

# CURRENT STATUS AND PROSPECT FOR PERIODIC SAFETY REVIEW OF AGING NUCLEAR POWER PLANTS IN KOREA

TAE EUN JIN\*, HEUI YOUNG ROH, TAE RYONG KIM<sup>1</sup> and YOUNG SHEOP PARK<sup>2</sup>

Korea Power Engineering Company, Ltd, 257 Yongudaero, Giheung-gu, Yongin-si, Gyeonggi-do, 446-713, Korea

<sup>1</sup>Korea Electric Power Research Institute, 103-16 Munji-Dong, Yuseong-Gu, Daejeon, 305-380, Korea

<sup>2</sup>Korea Hydro & Nuclear Power Co., Ltd, 508 Keumbyeong-ro, Yuseong-gu, Daejeon, 305-242, Korea

\*Corresponding author. E-mail : jinte@kopec.co.kr

*Invited February 11, 2009*

*Received April 1, 2009*

---

Korean utility has utilized a Periodic Safety Review (PSR) that assesses the cumulative effects of plant aging, modifications, operating experience, technical developments, and site characteristics since 2000. In particular, the assessment and management of plant aging is one of the major areas in PSR. It includes identification of critical Systems, Structures, and Components (SSCs) for aging, assessment of aging effects, and implementation of aging management programs. Since the PSR system was introduced based on the atomic energy acts and related laws, PSRs of eight sets for 12 Nuclear Power Plants (NPPs) that have been operating more than 10 years have been completed. PSRs of two sets for 4 NPPs are currently being carried out. The utility has confirmed that domestic NPPs have been operated safely through these PSRs and have implemented the follow-up corrective activities to increase the nuclear safety. In this paper, the status of PSR implementation is discussed and improvement programs to conduct PSR follow-up corrective activities efficiently for NPPs are suggested based on experiences with aging assessments.

---

**KEYWORDS** : Periodic Safety Review (PSR), Aging Evaluation, Aging Management Program (AMP)

## 1. INTRODUCTION

Since Kori Units 1&2 commenced commercial operations in 1978, Korea following the United States, France, Japan, and Russia is currently operating the fifth largest number of NPPs in the world [1,2]. As the number of aged NPPs increase, public concerns have focused on the nuclear safety of operating NPPs. In this regard, comprehensive and systematic nuclear safety assessments, termed Periodic Safety Review in addition to existing nuclear safety inspections has been proposed as an effective means of verifying that the operating NPPs maintain a high level of nuclear safety. The PSR takes into account the cumulative effects of plant aging, the operating experience, and the evolution of science and technology. In particular, the assessment and management of aging plants is a major area. In January of 2001, the Ministry of Education, Science and Technology (MEST), the nuclear regulatory body in Korea, established an institutional scheme through revision of the atomic energy act and related laws to introduce the PSR system in IAEA Nuclear Safety Guide 50-SG-O12 [3]. Accordingly, the utility has conducted PSRs on NPPs that have been operating for more than 10 years starting in May of 2000. The utility has confirmed that domestic NPPs are operating

safely through the PSRs of eight sets for 12 NPPs, and has implemented the follow-up measures to promote nuclear safety. This paper describes the status of PSR implementation and suggests on improvement program to conduct the existing PSR structure of NPPs efficiently based on experience with aging assessments.

## 2. IMPLEMENTATION STRUCTURES OF PSR

Atomic Energy Act, 23-3 requires a utility to evaluate nuclear safety periodically and to submit assessment reports to the Minister of Education, Science and Technology. The detailed objective and scope of the PSR is described in the Enforcement Decree of the Act (a Presidential decree) and in the Enforcement Regulation (Ordinance of MEST) of the Act. The objective of the periodic nuclear safety review is to review comprehensively whether the plant is safe as judged by current nuclear safety standards and practices and whether adequate arrangements are in place to maintain plant nuclear safety until the next PSR. There are 11 nuclear safety factors in the scope of the PSR including all nuclear safety aspects of a nuclear power plant as follows:

- (1) The Actual Physical Condition of the Plant
- (2) Nuclear Safety Analysis

- (3) Equipment Qualification
- (4) Management of Aging
- (5) Nuclear Safety Performance
- (6) Use of Operational Experiences & Research Findings
- (7) Procedures
- (8) Organization and Administration
- (9) Human Factors
- (10) Emergency Planning
- (11) Impact on the Environment

Korean utility voluntarily conducts PSRs in accordance with the objective and scope as described in the Enforcement Decree and Enforcement Regulation of the Atomic Energy Act.

