance facilities and the amount of construction work being performed in the plant.

Next, as a breakdown of the number of defects in decommissioning plants, Figure 5 indicates the number of facility-related defects among the average number of defects for multiple decommissioning plants in Figure 3. The number of facility-related defects refers to the number of defects that occur at facilities, excluding defects in desk work, document work, and manual violations in operations from the total number of defects. In addition, Figure 6 indicates the percentages of the four facilities that fall within the ROP monitoring area: fuel pool cooling facilities (SFP cooling facilities), waste treatment facilities (RW facilities), Boundary & Ventilation facilities, and fire protection facilities.

The facilities for the four ROP monitoring areas presented here were selected based on their important functions in the ROP monitoring areas in decommissioning plants. This concept is presented in a previous research paper [1], in which representative facilities with functions related to or affecting "confinement" and "radiation safety," which are necessary functions for decommissioning, were selected among the ROP monitoring items.

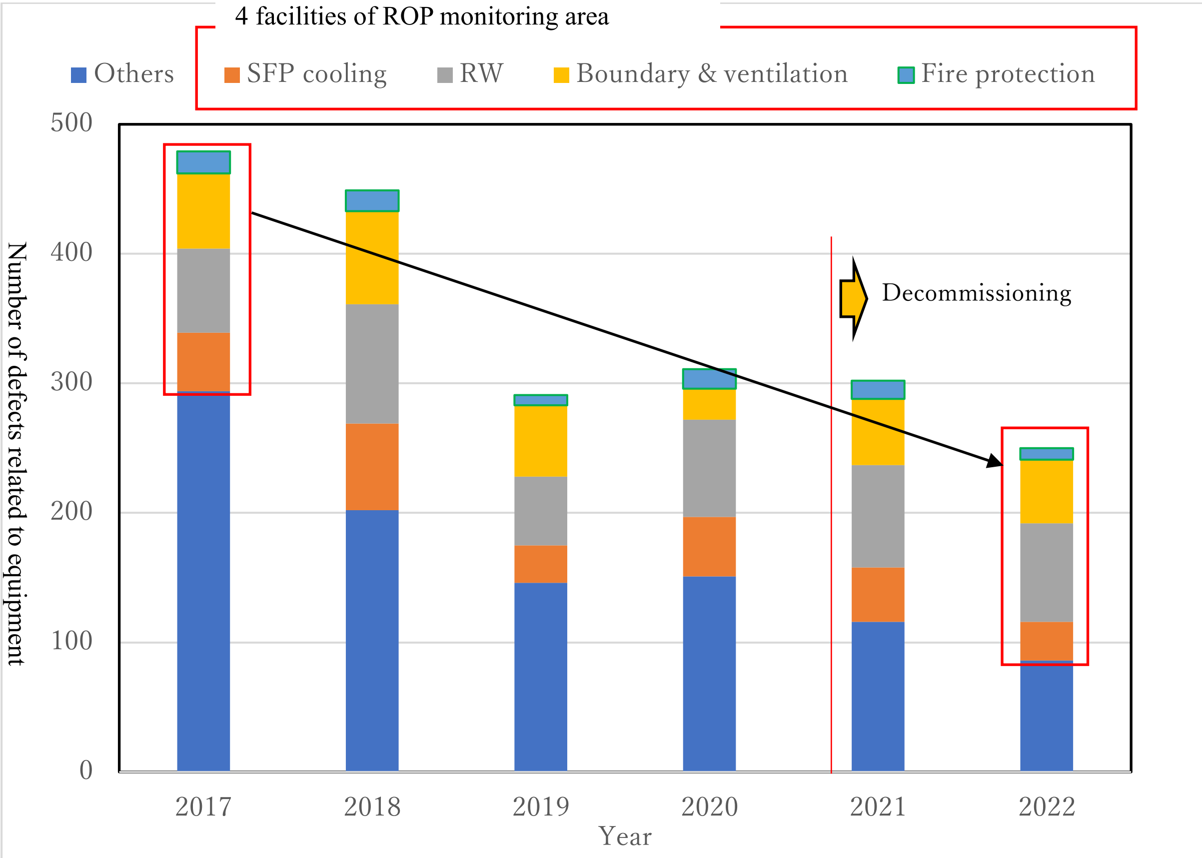

Fig.5 Number of total equipment defects and ROP related defects in and before decommissioning

