MAINTENANCE MEASURES RELATED TO PLANT LIFE MANAGEMENT TAKEN BY JAPANESE PWRS

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Abstract

Among 55 commercial light water reactors operating in Japan, over 30 units will have passed their 30th year of operation within the coming decade. While the number of ageing reactors is rapidly increasing, nuclear organizations in Japan have pulled together to discuss the optimization of plant life management measures. Under such a situation, the Japanese electric utilities have established a plan for research and development of technologies in need while recognizing their primary responsibility in assuring safety of nuclear installations, and have agreed wilth the governmental and academic sides including Nuclear and Industrial Safety Agency (NISA), research institutes and academic societies on the basic R&D plan and individual commitments. To develop the concrete R&D programs, the electric utility industry (i.e., electric utilities and plant vendors) investigated ageing phenomena, such as irradiation embrittlement, SCC and fatigue to identify the ageing-related issues, which are expected to emerge until around 2030 when the oldest group of plants marks its 60th year of operation. Then the industry investigated the timing of the implementation of maintenance measures considering the establishment and applicability of the ageing prediction, inspection/monitoring and repair/preventive maintenance technologies. Trough the investigation of the essential factors contributing to the enhanced maintenance management activities including the enhancement/analysis of experiences, improvement/development of maintenance methods, enhancement of the regulatory system and development/assurance of human resources, the industry came up with a clarified policy for plant life management. It is planned to review the established R&D plan every year to improve its effectiveness.

1. Significance of developing the roadmap for ageing management considering the current situation of ageing nuclear power plants in Japan.

As shown in Fig. 1, 13 of 55 commercial light water reactors in operation will have passed its 30th year of operation as of the end of 2007. Nearly half of the Japanese reactors will have passed its 30th year of operation in the coming 5 years and 21 more reactors will mark its 30th year of operation in 10 years. Under such a circumstance, plant life management (PLM) for nuclear power plants has become an urgent issue to be addressed.
The Japanese utilities are required to implement plant life management technical evaluations assuming a 60-year operation period before 30 years of commercial operation are reached, and prepare a long-term maintenance plan for the coming 10 years by identifying the maintenance measures to be added to the current plan. As of the end of 2006, 12 reactors completed the report showing the result of their technical evaluation and submitted it to the government for review. The long-term maintenance plan developed by the utilities will be extended to the detailed inspection programs for which the results will be reported to the government together with the improvements to the long-term maintenance plan incorporating updated knowledge. In addition to observing the requirements specified by the laws and regulations, the electric utilities are required to make commitment to continuous improvement

of maintenance activities. This can be achieved by developing R&D programs in cooperation with related organizations in an efficient way. In this regard, it is essential to build a consensus among related organizations by identifying major R&D subjects and their milestones.

2. Efforts made by related organizations toward the development of a R&D roadmap

Before a law was established to require the utilities to submit the report of PLM technical evaluations, the electric utility industry had been engaged in voluntary PLM evaluations and measures from the viewpoint of assuring the safety and public interest. On the other hand, the governmental organizations led by Japan Nuclear Energy Safety Organization (JNES) and Japan Atomic Energy Agency (JAEA) and universities had promoted research activities regarding the enhancement of safety regulations by referring to information from the U.S. NRC and other regulatory authorities worldwide as well as from domestic and overseas utilities. However, a question if the past efforts have been optimized to assure the reliability of the entire plant in the mid and long-term has been raised.

To address this issue, Atomic Energy Society of Japan (AESJ) issued a report on "the roadmap for plant life management", which aimed at achieving the safety and reliability of ageing nuclear power plants, in March 2005 in order to provide an agreed policy on the future actions to be taken by the industry, government and academia as a whole. In developing the report, experts from the government, industry and academia worked together to investigate the 4 major subjects of the roadmap consisting of the development of technical information infrastructure, promotion of technology development, development of guidelines and codes and advancement of maintenance management. As a result, total 26 ageing-related issues and their milestones have been identified in these four areas.

