Abstract. The Japanese commercial reactors have accumulated more than 40 years operating experience since Tsuruga-1 started commercial operation in March 1970. However, the severe accident occurred at Fukushima nuclear power plants triggered by East Japan Great Earthquake on March 11 last year. The facts that all the reactors having experienced core meltdown had operated for more than 30 years and Fukushima Daiichi unit 1 had just received the approval for its 40th year Ageing Management Technical Evaluation results from the Japanese government caused increasing distrust among the public in nuclear power plants operating for a long period of time. However, investigations of the accident conducted so far have not revealed any evidence that ageing degradation accelerated the accident. In addition, the analysis of seismic accelerations of the earthquake did not show that any component function was lost due to the accident. Considering these facts, I would like to discuss the issues to be continuously pursued and to be additionally implemented as part of the plant life management activities. In addition, I will introduce the efforts made by the Japanese utilities following the accident.

1. Introduction

Since the occurrence of 3.11 accident, the atomic energy administration in Japan has still been in a chaos. There is no operating plant in Japan after the last unit, Hokaido Electric’s Tomari-e shut its operation for outage inspection on May 5. However, there is a spark of hope that the Japanese government has approved the restart of Ohi units 3 and 4 stating that it confirmed the safety of the units. We finally reached a stage of restarging Ohi-3 and 4 if approval from the local municipalities is obtained. However, there remains much to be done before restarting the first unit. Even worse, there is no prospect for obtaining an approval for an exceptional extension of reactor operational period beyond 40 years. With a significantly low energy self sufficiency ratio and transmission network not being connected to overseas countries, there is no way for Japan to survive without the use of nuclear energy. Despite this, the accident was so grave that it interferes normal discussion. Looking back on the past efforts made by the utilities regarding long-term operation and related regulatory changes, I would like to discuss the activities to be consistently pursued and to be newly added.

2. History of plant life management

First, let me look back on the history of plant maintenance activities performed by the Japanese utilities.

In the 1970’s, we Japanese utilities launched operation of nuclear power plants. In this early stage of nuclear power plant operation, we experienced many initial failures caused by defective design, improper manufacturing, and so on.

In the 1980’s, the major activities were transferred from the construction stage to operation and maintenance stage. During these stages, maintenance data were accumulated and reflected in the maintenance programs. Through these operation and maintenance experiences, we obtained the knowledge about aging phenomena. The main issue in this age was the appearance of SCC in the primary components such as S/Gs and pipes.

In the 1990’s, we started the aging evaluation for nuclear power plants systematically. The basic investigation methods were developed. And, based on this methods, the Japanese utilities started the evaluation of their plants beginning from the oldest plant. Based on these studies, large scale
Component replacements were carried out such as S/G replacement, Core shroud replacement, and so on.

**In the first decade of the 21st century**, new inspection rules were established based on the experiences of operation and maintenance, and the results of aging studies. The Japanese utilities are implementing newly developed maintenance programs to pursue better maintenance.

Along with the development of plant maintenance activities as I mentioned, PLM has evolved in Japan. After the government announced the basic concept of AM in 1996, the Japanese utilities have conducted AM technical evaluations applying the concept of AM to all plant components and released reports summarizing the evaluation results before the plant marks its 30th year of operation. The AM activities were started as the utility’s voluntary program, and then the regulatory authority required the utilities to implement AM activities and then to submit a report. The regulatory requirements were finally upgraded to the licensing process. So far, total 25 plants have submitted their AM technical evaluation reports and the government reviewed them. Among them, Mihama-1, Tsuruga-1 and Fukushima Daichi-1 have released the reports on the 40th year AM Technical Evaluation. In 2005, the system of regulatory documents was improved and in March 2007, Atomic Energy Society of Japan issued the Implementation Standards for PLM. The Standards include the Ageing Degradation Mechanism Summary Sheets which have been formulated based on the results of Ageing Management Technical Evaluations conducted for 14 nuclear power plants, and reviewed by the government. The Ageing Degradation Mechanism Summary Sheets are useful and effective not only for the Japanese NPPs but also for NPPs worldwide. It is noteworthy that the Summary Sheets have been revised on a regular basis to update information.

Meanwhile, PLM activities in Japan have been promoted based on the collaboration among the industry, government and academia in an autonomous, distributed and cooperative way, and have developed as the relevant regulations are enhanced. As a result, related codes and standards were issued and have been improved by the academic societies.