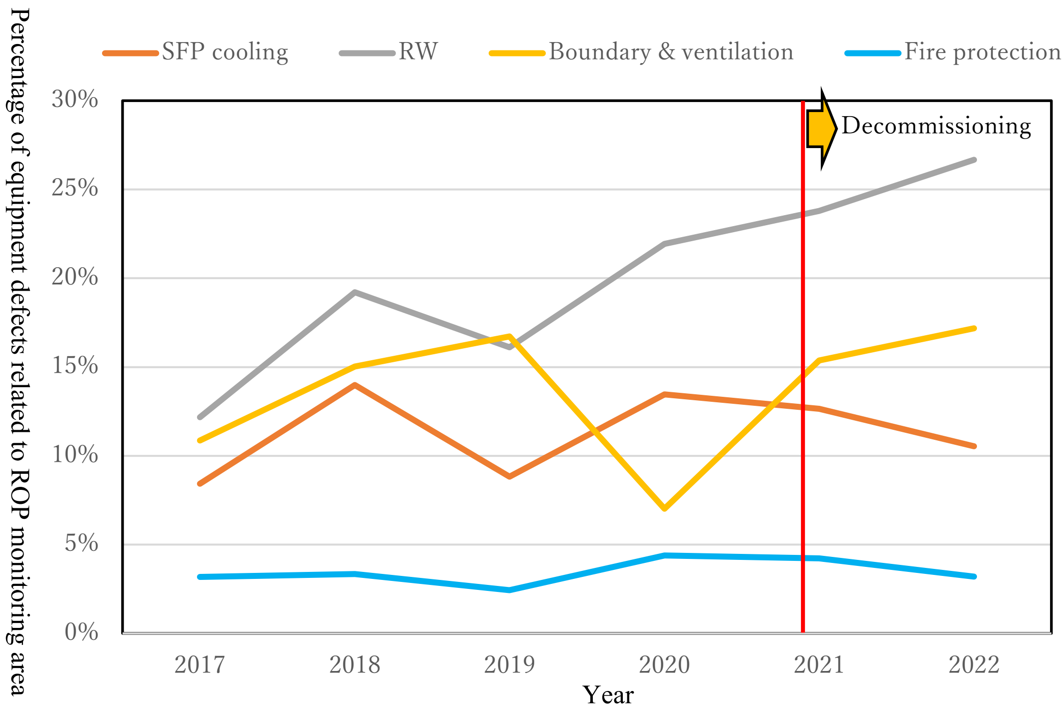

Fig.6 Percentage of defects of ROP related equipment in and before decommissioning

Figures 5 indicate that the total number of equipment defects has decreased from approximately 480 to 260, roughly in same proportion to the decrease in the number of all facilities in operation from 200 to 110 in decommissioning, which is consistent with the observation inferred from Figures 3 and 4 that "the total number of defects fluctuates with the number of facilities. In addition, most of the equipment defects were minor malfunctions (e.g., small leaks, instrument drift, etc.), and are reported as minor defects through CAP management, but even these minor events can be prevented by reviewing the maintenance methods for the aging deterioration conditions of the equipment. As an example of one of the causes of these minor malfunctions, many decommissioning plants have changed their maintenance methods from time-based maintenance (TBM) to condition monitoring maintenance (CBM) or after-the-fact maintenance (BDM) for rationalization, and lack of consideration for the inspectability of equipment and the degradation characteristics of aged equipment is considered a cause of these minor malfunctions. This is thought to be due to a lack of consideration for the inspectability of equipment and the degradation characteristics of aging equipment. This situation is also confirmed in the following discussion by the system.

Next, as a breakdown of equipment defects, the line graphs in Figure 5 and 6 indicate the equipment of the four systems that are important from the viewpoint of the ROP monitoring area. Figure 5 demonstrates that while the number of facility defects is decreasing, the number of defects for the four systems in the ROP monitoring area does not demonstrate a significant downward trend. This can be attributed to the fact that the number of maintenance facilities has decreased from about 200 in operating plants to about 110 on average in decommissioning plants, while the 4 facilities of ROP monitoring area shown in the line chart in Figure 5 and 6 continue to operate as same as maintenance facilities in operating plants.

In addition, of the number of facilities in these four systems, the SFP cooling system and the air conditioning and boundary facilities have been partially reduced through rationalization of their operation. The SFP cooling system is adopted to remove the heat generated by the spent fuel at all times. It is a regular facility with high maintenance importance and an emergency backup facility in the decommissioning plant. Figures 5 and 6 demonstrate that the number of defects in the SFP cooling system has slightly decreased since the transition to decommissioning, which is presumably due to the effect of this focused maintenance approach. The number of defects for air conditioning and boundary facilities exceeded that of SFP cooling facilities after the transition to decommissioning, and the number of defects tends to increase slightly at the transition timing. This can be considered to be the effect of the decrease in the number of facilities managed for air conditioning and the fact that the conventional

CBM maintenance method was not changed at the time of the decommissioning transition, and this can be considered to be the offset of defects due to the progression of deterioration over the operation period, which may indicate the possibility of equipment deterioration progress.