To deepen understanding of the results obtained so far, the representatives from the government, industry and academia met together again and started discussion in 2007. As a result of discussion, it was determined that the achievements at AESJ in research activities would be reviewed based on the updated knowledge and the responsibilities of individual participants would be clearly defined with an aim at making contribution to the effective maintenance management of operating plants corresponding to the plant-specific ageing phenomena as well as the design and construction of the next-generation nuclear power plant.

3. Efforts made by the industry (electric utilities and plant vendors)

Electric utility：
Hokkaido/Tohoku/Tokyo/Hokuriku/Chubu/Kansai/Chugoku/Shikoku /Kyushu Electric Power Co., The Japan Atomic Power Co., Electric Power Development Co.

Plant vendor： Toshiba Corporation, HitachiGENE Co., Mitsubishi Heavy Industries

3.1. Role of industry

The Japanese electric utilities maintain the existing policy that they are positioned to continuously engage in voluntary activities for the assurance and improvement of plant safety, reliability and economic competitiveness while recognizing their primary responsibility in assuring the safety of nuclear installations. To achieve this role, the electric utility industry should focus on the technology development in the fields of degradation prediction, inspection/monitoring and repair/preventive maintenance aiming at the application of those technologies to operating plants and the information collection and trend investigation while the governmental organizations, such as NISA, JNES and JAEA have to establish and

develop the regulations and promote the national nuclear policies. In addition, the electric utility industry is required to clarify the needs, investigate, develop and review draft standards and provide data from operating plants through the cooperation with the governmental research activities and fundamental research activities on the clarification of ageing mechanisms performed by the research institutes and academic societies at home and abroad and the participation to the activities to develop the standards by academic societies including Japanese Society of Mechanical Engineers. It is expected that all the related organizations working in a close relationship can contribute to the effective PLM activities while recognizing their own responsibilities shown above.

3.2. Organizational system

Considering the necessity to present a consensus of the electric utility industry, "The PLM Research Promotion Council Board" consisting of the members from all the Japanese electric utilities and plant vendors was established inside Japan Nuclear Technology Institute (JANTI). In parallel with such an activity, a subordinate organization established in this year "PLM Research Administrative review meeting" and Sub-Groups, which have been formed for individual research subjects, are to identify the research subjects and establish the concrete research programs. Since these subordinate organizations are required to investigate the detailed technical issues, CRIEPI who is familiar with the past efforts made by the industry has been selected as a coordinator in this year. The organizational system is shown in Fig. 1.
It is planned that these organizations will review the results of investigation every year on a continuous basis.

