# THE PROPOSAL EVALUATION APPROACH OF THE RISK INFORMED-INSERVICE INSPECTION AND THE RESULT OF TRIAL EVALUATION

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**Abstract**

Nearly a decade has passed since risk evaluation in form of risk informed – inservice inspection (RI-ISI) was introduced for maintenance of plants in U.S and Europe. In such a situation, if Japanese plants employ RI- ISI in future, an evaluation approach applicable to Japanese plants is desired to be applied. Some approaches have been already considered as a RI-ISI evaluation approach, and each has strong points and demerits. Application of existing approaches to the Japanese plants without modifications is considered to be difficult since there are some differences between U.S. and European plants and Japanese plants with respect to their degradation mechanisms, piping materials and circumferential environmental conditions, etc. Therefore, the RI-ISI evaluation approach was studied for domestic plants by making most of the advantages of the existing approaches in consideration of Japanese plant conditions, and implemented for representative systems as a trail.

## 1. Introduction

Nearly a decade has passed since risk evaluation in form of risk informed – inservice inspection (RI-ISI) was introduced for maintenance of plants in U.S and Europe. In such a situation, if Japanese plants employ RI- ISI in future, an evaluation approach applicable to Japanese plants is desired to be applied. Some approaches have been already considered as a RI-ISI evaluation approach, and each has strong points and demerits. Application of existing approaches to the Japanese plants without modifications is considered to be difficult since there are some differences between U.S. and European plants and Japanese plants with respect to their degradation mechanisms, piping materials and circumferential environmental conditions, etc. Therefore, the RI-ISI evaluation approach was studied for domestic plants by making most of the advantages of the existing approaches in consideration of Japanese plant conditions, and implemented for representative systems as a trail.

In developing the RI-ISI evaluation approach for domestic plants, it aimed at unifying piping management (to ensure consistency with maintenance activities for repair and replacement, etc.), achieving easy updating, and making objective judgments with emphasizing expert viewpoints.

## 2. Development of RI-ISI evaluation approach

The RI-ISI evaluation approach has been studied for domestic plants by making most of the advantages of the existing approaches in consideration of Japanese plant conditions and following purposes:

- Unify piping management (to ensure consistency with maintenance activities for repair and replacement, etc.),
- Achieve easy updating, and
- Make objective judgments with emphasizing expert viewpoints.

The evaluation procedure flow is shown in Fig.1. Details of each step are described in Section 2.1 to 2.5.

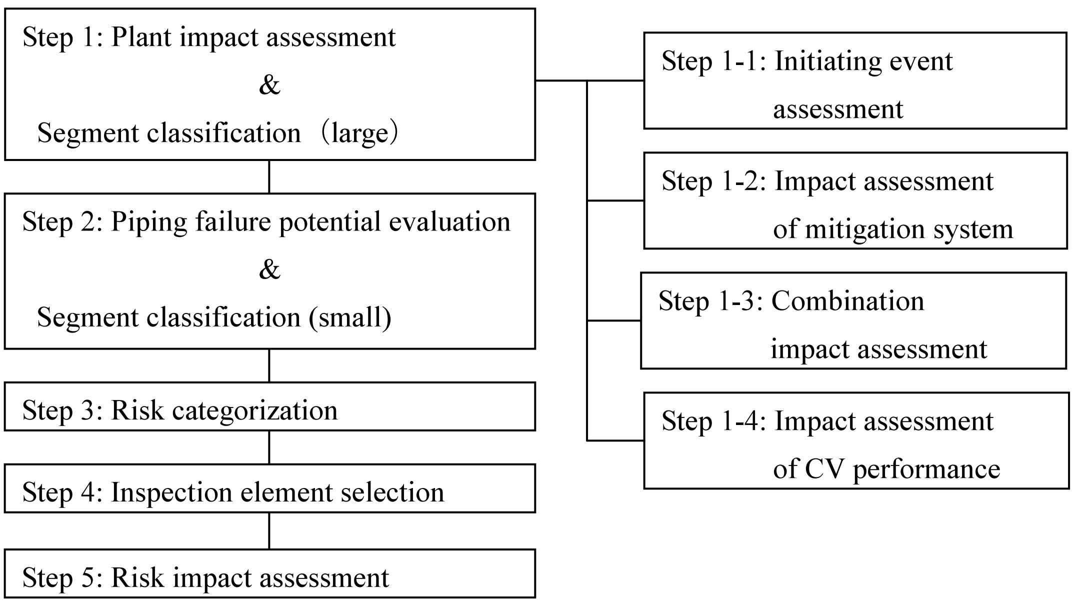


*FIG.1. RI-ISI evaluation steps*

## 2.1 Evaluation element selection

At the inception of the evaluation, area of piping was determined and clarified by describing in schematics or isometrics. The subject area can be arbitrary selected from among Class 1 to 3 pipes.

## 2.2 Plant impact assessment and segment classification (large)

In this assessment, areas having the same level of impact on the plant due to possible break are classified into the same segment by using the piping isometrics, and impact categories for each segment break are assessed.

