

## Inspection, Evaluation and Maintenance Guidelines for Reactor Vessel Internals in JAPAN

Akihiro SAKASHITA<sup>1,\*</sup>, Tomoya GOTO<sup>1</sup>, Shinro HIRANO<sup>2</sup>, and Koji DOZAKI<sup>3</sup>

<sup>1</sup> Tokyo Electric Power Company, 1-1-3 Uchisaiwai-cho, Chiyoda-ku, Tokyo 100-8560, Japan

<sup>2</sup> The Kansai Electric Power Company, 13-8 Goichi, Mihama-cho, Mikata-gun, Fukui 919-1141, Japan

<sup>3</sup> The Japan Atomic Power Company, 1-1 Kanda-Mitoshiro-cho, Chiyoda-ku, Tokyo 101-053, Japan

### ABSTRACT

Inspection and Evaluation Guidelines for reactor internals has been taken into the Rules on Fitness-for-Service for Nuclear Power Plants of The Japan Society of Mechanical Engineers. It is a base of the maintenance plan of each Nuclear Power Plant. A plant maintenance methodology will have more importance to maintain the plant safety and stable plant operation. This paper introduces the systematization of the maintenance such as repair, replacement, preventive maintenance in these guidelines. Maintenance methodologies are classified follows.

- Repair : methodology to reinforce degraded parts by some methods or prevent progress of degradation of without replacement of the existing structure when the degradation of structure is actualized.
- Replacement : methodology to replace the existing structure with new one when the degradation of structure is actualized.
- Preventive maintenance : methodology to mitigate the damaged condition.

When the maintenance methodologies are implemented in the actual plant, we have to consider the feedback of the inspection program and plant life management.

### KEYWORDS

Inspection and Evaluation, Guideline, reactor vessel internals, repair, preventive maintenance

### ARTICLE INFORMATION

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## 1. Introduction

In recent years, several SCC (Stress Corrosion Crack) at the austenitic stainless had been found and reported in domestic and foreign reactor vessel internals and primary boundary piping. [1]

In the U.S., the PWR Owners Group (PWROG) and BWR Owners Group (BWROG) have defined the function and ageing mode for reactor internals, published a guideline of inspection and evaluation for the reactor vessel internals. Moreover, they have discussed technical and reasonable inspection and evaluation methodology with the US Nuclear Regulatory Commission (NRC) based on these deliverables.

Similarly, Japanese Industry and Academic Committee has discussed and made a guideline of inspection and flaw evaluation since more than ten years ago in order to make a proposal on the existence of the reactor vessel internals inspection and evaluation.

These guidelines are classified following sections for each component that consist of the reactor vessel internals.

- Inspection and Evaluation
- Maintenance Methodology
- Preventive Maintenance Methodology

This inspection and evaluation guideline had been applied to JSME Fitness-for-Service rules already, and it has been basis of maintenance plan for the reactor vessel internals of Japanese BWRs and PWRs. [2] In the future maintenance, inspection for the structures after repair, the replacement and the preventive maintenance becomes important. This paper mentions inspection and flaw evaluation guidelines, moreover, introduces the systematization and the idea of the repair, the replacement and the preventive maintenance in the guidelines.

\*Corresponding author, E-mail: sakashita.a@tepcoco.jp

## 2. Inspection and flaw evaluation

Inspection guidelines consist of “Individual inspection” and “General inspection”. Individual inspection defines the scope, method and frequency of inspection to maintain each component integrity considered with the assumed ageing degradation. For more safety, General inspection is required for all internals even though the specific degradation is not assumed, in addition to Individual inspection.

When any flaw is found in the inspection, the influence for the component integrity has to be evaluated as follows. Detected flaw will be modeled on conservative length and depth. Residual stress and other mechanical stress distribution of the flaw propagate direction will be calculated by FEM analysis or the mock-up test. Crack propagation will be estimated depending on the K-value with conservative crack growth rate ( $da/dt$ ). Fracture evaluation will be done to confirm the component integrity in the plant life duration. If required, the component will be repaired or replaced based on the maintenance guidelines.

## 3. Comparison conventional with current maintenance

Before the establishment of Fitness-for-service Rules, repair or replacement was required when flaw is detected on time-based inspection. We have been able to implement flaw evaluation, and make judgments continuous operation or maintenance activity a result of structural integrity evaluation with flaw growth by using Fitness-for-Service. (Fig.1)

