PLANT LIFETIME MANAGEMENT AND RESEARCH PROGRAM

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1. INTRODUCTION

The importance of nuclear power generation has been increasing in Japan. Because the lower generation cost and more stable fuel supply, in comparison with the case of fossil fuel plants, are beneficial to Japan which has scarce natural resources. In addition, nuclear power generation is expected to help reduce carbon dioxide emission which causes global warming. In these circumstances, the safe and stable operations of nuclear power plants are of prime importance, and the frequency of unscheduled shutdown has been kept low in Japan as a result of thorough periodic inspections supported by aging management.

This paper covers the development process of the aging management program and related research programs in The Kansai Electric Power Co., Inc. (KEPCO). KEPCO runs 11 nuclear power units (PWR). Table 1 shows the commencement date of commercial operation and operating hours for each unit. The early plants, such as Mihama #2 Unit, have been operated for more than 100,000 hours and are in the phase of aging management.

Accordingly, we have been conducting aging management programs since 1987, in order to identify age-related degradation and work out countermeasures.

<table>
<thead>
<tr>
<th>Name of Plant</th>
<th>Date of Commercial Operation</th>
<th>Operating Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIHAMA #1</td>
<td>November 28, 1970</td>
<td>89,000</td>
</tr>
<tr>
<td>MIHAMA #2</td>
<td>July 25, 1972</td>
<td>105,000</td>
</tr>
<tr>
<td>MIHAMA #3</td>
<td>December 1, 1974</td>
<td>101,000</td>
</tr>
<tr>
<td>TAKAHAMA #1</td>
<td>November 14, 1974</td>
<td>94,000</td>
</tr>
<tr>
<td>TAKAHAMA #2</td>
<td>November 14, 1975</td>
<td>90,000</td>
</tr>
<tr>
<td>TAKAHAMA #3</td>
<td>January 17, 1985</td>
<td>56,000</td>
</tr>
<tr>
<td>TAKAHAMA #4</td>
<td>June 5, 1985</td>
<td>54,000</td>
</tr>
<tr>
<td>OHI #1</td>
<td>March 27, 1979</td>
<td>66,000</td>
</tr>
<tr>
<td>OHI #2</td>
<td>December 5, 1979</td>
<td>83,000</td>
</tr>
<tr>
<td>OHI #3</td>
<td>December 18, 1991</td>
<td>7,000</td>
</tr>
<tr>
<td>OHI #4</td>
<td>February 2, 1993</td>
<td>-</td>
</tr>
</tbody>
</table>

2. AGING MANAGEMENT PROGRAM

2.1 Outline of Aging Management Program

The purpose of our aging management programs is to identify age-related
degradation, evaluate component life and put the results into maintenance plan. To achieve this purpose, the program comprises the following four tasks:

1. Selection of important components
2. Identification of important degradation modes
3. Life assessment
4. Countermeasures in maintenance

Fig. 1 shows the process chart of the aging management program.

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2.2 Selection of Components

A nuclear power plant consists of approximately 2,300 kinds of components. From these, important components were selected as shown below.

2.2.1 Screening Criteria for Important Components

The following three criteria were applied to all the components.

1. Components whose failure would impact on plant safety, cause
Immediate shutdown or cause the limitation of power supply.

(2) Components whose failure would cause a long period for repair or replacement.

(3) Components whose failure would cause much radiation exposure for repair or replacement.

(1) criterion was applied to all the components for the first priority. Then (2) and (3) criteria were applied to the remaining ones for the second priority.

2.2.2 Grouping

Selected components were classified into similar groups, and representative ones were selected from each group. The following classification conditions were taken into account.

(1) Types (pumps, valves, pipes, high-pressure vessels etc.)

(2) Materials (carbon steel, stainless steel etc.)

(3) Operating conditions (water chemical, temperature, pressure, etc.)

Fig. 2 is the example of the important components selected as a high pressure vessel or tank. In this group, the reactor vessel and pressurizer were selected as representatives in view of high temperature and high pressure.