The number of defects of RW in Figure 5 demonstrates no significant increase or decrease. However, the percentage of defects of RW in Figure 6 began to increase significantly before the transition to decommissioning. In light of the situation where the number of defects has not been reduced, it is considered important to select a maintenance method that reduces the number of defects due to equipment deterioration and to control the increase in the number of defects.

Although the number of facilities to be maintained and maintenance methods for fire protection equipment have not been changed because of decommissioning, the maintenance methods are determined by the Fire Service Law, and it is believed that defects can be controlled by ensuring that these methods match the equipment specifications, frequency of use, and other conditions.

The defects of important equipment utilized frequently indicates that the maintenance does not conform with the actual condition of equipment utilized in the decommissioning plant, which is reflected in the equipment deterioration. Because many facilities in decommissioning plants have been in operation for a longer time than those in operating plants, the relationship between facility degradation and maintenance is more pronounced, i.e., the sensitivity of maintenance to degradation is considered high.

5.2 Results of CAP Analysis of Human Aspects

Among the CAP data for decommissioning plants, Figure 7 demonstrates the evolution of the average number of HE defects for five years that occurred from three years before to two years after the transition to decommissioning for several plants that have recently been decommissioning.

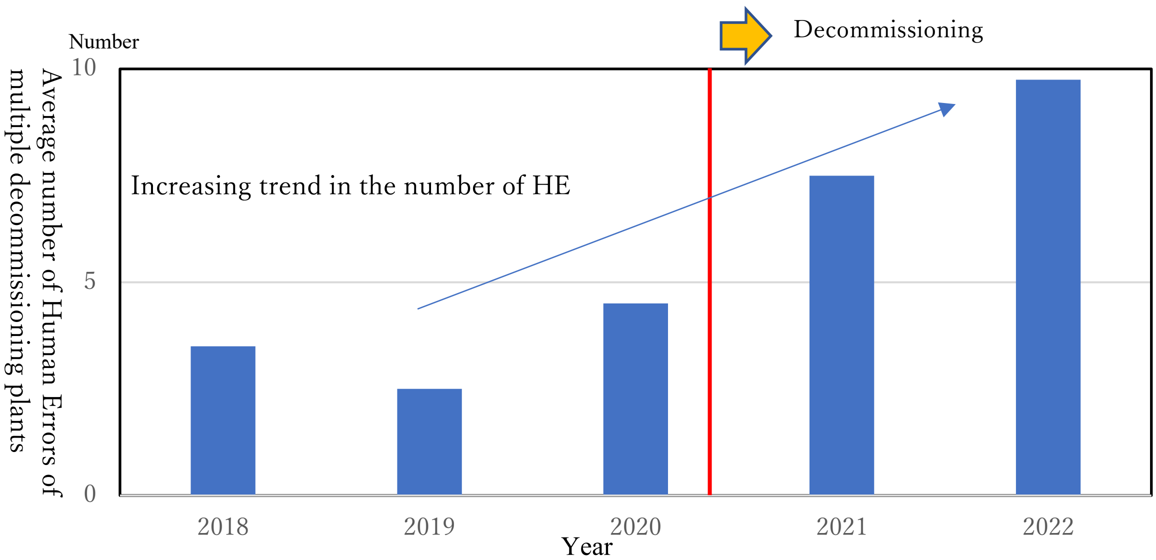

Fig.7 Number of HE in and before decommissioning

According to IAEA TECDOC-538 [8] and TECDOC-1957 [9], environmental changes, organizational environment, and education are the main factors during the transition from construction to operation, and the transition to decommissioning is a time when major environmental changes occur as in the start of operation. Therefore, as a hypothesis for the increase in HE, it can be inferred that the main factors for the increase in HE are changes in the management status of facilities, organization, and work content (the "environment" element in the HE analysis model) due to the transition to decommissioning. In this chapter, we examine the hypothesis of the transition stage of decommissioning, understand the characteristics of CAP management in the initial phase of transition to decommissioning, verify the validity of the aforementioned hypothesis in decommissioning plants, and improve HE management.

Figure 8 indicates the factor classification table as a tool for TWIN analysis [3].