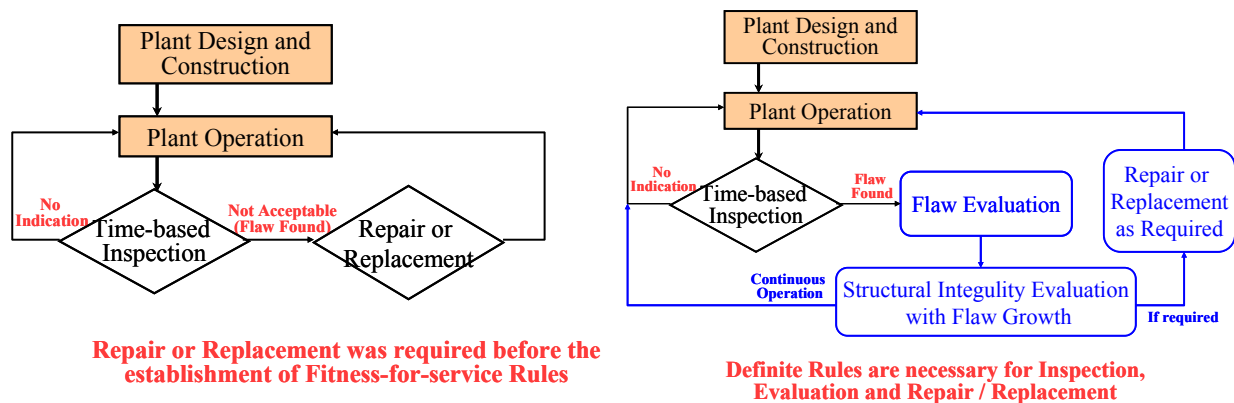


Fig. 1 Conventional and current maintenance flow diagram

## 4. Position of Repair / Replacement / Preventive maintenance

Under time-frame of nuclear plant management in Japan, the guideline is applied on the step of maintenance actions after starting plant operation. The maintenance actions contain repair, replacement, preventive maintenance (Fig 2).

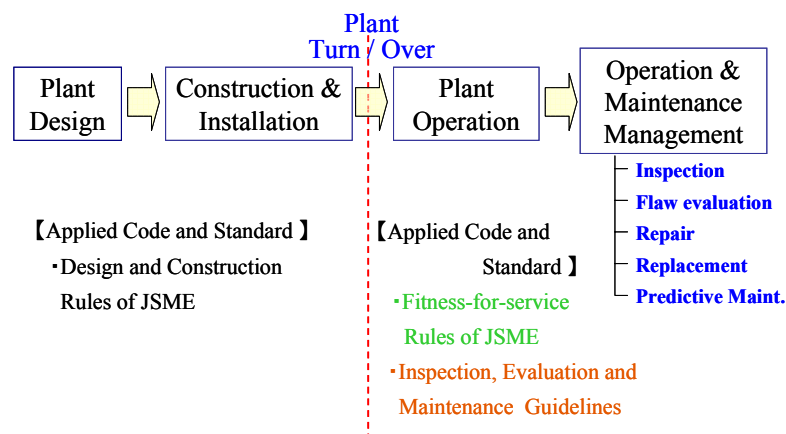


Fig 2 Time-frame of Nuclear Plant Management in Japan

Fig.3 shows the maintenance activities schematically. Repair is performed when ageing degradation such as SCC and/or fatigue crack are conformed tangibly. Replacement is performed regardless of subconscious or tangible of ageing degradation. Preventive maintenance is performed before ageing degradation is actualized.

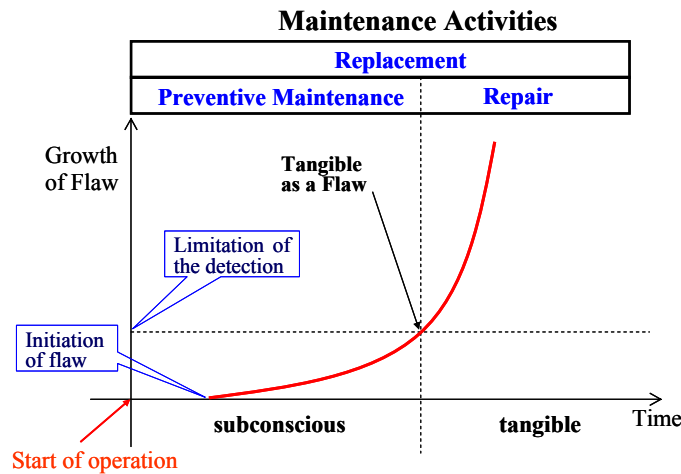


Fig 3 Definition of the maintenance activities

## 5. Definition and Classification

A repair, replacement and preventive maintenance are defined as follows.

- Repair : methodology to restoration degraded parts by some methods such as welding so on, or to prevent progress of degradation of without replacement of the existing structure when the degradation of structure is tangible.
- Replacement : methodology to replace the existing degraded structure with a new one or improved one when the degradation of structure is tangible.
- Preventive maintenance : methodology to mitigate the degradation or damaged condition.

Also, the parts to which it applied the above maintenance methodologies are classified into the required function (structural strength, sealing function, other safety function).

## 6. Prescribed Items in the Maintenance Guidelines

There are several repair and replacement activities for the reactor internals. We clarify the three fundamental methodologies and seven actual controlled items for each maintenance method.