Technology Information Coordination Committee organized in JNES formulated and released the Strategy Maps for Ageing Management describing the basic policies on PLM activities, and specific activities and responsibilities of individual stakeholders. To provide information from the industry to help develop the strategy maps, PLM Research Administrative Review Meeting was formed in 2006. The review meeting, which consists of 10 sub-working groups to study individual issues and a general examination committee, is continuously working on the studies in an active manner.

To summarize the plant life management on the side of utilities, it represents the process from setting the plant operating period, to selecting the maintenance programs which can optimize the cost performance throughout the plant operating period, and implementing the maintenance programs. On the other hand, the concept of ageing management does not consider costs but pursues the safety. Ageing management involves the investigation and implementation of preventive maintenance measures based on the understanding about the mechanisms how component functions degrade as well as their limits. PLM takes into account the cost performance besides AM. Accordingly, an integrated replacement may be included as the maintenance option even for a component which has not experienced significant ageing degradation if the integrated replacement is determined to be most effective from the economic viewpoint. For example, when considering the timing of replacing multiple stages of turbine discs, it should be noted that the replacement of one disc may cause damage to other discs because they are shrink-fitted, and furthermore sending the turbine to a shop for disc replacement takes transportation fees. Accordingly, it may be determined that the integrated disc replacement would be the best option from the viewpoint of cost effectiveness. In making such a decision, a plant operating period needs to be assumed. We at Kansai have selected optimized maintenance activities assuming a 60-year operating period. However, the concept of PLM should consider risks as well as costs. In particular, there is an increasing concern about the risks resulting from the lack of human resources and insufficient transmission of technologies to younger generations, which may increase trouble. Taking examples of traditional architectural structures, Horyu-ji temple still exists owing to appropriate maintenance work although more than 1400 years
have passed since it was erected. At Ise Jingu, all the shrines are rebuilt every 20 years. One of the objectives of this event of transfer is considered to conserve particular architect technologies. If it applies to nuclear power plants, a plant can survive for a long period of time by taking appropriate maintenance actions on an assumption of an operating period. However, without any plan to build a new plant, technologies and skills related to nuclear power generation may fade away. In this regard, plant replacement has significance, and thus we started investigations about the replacement plant while announcing operating strategies for Mihama-1, which includes a plan to limit the plant operation up to 50 years. However, following the accident at Fukushima NPP, we have to face up to a great deal of hardships in stating our concept of plant replacement. The populism rampant in the current Japanese society interferes even the discussion about energy security.

3. The 40th year AM Technical Evaluation at Mihama-1

Tsuruga-1, Fukushima Daiichi-1 and KEPCO’s Mihama-1 submitted AM technical evaluation reports for review and the government approved the maintenance programs to be added in the coming 10 years for these units. Regarding Fukushima Daiichi-1, no damage caused by ageing degradation has been identified so far although the unit experienced core meltdown. We believe that this is the result of aging management evaluation conducted in a correct manner and maintenance activities taken in an appropriate manner. Today, I would like to introduce a part of our 40th year AM technical evaluation. After obtaining an approval for its long-term maintenance management strategies, Mihama-1 have operated since the 30th year AM technical evaluation while setting maintenance programs on an assumption of 60-year operating period and implementing the programs including the replacement of the reactor vessel head and core internals, such as baffle former bolts. The specific features of the 40th year technical evaluation include the assessment of 3 ageing degradation trends, which occurred during the decade after the 30th anniversary. Of the 3 ageing degradation trends, SCC in Alloy 600 material used in the reactor vessel is particularly specific to Mihama-1. The evaluation result demonstrates that appropriate maintenance activities can deny the general belief that age-related problems will increase as a plant ages.

The next finding related to irradiation induced embrittlement of the reactor vessel. Microstructural observations of the surveillance test specimens placed inside the Mihama-1 reactor vessel, which was fabricated by Combustion Engineering, showed that the modeling used in the equation to predict irradiation induced embrittlement, which was established using the data from Japanese steel materials, was applicable to the CE design reactor vessel.