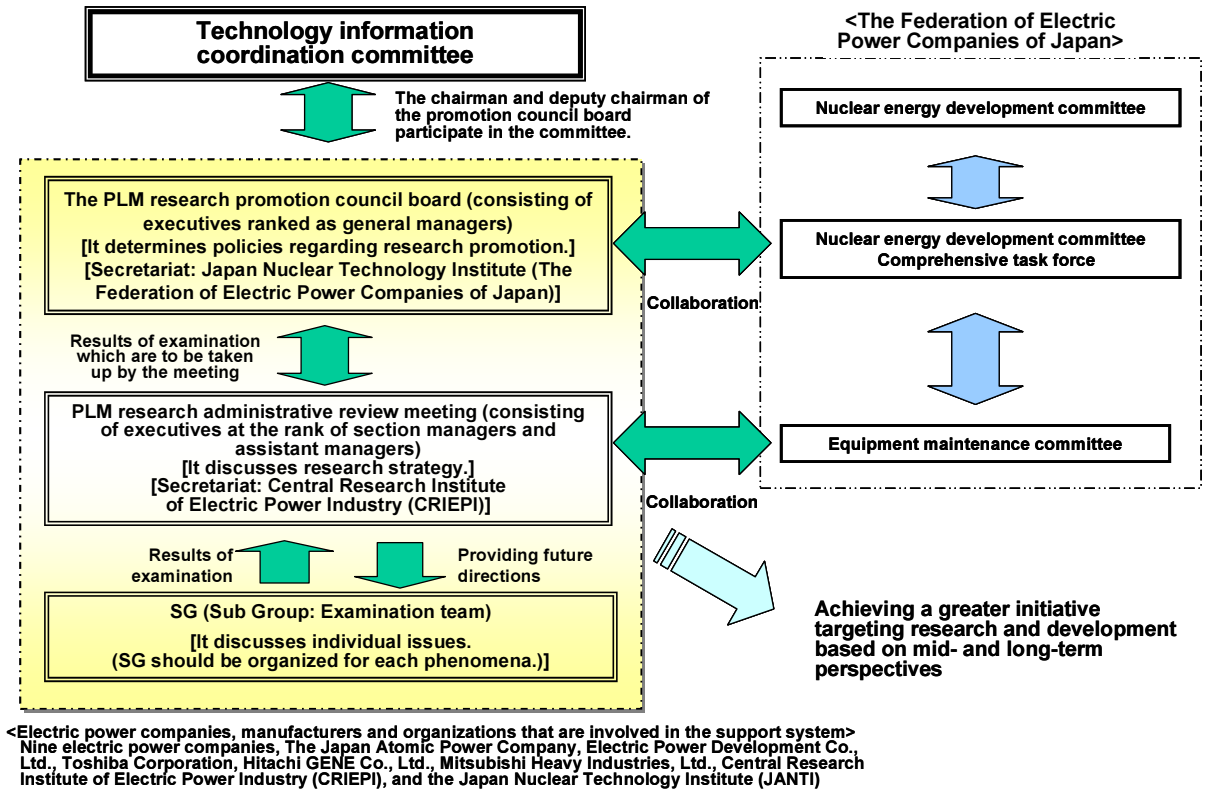

FIG.1 Framework of further PLM research in the industrial sector.

3.3. Investigation

In order to select the major research subjects required for PLM, it was determined to identify issues in a wider range from the viewpoint shown in (b)~(g) in addition to the conventional subject (a).

［Subjects for which technology development is needed according to individual ageing phenomena］

(a) Development of new technologies
Technologies required for ageing prediction, inspection/monitoring and repair/preventive maintenance, which have been conventionally applied to troubleshooting and preventing recurrence of trouble

(b) Application of newly developed technologies to operating plants
Issues involving the course of application of newly developed technologies to operating plants, including the establishment of evaluation techniques, verification tests, codifying process and endorsement by the government.

(c) Fundamental research
Clarification of ageing mechanisms focusing on the verification of long-term integrity and the development of next-generation reactors, understanding of proactive phenomena and development of alternative materials

［Subjects required for the enhancement of maintenance management］

(d) Construction of database
Construction of database required for PLM evaluation including equipment inspection records, knowledge and evaluation methods

(e) Improvement of management methods
Improvement of conventional management methods such as overhaul inspection conducted at constant intervals during plant shutdown by introducing the risk assessment, on-line monitoring and evaluation of defective ratio, and the application of those techniques to operating plants

(f) Improvement of regulatory system
Identification of problems with the current regulatory system and proposal for improvement

(g) Development and assurance of human resources
Handing over engineers' skills to the next generation, development of management ability at ageing plants, measures to assure human resources in the ageing society

Total 10 sub-groups have been established covering the subjects of SCC, irradiation embrittlement, seismic safety, concrete degradation, dielectric degradation, pipe wall thinning, inspection/monitoring technologies, preventive maintenance/repair technologies and enhancement of maintenance technologies to have separate investigation according to the policies shown above. The results of the discussion were investigated according to the written basic policy in selecting the issues to be resolved. Then, as shown in Fig. 2, a table showing the importance level, timing of implementation and developed technologies for a large number of issues selected by the experts was prepared. In addition, regarding the important issues, a worksheet describing future plans for concrete activities was developed.

It is planned that the investigation results will reflect in the budgetary plans for the next and subsequent fiscal years.