Task Demands : T	Individual Capabilities : I
1. Time Pressure (in a hurry)	1. Unfamiliarity with task / First time
2. High workload (large memory)	2. Lack of knowledge (faulty mental model)
3. Simultaneous, multiple actions	3. New techniques not used before
4. Repetitive actions / Monotony	4. Imprecise communication habits
5. Irreversible actions$^{\alpha}$	5. Lack of proficiency / Inexperience
6. Interpretation requirements	6. Indistinct problem-solving skills
7. Unclear goals, roles, or responsibilities	7. Unsafe attitudes
8. Lack of or unclear standards	8. Illness or fatigue; general poor health or injury

Work Environment : W	Human Nature : N
1. Distractions / Interruptions	1. Stress
2. Changes / Departure from routine	2. Habit patterns
3. Confusing displays or controls	3. Assumptions
4. Work-arounds / OOS$^{\beta}$ instrumentation	4. Complacency / Overconfidence
5. Hidden system / equipment response	5. Mind-set (intentions)
6. Unexpected equipment conditions	6. Inaccurate risk perception
7. Lack of alternative indication	7. Mental shortcuts or biases
8. Personality conflict	8. Limited short-term memory

Fig. 8 TWIN analysis factor table [3].

The results of classifying HEs according to the classification presented in Figure 8 are presented in Figure 9. Because multiple factors can be considered for one HE, multiple items in Figure 8 are counted for one HE and illustrated in Figure 9. In addition, the items related to the aforementioned changes in the management status of facilities, organization, and work content (the "environment" element of the HE analysis model) are indicated by red frames in Figure 8.

The results in Figure 9 indicate that the hypothesis that "changes in the management status of the facility, organization or work content are the main factors" was not a major factor in the initial cross-section of the decommissioning process. In contrast, the factor that accounted for the largest number of cases was T8 "Lack of standards, unclear standards," which occurred in more than 30 cases. The "T-task demands" category was also notably dominated by T1 "Time pressure" and T7 "Unclear goals and roles. The "T-task demands" category reflects the organization's own attitude toward work, including basic work standards (manuals and procedures), organizational structure, and how standards are utilized in the field, regardless of changes in the environment. This is also reflected in the report of the OECD/NEA workshop on human factors, which similarly states that promoting communication within the organization and the use of past defects is a matter that should be utilized in HE prevention [10]. The "H3 Assumptions" on the Figure 8 and 9 is also notably common. However, it is considered a natural conclusion that personal ideas are one of the main characteristics of HE, and is not specifically added to the discussion to verify this hypothesis.