### 3. IMPLEMENTATION STATUS OF THE PSR

Korean utility has conducted Periodic Safety Reviews on all NPPs that have been operated for more than 10 years according to related regulations. The PSR implementation schedule is shown in Table 1. Thus far, PSRs for eight sets of 12 NPPs have been completed and PSRs for two sets of 4 NPPs have been evaluated. The PSRs for Kori Unit 1, Wolsong Unit 1, and Kori Unit 2 were supervised by the

Korea Electric Power Research Institute (KEPRI). PSRs for other NPPs have been supervised by the Nuclear Engineering and Technology Institute (NETEC). KOPEC has continuously played a major role in assessing the current physical condition and evaluation of the aging of plants.

### 4. AGING ASSESSMENT

The management strategy for aging in a PSR is similar to that pertaining to the life extension; indeed, there are many similarities in the methodology of aging management between the PSR and the license renewal process in the United States. Accordingly, experiences related to the license renewal process of NPPs and other experiences with processes that originated overseas are reflected in the domestic review process. In the PSR, aging management programs and feedback mechanisms consist of all relevant activities, such as surveillance, maintenance, chemistry control, and feedback related to the operating experience. These programs ensure that the required nuclear safety margins of SSCs important to nuclear safety are maintained throughout plant service life [4-7]. Aging management programs includes managerial and technical aspects.

**Table 1.** PSR Implementation Schedule for Domestic NPPs

| Plants      | Operation Permission<br>Date                        | Accomplishment Schedule              |     |     |     |     |     |     |     |     |     | Remarks  |
|-------------|---|--------------------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|----------|
|             |   | '00                                  | '01 | '02 | '03 | '04 | '05 | '06 | '07 | '08 | '09 |          |
| Kori-1      | June 19, 1977*<br>(Operation : May 31, 1972)        | <div><div>5</div><div>11</div></div> |     |     |     |     |     |     |     |     |     | Complete |
| Wolsong-1   | November 21, 1982*<br>(Operation : February 15, 19' | <div><div>5</div><div>6</div></div>  |     |     |     |     |     |     |     |     |     | Complete |
| Kori-2      | August 10, 1983                                     | <div><div>4</div><div>12</div></div> |     |     |     |     |     |     |     |     |     | Complete |
| Kori-3      | September 29, 1984                                  | <div><div>7</div><div>6</div></div>  |     |     |     |     |     |     |     |     |     | Complete |
| Kori-4      | August 7, 1985                                      |                                      |     |     |     |     |     |     |     |     |     |          |
| Yonggwang-1 | December 23, 1985                                   | <div><div>7</div><div>6</div></div>  |     |     |     |     |     |     |     |     |     | Complete |
| Yonggwang-2 | September 12, 1986                                  |                                      |     |     |     |     |     |     |     |     |     |          |
| Yonggwang-3 | September 9, 1994                                   | <div><div>5</div><div>3</div></div>  |     |     |     |     |     |     |     |     |     | Complete |
| Yonggwang-4 | June 2, 1995  |                                      |     |     |     |     |     |     |     |     |     |          |
| Ulchin-1    | December 23, 1987                                   | <div><div>1</div><div>12</div></div> |     |     |     |     |     |     |     |     |     | Complete |
| Ulchin-2    | December 29, 1988                                   |                                      |     |     |     |     |     |     |     |     |     |          |
| Wolsong-2   | November 2, 1996                                    | <div><div>8</div><div>5</div></div>  |     |     |     |     |     |     |     |     |     | Complete |
| Ulchin-3    | November 8, 1997                                    | <div><div>5</div><div>5</div></div>  |     |     |     |     |     |     |     |     |     | -        |
| Ulchin-4    | October 29, 1998                                    |                                      |     |     |     |     |     |     |     |     |     |          |
| Wolsong-3   | December 30, 1997                                   | <div><div>8</div><div>5</div></div>  |     |     |     |     |     |     |     |     |     | -        |
| Wolsong-4   | February 8, 1999                                    |                                      |     |     |     |     |     |     |     |     |     |          |

\* : the First Criticality

**Managerial Aspects**

- (1) Program Policy
- (2) Procedures
- (3) Performance Indicators
- (4) Staffing, Resources
- (5) Record Keeping

**Technical Aspects:**

- (1) Aging Management Methodology
- (2) Extent of Understanding of Relevant Aging Phenomenon
- (3) SSC-Specific Acceptance Criteria
- (4) Aging Detection and Mitigation Methods
- (5) Actual Physical Condition of SSCs.