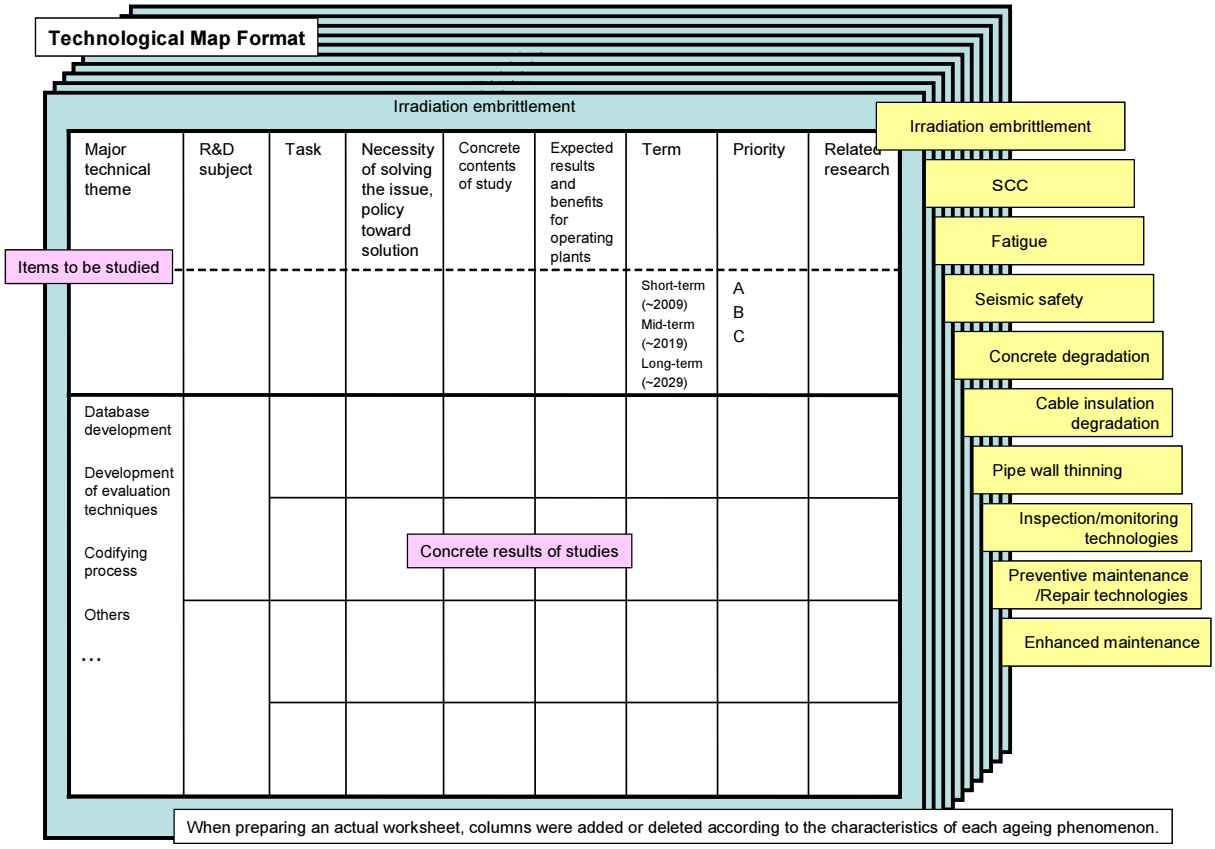

FIG.2 An Example of Technological Map Format.

3.4. Example of technology development

Irradiation embrittlement, PWSCC and enhancement of maintenance technologies are good examples to illustrate the current status of technology development.

3.4.1. Irradiation embrittlement

The establishment of a technique to predict fracture toughness has been conventionally recognized as a task to be achieved. The Japanese conventional equation to predict embrittlement, which has a low accuracy in highly irradiated areas for PWRs and for BWRs in applying it to older plants with a great deal of impurities, is being improved by incorporating the mechanism theory. However, further improvement in the prediction accuracy for the range of high irradiation is needed. To resolve the problems with the lack of surveillance test specimens, a technology to regenerate spent test pieces has been successfully established. One of the remaining issues is the development of a new surveillance method which can complement the existing surveillance test technologies. In addition, there are other remaining tasks. The other issues include the development of advanced techniques to evaluate the integrity of the sections, such as the weld heat affected zone and containment clad for which embitterment cannot be easily detected only by using surveillance test specimens, the development of advanced integrity evaluation methods (e.g., introduction of probabilistic fracture mechanics) and the establishment of repair techniques.