<table>
<thead>
<tr>
<th>Type</th>
<th>Component or Structure</th>
<th>Material</th>
<th>Environment</th>
<th>Irradiation</th>
<th>Water Chemistry</th>
<th>Temp [°C]</th>
<th>Pressure [Kg/cm²]</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Pressure Vessel or Tank</td>
<td>Reactor Vessel</td>
<td>Low Alloy Steel with stainless overlay</td>
<td>YES Primary Water</td>
<td>343</td>
<td>157</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pressurizer</td>
<td>Same as Reactor Vessel</td>
<td>NO Same as R/V</td>
<td>360</td>
<td>157</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Accumulator</td>
<td>Same as Reactor Vessel</td>
<td>NO Same as R/V</td>
<td>150</td>
<td>50</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Boron Injection Tank</td>
<td>Same as Reactor Vessel</td>
<td>NO Same as R/V</td>
<td>150</td>
<td>2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig. 2 Example of Selected Important Component

2.3 Identification of Important Degradation Mode

For the representative components selected as shown in 2.2, important degradation modes were identified as follows.

2.3.1 Breakdown to the Level of Parts

Selected components were broken down to the level of parts by means of reliability block diagrams. Fig. 3 shows the example of the reliability block diagram of a reactor vessel.
Fig. 3 Example of Reliability Block Diagram of Reactor Vessel

2.3.2 Identification of Important Degradation Modes
For each part, all possible degradation modes were extracted based on all available information such as design documents, malfunction records and research papers. Then, important degradation modes were selected in view of the effect on plant operation, the probability of degradation occurrence and the difficulty in maintenance. The part of important degradation modes of the Reactor Vessel is shown in Fig. 4.

<table>
<thead>
<tr>
<th>Part</th>
<th>Function</th>
<th>Degradation Mode</th>
<th>Importance Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Closure Head</td>
<td>Pressure Proof</td>
<td>Fatigue</td>
<td>A B A 0</td>
</tr>
<tr>
<td>Head Penetration</td>
<td></td>
<td>Corrosion</td>
<td>C A A 0</td>
</tr>
<tr>
<td>Lower Shell</td>
<td></td>
<td>PWSCC</td>
<td>A A A 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Embrittlement</td>
<td>A A A 1</td>
</tr>
</tbody>
</table>

*1: Effect on plant operation  
*2: Probability of occurrence  
*3: Difficulty in maintenance 

Fig. 4 Example of Identification of Important Degradation Modes
2.4 Life Assessment
Component life was assessed as to each degradation mode identified in 2.3. Typical life assessment methods which have been applied are inspection data trend analysis, statistical data analysis, analysis such as stress analysis, fatigue analysis, fracture mechanical analysis and so on. The following examples are some of them.

2.4.1 Example of inspection data trend
In degradation modes whose mechanism are clear and whose progresses depend on time, degradation data trend analysis was conducted. Fig. 5 is an example of inspection data trend analysis, concerning the erosion of the piping of the secondary system in PWR.

![Diagram of Life Assessment](image)

Fig. 5 Example of Life Assessment (Piping Erosion)

2.4.2 Example of Analysis
The life of a low pressure turbine rotor was assessed by the combination of experimental data, actual inspection data and fracture mechanical analysis as shown in Fig. 6. It is the example of stress corrosion crack growth.

![Diagram of Life Assessment](image)

Fig. 6 Example of Life Assessment (Turbine Rotor)
3. Research and Development

As shown above, important degradation modes were checked if they had the life assessment methods. Unless any of them had the life assessment methods, the proper research and development programs were planned and carried out. The follow research and development are a portion of KEPCO's program which have been carried out.

- Radiation embrittlement of reactor vessel
- Fatigue of stainless steel
- Development of fatigue monitoring system
- IG A of S/G
- SCC of turbine rotor
- SCC of closure head penetration of R/V
- Repair equipment of closure head penetration of R/V
- Thermal embrittlement of dual phase stainless steel

4. CONCLUSION

The aging management programs have ensured safe and stable operation of nuclear power plants.

Each result of the lifetime assessment has provided us with the information which helps establish maintenance programs. For example, the result of the lifetime assessment has been reflected to the intervals of overhauling and inspections, and the replacement timing of some components.

As the future plan, we should review our activities of aging management which have been carried out, and should focus lifetime assessment on components which give us difficulties in inspections because of high radiation exposure or high inspection cost.

[REFERENCE]