The third ageing degradation is IASCC of core internals. The evaluation showed that the possibility of cracking in baffle former bolts could not be ruled out if the baffle plates were not replaced although all the BfBs at Mihama-1 were replaced with new ones. The result underscores the importance of improving the inspection. In other words, we can learn a lesson from this result that assuming that the replacement is the ultimate maintenance is dangerous, and it is essential to implement appropriate maintenance in view of the entire period of plant operation. (An authentic replacement plan may begin with a part replacement followed by a component replacement, system replacement as a whole and then plant replacement. A new plant will be subject to failures in the early stages. However, a new plant built on the new findings and extensive operating experience is expected to experience less initial failures and can maintain its reliability in a long term.)

Next, to show a prospective way to fully feedback operating experience in the past 40 years, I would like to suggest the concept of TMS. This is what I have come up with through my entire experience in the field of nuclear energy. I think that handing over experience and knowledge to the next generation is essential because nuclear power generation requires a long term approach. It is important to reflect the experience and research results in the development of next-generation reactors as well as in maintenance activities at existing plants. Through my long career in operating various types of reactors although they are all PWRs, I have recognized the importance of handing over knowledge and experience. I’m excited when I think that our experience may help develop and build next-generation reactors. In addition, I’m happy to see young people are increasingly interested in the field of ageing management. I believe that the TMS shown here plays an important role in attracting young
engineers. The TMS is a mechanism of information management in which the utilities and manufacturers can share the data and utilize them on time in a seamless manner by collecting data efficiently throughout the plant lifetime covering the design, manufacturing, construction, operation, maintenance and decommissioning phases by utilizing advanced information technologies.

4. Prospect for long-term operation after the accident at Fukushima NPP

(1) What is required to achieve long-term operation?

(a) Existing policies to be consistently pursued

Ageing management for Japanese NPPs is transferring from the early days to the mature period. It is essential to continuously perform ageing management technical evaluations taking into account new findings from seismic assessments considering ageing degradation and environmental fatigue assessment. To support this effort, Atomic Energy Society of Japan has established a system of collecting, analyzing and assessing new knowledge about ageing degradation, including the revision of ageing degradation mechanism summary sheets on a regular basis.

Some ageing degradation mechanisms remain unresolved although part of the mechanisms has been clarified. Therefore, it is necessary to continuously work on the study of unexplained ageing degradation mechanisms and enhance condition monitoring to understand those phenomena in a more precise manner.

People tend to believe that the ultimate maintenance is replacement. The “replacement” includes part replacement, component replacement, system replacement as a whole, and plant replacement eventually. As steam generators at PWR plants have been replaced, the replacement of the reactor vessel and even the entire system inside the containment vessel becomes a feasible option. I heard that an overseas plant is considering a plan to replace all the components and systems other than the containment vessel and base mat. Even a plant selecting an option of replacing the entire system has a lot of things to learn from accumulated knowledge and experience in the field of plant life management. It will lead to the fulfillment of the concept, called total management system, taking the total process from plant construction through decommissioning as a whole.

Incorporating living information in an appropriate manner is also essential. It is necessary to take proactive actions in advance based on the prediction of event initiation and development rather than taking corrective actions to address trouble. To achieve this, we have to continuously make an effort to obtain the state-of-the-art knowledge and expertise through research activities and make immediate and correct judgment if such knowledge should be incorporated into ageing management activities.

(b) Policies to be newly added

One of the factors which have led to the success of PLM activities is the collaboration among the industry, government and academia in an autonomous, distributed and cooperative manner. The collaborative relationship should be introduced to other fields than PLM. In addition, top priority should be given to setting an organization which will lead the activities to feedback the latest safety knowledge to operating plants. In this regard, the Japanese electric power companies have just declared that they will establish an organization like Japanese INPO while abolishing existing organizations including JANTI.

(2) Enhancement of regulations related to Ageing Management and Plant Life Management