The impact assessment steps are as follows:

(1) Initiating events assessment
When a segment break results in initiating event, CCDP is calculated and assessed their impact depending on types of initiating events (large/medium/small LOCAs, and transient, etc.)

(2) Impact assessment of mitigation system
When the mitigation system is affected, the impact is evaluated based on frequency that requires the relevant line operation, exposure time, and quantity of backup trains.

(3) Combination impact assessment
When a segment failure results in both initiating event and the degradation or loss of a system as above mentioned, quantity of systems available to perform mitigating function without being affected by the failed segment is evaluated to determine whether its consequence shall be prioritized over the impact assessment result for initiating event only.

(4) Impact assessment of CV performance
As a qualitative assessment of Level 2PSA, the impact on containment isolation is evaluated. A rank of the category, which is higher than that resulting from (1) to (3), is designed to be classified into this segment impact category.

### 2.3 Piping failure potential evaluation and segment classification (large)

The classified segments in Section 2.2 are further divided such that the segments having the same likelihood of degradation are categorized by describing the area subject to postulated degradation in piping isometrics. This allows likelihood of degradation categories for each segment to be evaluated and classified. Furthermore, follows are considered in studying the evaluation procedure.

— In the existing evaluation approach, initiating events such as SCC and high cycle fatigue which have low potential for rupture are uniformly evaluated as “Low potential for rupture”. In other words, evaluation is based on a degree of potential for “rupture (or a large leakage)”. This is because only large leakage will lead to damage on plant core. However, since even a crack detected poses problem in current Japanese situation, potential for leakage and degradation occurrence are taken into consideration based on the viewpoint of attitude toward maintenance, “Even a leakage shall not occur to the piping where a rupture has impact on the plant safety”.

— For postulated degradation mechanism, existing domestic evaluation approaches shall be considered with respect to Plant Life Management (hereinafter abbreviated as PLM) evaluation, etc.

The evaluation elements are designed as follows by referring to guideline for countermeasure against each degradation in current domestic plant:

— Degradation mechanism
A mechanism developing degradation with aging was designed for a subject degradation mechanism among the postulated domestic degradation mechanism in consideration of correspondence with elements mentioned for PLM.

— Evaluation of likelihood of degradation for each degradation mechanism
Each degradation mechanism is designed to be classified into Category I to III based on each level of concern for degradation by referring to maintenance guideline for the domestic piping degradation. The example of classification guideline is shown in Table 1. These categories were qualitatively determined based on the occurrence conditions of degradation events in Japan and abroad

*Table 1 Likelihood of degradation classification for piping*

| Category | Condition | Specific area (eg.) | Response |
|---|---|---|---|
| I+ | There is a possibility for rupture. | FAC | Repair/replacement, operational change, etc. are desired to perform as maintenance. |
| I | Since it may not result in rupture, however there is a possibility for leakage. | $O_2$SCC(SUS304), SCC from outer surface (Unidentified area) | |
| II | There is a possibility for crack (degradation) occurrence. | Valve sheet leak type thermal stratification, thermal fluctuation (RHR cooler) | Integrity is checked by performing periodic inspection. |
| III | There is a slight possibility for degradation. | $O_2$SCC(SUS316), thermal fluctuation (MCP charging nozzle) | Areas arbitrary inspected by the present ISI. |
| - | There is no possibility for degradation. | No possibility for degradation, SCC from outer surface (identified) | |

## 2.4 Risk categorization and inspection element selection

Each piping segment is assigned to the risk category and inspection requirement based on the result of combination of impact assessment and evaluation of likelihood of degradation performed in accordance with Section 2.2 and 2.3, respectively.

In current situation, the piping assigned to Category I+ and Category I require the fundamental countermeasure against degradation to be taken, namely, not by inspection, but by repair or replacement in order to lower its potential category. Accordingly, inspection proportion of 100% is applied. This requires further discussion.

In case when there is low potential for rupture but large impact can be anticipated, inspection demand of 10% is applied by referring to the existing approach.

Judging from the present ISI which imposes the inspection demand of 25% on the Class 1 piping, it is necessary to give basis that the inspection demand of 10% is sufficient to apply to RI-ISI in future. In U.S. implemented case research explains the basis. ISI consists of approx. 5% of all inspections which detected degradations, therefore most of the degradations were detected by concurrently implemented specific inspections.