To address the above issues, the entire electric utility industry is mainly responsible for the process spanning from technology development to codifying. While the government is in charge of the verification of the standards and regulations and the fundamental studies including long-term tests, the academic world works on the fundamental research activities and human resources development. Accordingly, the clarification of irradiation mechanism depends on the close relationship among the government, industry and academia. The coordinated responsibilities among these three fields are common to all the studies about ageing phenomena.

3.4.2. PWSCC（SCC in Ni alloy）

The evaluation of SCC at Japanese PWRs is conducted according to the two different stages, that is, “initiation” and “growth” in the course of process from the start of plant service and the occurrence of leakage. Basically, the data about “initiation” are obtained from the constant load tests under the simulated primary coolant environment, and those for “growth” are from CT tests.

Regarding the “initiation” of SCC, the industry has been making an extensive effort to accumulate the data about Inconel 600 parts which have a high possibility of failure since some NPPs have experienced SCC in Inconel 600 steam generator tubes and reactor vessel head penetration nozzles. Considering that the correlation between the stresses in each part and the timing of SCC initiation has been fully understood and the preventive maintenance measures such as the peening are being applied to the concerned parts, the utilities have determined there is little urgency to perform more detailed evaluations. The industry recognizes that the future tasks should include the evaluation of long-term integrity of Inconel 690 parts which are used in the replaced reactor vessel head penetrations and the evaluation of water chemistry improvement measures such as the zinc addition and optimization of dissolved hydrogen concentration on the initiation of SCC.

The tasks regarding SCC “growth” include the implementation of tests in low K-value regions for which less data have been accumulated, the establishment of equations to predict the SCC growth, and the evaluation of K-value in the complicated configurations such as reactor vessel head penetrations. The electric utility industry will be mainly responsible for preparing the data for the purpose of codifying. At the same time, the government is expected to participate to the validation of the data since the result of evaluations may be incorporated into the regulations. In addition, the effect of water chemistry improvement needs to be closely investigated like the investigation about “initiation”.

It was determined that the government, industry and academia work together on the studies about the ageing mechanisms and the development of prediction models in order to clarify the root causes of ageing phenomena since it will take a long period of time to perform the theoretical investigation.

3.4.3. Improvement of maintenance management practices

In addition to the research subjects for which maintenance measures need to be established according to individual ageing phenomena, the issues and corrective actions to be taken to improve the maintenance management practices have been identified. Those issues and corrective actions were investigated from the viewpoint of enhancement/analysis of

experiences, improvement/development of management methods, improvement of regulatory system and development/assurance of human resources. The major issues for which the electric utility industry is required to tackle are shown below.

Regarding the enhancement/analysis of experiences, the electric utilities have already set about the activities aiming at the development of the system which all the utilities can commonly utilize by sharing the database consisting of the findings from the field maintenance records (Fig. 3).