After the government announced the basic concept of AM in 1996, the Japanese utilities set about AM technical evaluations for their oldest plants, including Mihama-1, Tsuruga-1 and Fukushima Daiichi-1, and they released AM technical evaluation reports incorporating opinions from experts in 1999. Since then, the utilities have prepared technical evaluation reports for their plants successively
before they marked the 30th year of operation while consistently improving the contents of the report. To date, total 26 plants (including 2 times each for Mihama-1, Tsuruga-1 and Fukushima Daiichi-1) have released their final AM technical evaluation reports. In the mean time, the regulatory authority has reinforced the AM regulations almost every 3 years. In the revised ministerial ordinance, which was issued in 2003 following the data falsification scandal in Tokyo Electric Power Company, the related ministerial ordinance was revised to require the utilities to formulate the AM technical report. The ministerial ordinance was revised again in 2006 taking into account the lessons learned from the Mihama-3 secondary tube rupture accident, which caused deaths and casualties. As a result, the systematic structure of Japanese regulatory documents became compatible to the international standards. Then, the Japanese government formally announced its targets of reducing CO₂ emissions by 25% and increasing the ratio of nuclear power generation in the energy portfolio to 50% by 2030. To achieve these targets, the Japanese utilities intended to introduce longer cycle lengths of reactor operation. In an effort to extend the operating cycle length from 13 months to 18 and then to 24 months, the utilities accepted the request from the local governments related to long-term operation regulation, and upgraded the requirement for submitting AM technical evaluation reports to the regulatory process. As such, although it was incidentally rather than intentionally, the regulations related to AM have been reinforced every 3 years, and accordingly AM technical evaluation reports were exposed to the environment requiring consistent improvement. The ageing degradation evaluations conducted as part of the PLM are backfitted by incorporating the latest knowledge, including the revised JSME design and construction codes, environmental fatigue analysis results and seismic assessment results.

On the other hand, regarding PSR, the utilities have been required only to implement PSR and the regulatory authority has verified the process of PSR alone rather than reviewing the details. The Japanese government issued a report on the accident at Tokyo Electric Fukushima Daiichi Nuclear Power Station last June. In the report, the lesson 24 regarding the establishment and reinforcement of legal structures, criteria and guidelines noted in the report states that “the Japanese government will review and improve the legal structures governing nuclear safety and nuclear emergency preparedness, along with related criteria and guidelines. During the process, it will reevaluate measures taken against age-related degradation of existing facilities, from the viewpoint of structural reliability as well as the necessity of responding to new knowledge including progress in system concepts. Also the Japanese Government will clarify technical requirements based on new laws and regulations or on new findings for facilities that have already been licensed, in other words, it will clarify the status of backfitting in the legal and regulatory framework”. This statement drew attention to the system safety.

(3) Aiming at improved system safety design

As I mentioned above, the recognition about the importance of incorporating new knowledge into the system safety design has been renewed. In this regard the electric power companies have just declared that they will establish a new independent organization which is in charge of analyzing new knowledge and findings and transmitting the result.

The new organization is expected to play following roles in regards to the relations with the utilities, regulatory bodies and overseas institutions:

For the Japanese utilities: It conducts various safety and technical studies in light of the world’s highest level of safety, and makes suggestions, directions, or recommendations. If the utility is reluctant to adopt these suggestions, it takes direct actions to the utility’s CEO, either toward the individual utility or through FEPCO Comprehensive Policy Study Committee; for the regulators, it exchanges technical information with the new regulatory authority to be established and JNES; with international organizations, it will establish the institutional and close relationship. The new organization is expected to exchange opinions with the regulators independently from the utilities.

In the past year, determined to prevent a recurrence of an extremely serious accident like the Fukushima Daiichi disaster, Kansai Electric has been taking comprehensive safety measures for
improved emergency preparedness in a prompt and intensive manner. Those safety measures are intended to enhance the redundancy and diversity of safety functions, such as power sources, core and SFP fuel cooling and flooding prevention functions. In particular, various preventive measures against earthquake, tsunami and SBO were taken and those measures have been improved after the stress test report was submitted to the government. Furthermore, Kansai Electric has drawn up an implementation plan for the measures to improve the safety and reliability of Ohi units 3 and 4 in response to the safety judgment criteria for restarting nuclear power plants, which were newly established by the government. In the plan, the President of Kansai Electric declared that “I will take the initiative to ensure that Kansai Electric continuously enhances nuclear safety as its most important policy, spends the necessary management resources, and achieves the worlds’ highest level of safety.”

5. Conclusion

In conclusion, I would like to renew my resolution that we will continuously work on the collection and analysis of new knowledge about the mechanisms of ageing phenomena, integrity assessment results, and maintenance technologies, including inspection, repair and replacement, which can help improve maintenance activities. In addition, as our President declared, we at Kansai, will make a consistent effort to enhance the system safety of our plants to achieve the world’s highest level of safety with strong determination. I believe our voluntary activities will help maintain the plant safety, paving the way for long-term operation. The contributing factors to SCC can be categorized into three areas: aggressive environment, susceptible material and tensile stress. Mitigation can be accomplished by removing or reducing any one of the three areas.

REFERENCES