On the other hand, the regulatory body requires the additional information on the results of their review process. The amount of this additionally required information related to the regulatory review process of a plant-specific PSR is summarized in Table 2.

With the successful implementation of the PSR, the nuclear safety of the NPPs is confirmed and estimated to be enhanced through successive nuclear safety enhancement activities. The major results are refurbishment of aged components, additional aging assessments, and the establishment or supplementation of aging management plans for SSCs.

Typical aging evaluation results in the PSR of each plant are given below:

**Kori Unit 1**

In the first Kori Unit 1 PSR during 2000~2003, the main concern focused on the aging effects due to: a) radiation embrittlement of the reactor pressure vessel, b) Stress Corrosion Cracking (SCC) of alloy 600 components and component support bolts, c) thermal embrittlement of cast austenite stainless steel components, and d) wall thinning of heat exchangers. A number of other factors

were also considered. Additionally, projects such as the improvement of boric acid corrosion program and the application of a fatigue monitoring system were recommended. A majority of the recommended aging issues and enhancement programs were completed.

**Wolsong Unit 1**

The major issue of Wolsong Unit 1 involved management of aging effects due to: a) elongation, diametral expansion, sagging, and creep of pressure tubes, b) wall thinning of feeder pipes, as well as other expected issues. Wolsong unit 1 is planning to refurbish several aged components. These include the pressure tubes, calandria tubes, and feeders during the course of a general overhaul. Additionally, wall-thinning management programs for the primary and secondary system piping including the carbon steel components have been applied, and a procedural change of the heat exchangers is in progress.

**Kori Unit 2**

The Kori Unit 2 results showed that a fatigue monitoring program and aging management programs for the SCC of alloy 600 components and programs pertaining to the component support bolts, wall thinning of heat exchangers, and boric acid corrosion were necessary for nuclear safety enhancement. Currently, a project for the development of the fatigue monitoring system is in progress. Other nuclear safety enhancement items have been promoted as follow-up measures according to the implementation schedule.

**Kori Units 3 & 4**

The main aging issue of Kori Units 3&4 was related to several factors. Among them, there are : a) establishment of supplemental aging management plans for electrical passive components and nuclear safety-related structures including the containment building, b) improvement of the component examination and performance management procedures, c) strengthening the visual inspection of reactor

**Table 2.** Status of PSR Aging Assessment

| Plants        | Supervisor | Aging Assessment Organization | Number of Questions |     |     |       | Remarks       |
|---------------|------------|-------------------------------|---------------------|-----|-----|-------|---------------|
|               |            |                               | 1st                 | 2nd | 3rd | Total |               |
| Kori-1*       | KEPRI      | KEPRI/KOPEC                   | 176                 | 130 | -   | 306   | Completed     |
| Wolsong-1     | KEPRI      | KEPRI/KOPEC                   | 222                 | 105 | -   | 327   | Completed     |
| Kori-2        | KEPRI      | KEPRI/KOPEC                   | 157                 | 73  | -   | 230   | Completed     |
| Kori-3,4      | NETEC      | NETEC/KOPEC                   | 153                 | 72  | -   | 225   | Completed     |
| Yonggwang-1,2 | NETEC      | NETEC/KOPEC                   | 191                 | 94  | 27  | 312   | Completed     |
| Yonggwang-3,4 | NETEC      | NETEC/KOPEC                   | 214                 | 96  | 24  | 334   | Completed     |
| Ulchin-1,2    | NETEC      | NETEC/KOPEC                   | 275                 | 130 | 16  | 421   | Completed     |
| Wolsong-2     | NETEC      | NETEC/KOPEC                   | 245                 | 96  | 21  | 362   | Review        |
| Ulchin-3,4    | NETEC      | NETEC/KOPEC                   | -                   | -   | -   | -     | Not Completed |
| Wolsong-3,4   | NETEC      | NETEC/KOPEC                   | -                   | -   | -   | -     | Not Completed |

\* : Continued Operation

internals, and d) performance management of heat exchangers. All of these aging issues have been promoted as follow-up measures according to the implementation schedule.