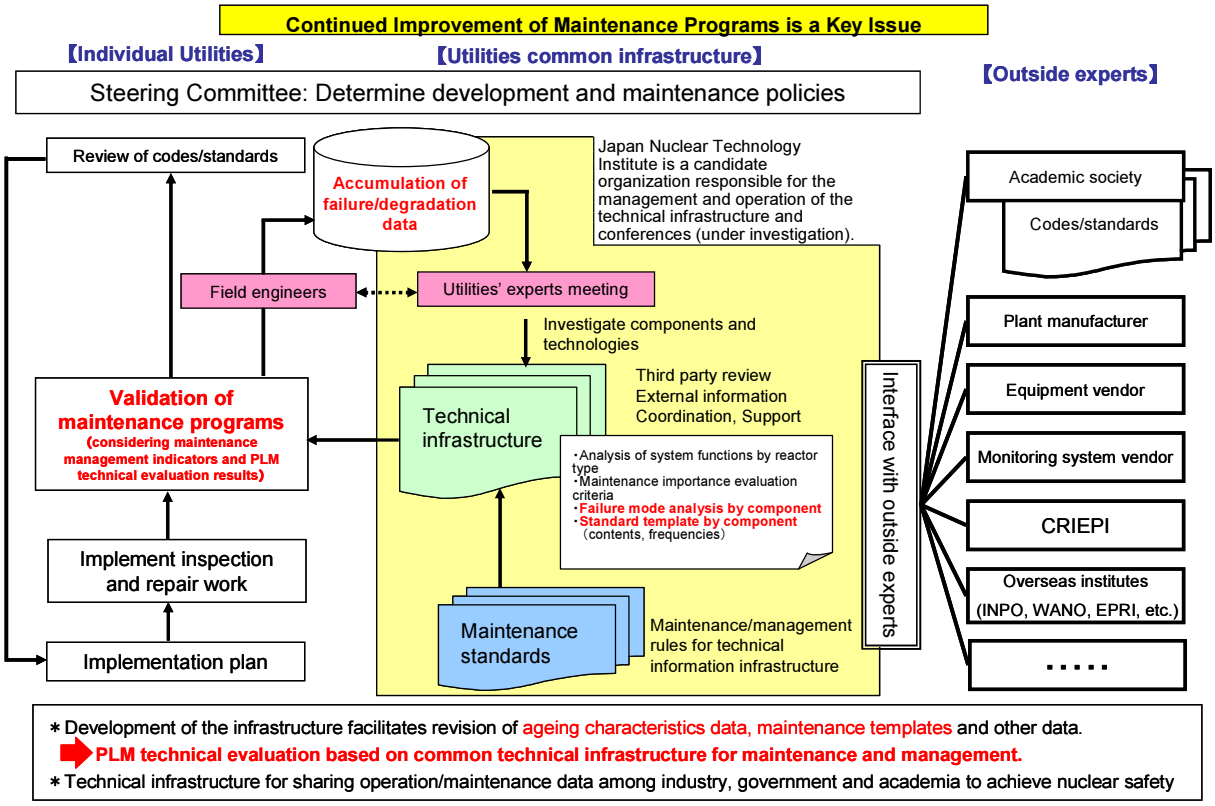

FIG.3. Development of Technical Information Infrastructure for AM including PLM[1]

For the purpose of the improvement and development of maintenance methods, the conventional and uniform inspection methods need to be reviewed based on the probabilistic approaches by introducing the risk-informed maintenance approach and the assessment of fracture probability. The introduction of on-line monitoring in addition to the conventional inspection conducted during plant shutdown also draws attention.

Considering the concern about the improvement of the regulatory system that the lack of the concrete scheme in which the regulatory authority endorses new maintenance approaches may discourage the development of new technologies, the industry identified the need for their positive participation to the construction of such a scheme.

For the development and assurance of human resources, the issues about handing over engineers' skills and improvement of the image toward nuclear energy have been identified.

4. Conclusion

In Japan, the nuclear organizations from the government, industry and academia have been working together to promote the PLM activities in an efficient and optimized way. As a part of such a cooperative effort, the electric utility industry has identified its basic policy, tasks and milestones as the organization which has the primary responsibility in assuring the safety of nuclear installations.

On the other hand, a realistic movement toward “nuclear renaissance” is growing worldwide such as the construction of new reactors from the concerns about greenhouse gas emissions and energy security. Therefore, the international nuclear-related organizations have to make utmost use of limited resources of facilities, personnel and knowledge as the Japanese nuclear industry does.

Accordingly, it is expected that building cooperative relationship and partnership with overseas organizations in charge of PLM activities in accordance with the established policy will become a major task in future. In this respect, we are planning to build a worldwide network targeting around 2010.

ACKNOWLEDGEMENTS

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