[Three fundamental methodologies]

### A. Precondition

To clarify the scope of the portion, environment, material, so on, as the application of the precondition.

### B. Essential Valuables

Prescribe the essential variables based on the precondition. To define the expected effectiveness and secondary effect on certain various condition.

### C. Basic Procedure

To confirm the boundary condition of the essential valuables on the operating procedure to maintain the expected effectiveness.

[Seven actual controlled items]

Effectiveness, Precondition, Applied parts and Equipments, Operating devices, Operating procedure, Operator, Others

## 7. Sample of Maintenance Guideline

In this section, we illustrate two examples of maintenance guideline that developed pursuant to above prescribed items.

### 7.1. Seal welding [3][4][5]

Seal welding can prevent the crack growth of SCC due to isolation of SCC from corrosion environment in reactor coolant. Also, seal welded parts have the function to prevent reactor coolant from leaking out of pressure boundary. (Fig.4)

#### A. Precondition

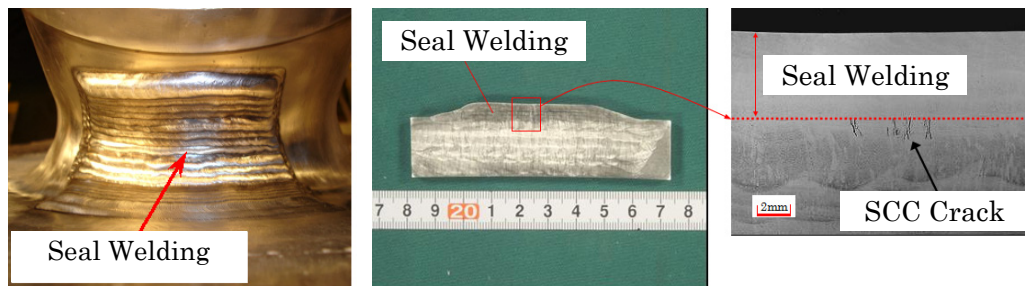
Seal welding is applied to the components of BWR and PWR core internals, including pressure boundary components; core shroud, shroud support, control rod drive housing and stub-tube. Materials are austenitic stainless steel and nickel based alloy. It required that the necessary structural strength of parts is ensured by the remaining portion. This welding method does not need machining / grinding for removing cracks, preparing grooves, nor buttering by weld.

#### B. Essential Valuables

It required to define welding method and condition as the essential valuables. Weld condition includes heat input and welding wire supply rate and so on.

#### C. Basic Procedure

Laser welding and TIG welding have been applied as overlaying method. It is necessary to confirm that welders qualified for each method are selected and trained before the actual operation.



**Fig 4 Pictures of seal welding**

### 7.2. IHSI for pipings [6][7]

IHSI (Induction Heating Stress Improvement) can prevent SCC for piping. Through this process, residual stress in the inner surface is improved for compression by induced thermal stress. The fundamental methodologies on IHSI are as follow. (Fig.5)

#### A. Precondition

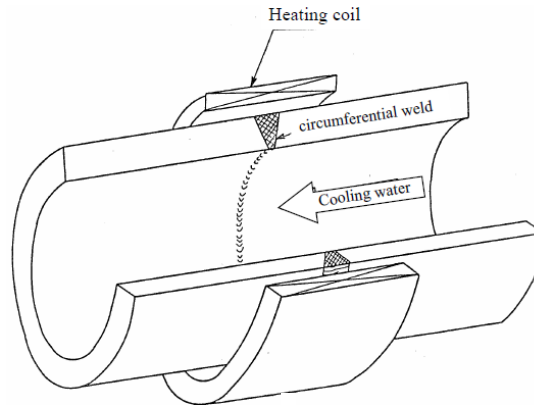
IHSI is applied to piping and nozzle safe-end such as Primary Loop Recirculation piping of BWR. Materials are austenitic stainless steel and nickel based alloy. IHSI needs water cooling of inner surface and heating of outer surface using heating coil in order to induce temperature difference in pipe wall thickness direction.

#### B. Essential Valuables

It required to define minimum requirement such as the specification of objective location and the heating condition by mock up test to ensure the expected effectiveness. The specification of objective location is outer diameter and base material thickness. The heating condition is maximum heating temperature and heating time, difference in temperature between outer and inner surface.

### C. Basic Procedure

In management of the essential valuable, it is necessary to confirm the heating condition within the range among operation. In the actual operations, if you have any concern to disturb the above operating condition you can control the operating parameter, based on the previous test result such as duration of the heating time, so on.



**Fig 5 Concept of IHSI**

## 8. Conclusion

Inspection, Evaluation and Maintenance Guidelines are extremely useful to manage the nuclear power plants, and these importance will be increase with the plant ageing. These guidelines have to be developed with the technical and engineering improvement. Especially, the maintenance technologies are making rapid progress.

## Acknowledgement

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