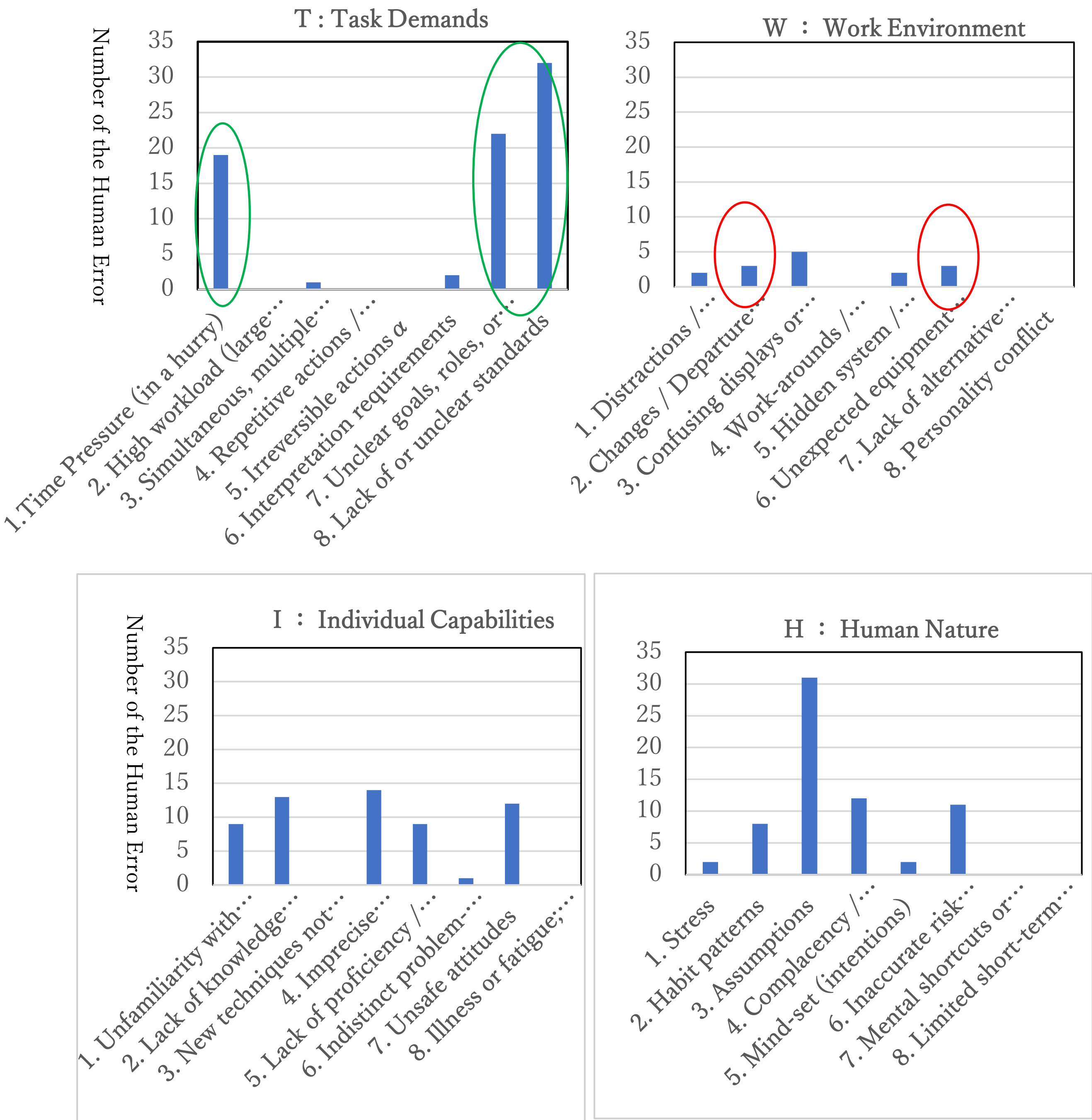

Fig. 9 Results of TWIN analysis

6. Discussion

From the results of the analysis of the equipment aspect, it was found that the number of equipment defects decreased in proportion to the decrease in the number of equipment required to maintain, even after changes to decommissioned plants. On the other hand, the number of defects in the four ROP monitoring areas required for decommissioning and the percentage of them have not decreased, and even some of them have increased. This fact indicates that it is important to select a maintenance method that is compatible with the characteristics and inspectability of the equipment when considering maintenance management methods in the case of major environmental changes such as decommissioning.

As for human incompatibility, no previous papers analyzed HE in the transition phase to decommissioning, but some papers analyzed HE in the design, construction, and operation and transition phases, and these were confirmed. According to the results, environmental changes [11], organizational environment [12], and education [10] are considered to be the main factors during the transition of each phase, while the contents and utilization of procedure manuals [8] are mentioned in the operation phase.

From the analysis conducted in this study, a new finding was that changes in facilities and operating organizations, and the associated changes in environment and operational management, were not major factors in HE nonconformity in the process of decommissioning transition. In the analysis results of this study, the main factors of many HE defects, even in situations where environmental changes such as facility conditions at the time of decommissioning transition occurred, were the organization's own attitude toward operations, including basic work standards (manuals and procedures), organizational structure, and on-site utilization of standards. This is considered a common cause of nonconformity throughout operating and decommissioning plants.

7. Conclusion

CAP data from an initial decommissioning plant were analyzed from the perspective of equipment as a validation of the equipment degradation model discussed in the previous study utilizing CAP. As a result, there was an increase in the percentage of defects for specific facilities in the ROP monitoring area while the number of total equipment defects was decreasing at the time of transition to decommissioning. This verification is in good agreement with the evaluation results of the model to review the importance of maintenance according to the facility management status of decommissioning, which was discussed in the previous study. Because results of the analysis demonstrated that the content of maintenance management was related to the occurrence status of equipment nonconformity, it is effective as a countermeasure to classify effective TBM and CBM at the same time as rationalization of equipment management for decommissioning. In addition, it is thought that this will contribute to further improvement of the maintenance of operating plants, such as selecting the optimal maintenance for each facility, for example, by separately classifying dynamic equipment and static equipment in the maintenance management classification for each system.

As a CAP data analysis from the human aspect, the model for estimating the occurrence of HE was validated. Hence, it was discovered that environmental changes due to the transition to decommissioning were not a major cause of HE in the initial decommissioning phase. Factors other than the initially estimated model were the main causes of nonconformity. The standard of normal operations (manuals, procedures), organizational structure, and other factors that contribute to HE nonconformity obtained from this analysis are considered to be factors related not only to decommissioning but also to basic matters in on-site and desktop operations (the organization's attitude toward operations). The measures to reduce these factors include basic matters such as the preparation of procedure manuals (preparation) focusing on the prevention of HE, reliable implementation, and clarification of roles to be checked, which are common to both operating and decommissioning plants; the cross-sectional measures for HE are detailed in the reference document [3].

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