#### Yonggwang Units 1&2

Aging issues in Yonggwang Units 1 & 2 were related to the following: a) condition monitoring and preventive maintenance improvements, b) performance management of heat exchangers, c) management of pipe wall thinning, d) chemistry control of the secondary system, and e) establishment of aging management plan for structures, containment building, and electrical circuit cards. Currently, the items pertaining to the management and procedure implementation for piping wall thinning and chemistry controls of the secondary system have been completed. Other items have been promoted as follow-up measures according to the implementation schedule.

#### Yonggwang Units 3 & 4

The main aging issues were related to condition monitoring and preventive maintenance improvement, performance management of heat exchangers, and assessments of nuclear safety-related structures including the containment building. All aging issues have been promoted as follow-up measures according to the implementation schedule.

#### Ulchin Units 1&2

Aging issues for Ulchin Units 1&2 were related to management of the aging effects of a) concrete structures, b) HVAC ducts, c) electric structural supports and cables, d) performance of heat exchangers, e) SCC for high-strength (more than 150ksi) anchor bolts, and f) the wall thinning of carbon steel components. Currently, aging issues for concrete structures, HVAC ducts, and high-strength anchor bolts are in the planning stage to fulfill the follow-up measures. Other aging issues are scheduled to be implemented.

All of the recommendation and additional nuclear safety enhancement activities that arise during a plant-specific PSR are systematically reported and are managed based on the PSR results. Each NPP scheduled to complete these aging issues by the next PSR in accordance with the plant-specific implementation plan. Common aging issues are formulated with proper measures to be applied to all nuclear power plants.

## 5. SUGGESTIONS FOR PSR IMPROVEMENT PROGRAMS

The designed lifespan of the operating NPPs apart from the Kori Unit 1 and CANDU-type reactors is 40 years. Therefore, all NPPs should perform two to three PSRs during their lifespan. According to previous experiences with PSR aging evaluations, there were no major aging issues in the first PSR of NPPs that had operated for a length of time up to 10 years, unlike NPPs that had operated

for more than 10 years. Therefore, the current PSR structure can be improved based on the PSR implementation experiences. This is summarized below:

- (1) The first PSR after the first 10 years of operation showed no significant aging issues. The first PSR can be implemented in a quick review based on the construction records and first 10 years of operating experience. Plant-specific aging issues can be considered based on the "use of operating experiences and researched findings."
- (2) The second PSR after 20 years of operation is recommended to conduct the PSR according to the standing rules, including the classification of systems, structures, and components.
- (3) The third PSR after 30 years of operation of NPPs with a 40-year design life includes the supplements submitted as follow-up measures in the nuclear safety promotion items of the second PSR.
- (4) The third or fourth PSR at the end of the design life (30 years or 40 years) includes conduction of an enhanced PSR according to the standing rules pertaining to continued operation.
- (5) NPPs that were built with the same design criteria could have PSRs conducted as integrated evaluations.

## 6. CONCLUSIONS

Korean utility has carried out PSRs that assess the cumulative effects of plant aging and plant modifications. These processes include: a) the operating experiences, b) the technical developments, and c) the site characteristics. Aging evaluation and aging management planning are among the major areas carried out in the PSRs. These assessments include identification of SSCs for aging management, assessments of aging effects and preparation of aging management programs. Based on the PSR experiences with ten sets of 16 NPPs, it can be concluded that domestic NPPs are safely operated, as they have had the recommended corrective actions implemented properly for nuclear safety enhancement.

## REFERENCES

- [ 1 ] The Republic of Korea, National Report for the Convention on Nuclear Safety, September 2007
- [ 2 ] MEST, White Paper on Nuclear Safety, 2008
- [ 3 ] IAEA Nuclear safety Series No. 50-SG-O12, Periodic Nuclear safety Review of Operational NPPs, 1994
- [ 4 ] IAEA, "Implementation and Review of a NPP Aging Management Program", Safety Series No.15, Vienna, 1999
- [ 5 ] IAEA, "Methodology for the Management of Aging of NPP Components important to Nuclear Safety", Technical Report Series No.338, Vienna, 1992
- [ 6 ] USNRC, "Standard Review Plan for the Review of License Renewal Applications for NPPs", NUREC-1800, 2005.9
- [ 7 ] USNRC, "Generic Aging Lessons Learned (GALL) Report", NUREC-1801, 2005.9