*Table 2 Inspection requirements for RI-ISI procedure*

| | | | Impact assessment | | | |
|---|---|---|---|---|---|---|
| | | | - | Low | Middle | High |
| Failure potential category | I+* | There is a possibility for rupture. | 10% | 25% | 100% | 100% |
| | I* | Since it may not result in rupture, however there is a possibility for leakage. | 0% | 10% | 25% | 100% |
| | II | There is a possibility for crack (degradation) occurrence. | 0% | 0% | 10% | 25% |
| | III | There is a slight possibility for degradation. | 0% | 0% | 5% | 10% |
| | - | No possibility for degradation | 0% | 0% | 0% | 10% |

## 2.5 Risk impact assessment

The risk impact assessment is performed in a manner of multiplying increase or decrease of number of weld lines in the segment by the risk of each segment to check if the safety of the plant (PSA evaluation) at the inspected area is equivalent or less due to change of inspection technique from the present ISI to RI-ISI.

$$\Delta CDFi = (Nb,i - Na,i) \times \lambda i \times CCDP$$

ΔCDFi : Risk variation of Segment i due to introduced RI-ISI ( /core life)
Nb,i : Inspection elements /number of weld lines of Segment i for present ISI
Na,i : Inspection elements /number of weld lines of Segment i for RI-ISI
λi : Failure frequency of Segment i ( /core life)
CCDPi : Conditioned core damage probability for Segment i

This assessment is implemented by utilizing this equation, which is a simplified model on condition that degradation can be prevented at 100 % by inspection. An adequacy of the assessment will be further studied and, if necessary includes consideration of degradation detection capability depending on the inspection methods.
Additionally, assumed value of break probability for each potential category needs further investigation.

## 3. Trial evaluation and study

— Two representative systems (RCS and CVCS) were evaluated as a trial in accordance with RI-ISI evaluation procedure.
In performing the trail evaluation, for SCC from outer surface concerned for hot piping, following two case studies were performed to evaluate. In this degradation mechanism, once absence of fouling on the piping external can be confirmed by the external surface inspection, then it concludes no concern for degradation.

Case 1: assumed that all SCCs from outer surface have been already inspected (or checked) (Pipe failure potential category [-])

Case 2: assumed that SCCs from outer surface have yet to be identified (Pipe failure potential category [I])

*Table 3 Trial evaluation result*

| | Quantity of Inspection elements | | Present ISI |
|---|---|---|---|
| | Case 1 | Case 2 | |
| RCS | 34 | 61 | 62 |
| CVCS | 1 | 30 | 19 |
| Total | 35 | 91 | 81 |

In Case 1, quantity of inspection elements was significantly decreases comparing to the present ISI, while in Case 2, the quantity of selected inspection elements is equivalent to or more than that of present ISI. Furthermore, for the areas subjected to possible SCC from outer surface, inspections such as PT and visual inspection, etc are to be implemented, hence quantity of elements for the volumetric inspection is estimated to be equivalent to that of Case1.

Additionally, since $O_2$SCC of SUS316 materials and area subjected to potential thermal stratification, etc. are assigned to the potential Category III, inspection proportion decreases for this degradation mechanism. On the contrary, some plant with piping for replacement increases it inspection demand percentage by being classified into the potential Category I and results in anticipated increase of quantity of inspection elements. (The more maintenance countermeasures are taken, the less quantity of elements need inspections.)

The trail evaluation demonstrated following risk changes. I=10E-3, II=10E-5, III=10E-6, and --=10E-8 are assumed as break probability values classified into the potential categories (I through III). Since the evaluation basis requires close study in future, the result shows decrease in risk.

*Table 4 Risk change*

| ΔCDF | Case 1 | Case 2 |
|---|---|---|
| RCS | -4.43E-5 | -2.45E-7 |
| CVCS | -7.63E-9 | -5.93E-10 |

— In this approach, required quantity of inspection elements varies depending on the status of implementation of the countermeasures against degradation. It was found that the more countermeasures against degradations were taken, the less number of inspections was required.

Main subjects to be studied in future are described as follows.

— Impact assessment : In current situation, only Level 1PSA can be assessed, however, in case when evaluation requires for Level 2 and overflow etc., the impact assessment shall include them as additional items.
— The subject degradation mechanisms and assessment guideline shall be clarified.
— Inspectional proportion: Since this evaluation was studied based on existing approach, the inspection proportion of the existing approach needs to be evaluated if it is applicable to the domestic plants.

## 4. Conclusion

This study developed and examined the RI-ISI approach already applied in the U.S and Europe such that the evaluation approach is applicable to Japanese plants in consideration of domestic plant condition. Through this study, the evaluation of the likelihood of degradation for each piping segment can achieve high accuracy comparing with the existing approaches by selecting and considering piping materials and circumference environmental conditions.

The areas evaluated as “High” among the risk categories are subjected to high level of concern for failure, hence assumed as critical areas which require repair or replacement as maintenance and assigned to inspection demand of 100%. Therefore the trial evaluations were performed for these areas in RCS and CVCS and confirmed that this approach can assure risk reduction of the plant.

There is some challenges for application to the operating plant, however, evaluation of the entire plant will be carried out and studied from now on.

## REFERENCES

[1] WCAP-14572-Revision 1-NP-A “Application of Risk-Informed Methods to Piping Inservice Inspection Topical Report”,

[2] EPRI Topical Report TR-112657 Revision B-A, “Revised Risk-Informed Inservice Inspection Procedure”, December, 1999.

[3] ASME Section XI Non-mandatory Appendix R,°“Risk-Informed Inspection Requirements for Piping”