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The proposal evaluation approach of the risk informed-inservice inspection and the result of trial evaluation

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16 Oct, 2007

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1. Maintenance conditions of domestic plants

- Deterioration of plant safety due to aging.
  →Reinforcement of countermeasures to aging degradation and safety culture.

- Inspection performed with respect to all periodically specified items. (Excessive maintenance)
  - Exposed dose reduction remains the same level as in 1990.
  - Decrease of recent plant availability. (Approx. max.70%)
    →Needs to optimize the maintenance corresponding to equipment.
    →Introduction of new inspection system in April 2008.
    →Start of the operation of the systematic maintenance program with response to maintenance significance with utilizing the risk information.

1-1. Domestic plant present inspection system

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Operating company's activities to maintain safety

- Maintenance of system integrity
- Maintenance of operation management integrity

Inspection (→ Maintenance of system integrity)

- Periodical inspection (Approx. 80 to 90 items)
- Weld inspection（ISI）
- Fuel assembly inspection
- Periodical safety control review

Inspection and check (→ Maintenance of operation management integrity)

- Maintenance inspection (4 times per year)
  - Check compliance to the safety rule (Approx. 130 acts)
- Check the routine operation management condition

※ Inspection items are determined from the viewpoint of safety and inspection is performed with respect to all items.

Fig1:Domestic inspection system outline

1-2.Improvement Maintenance Program

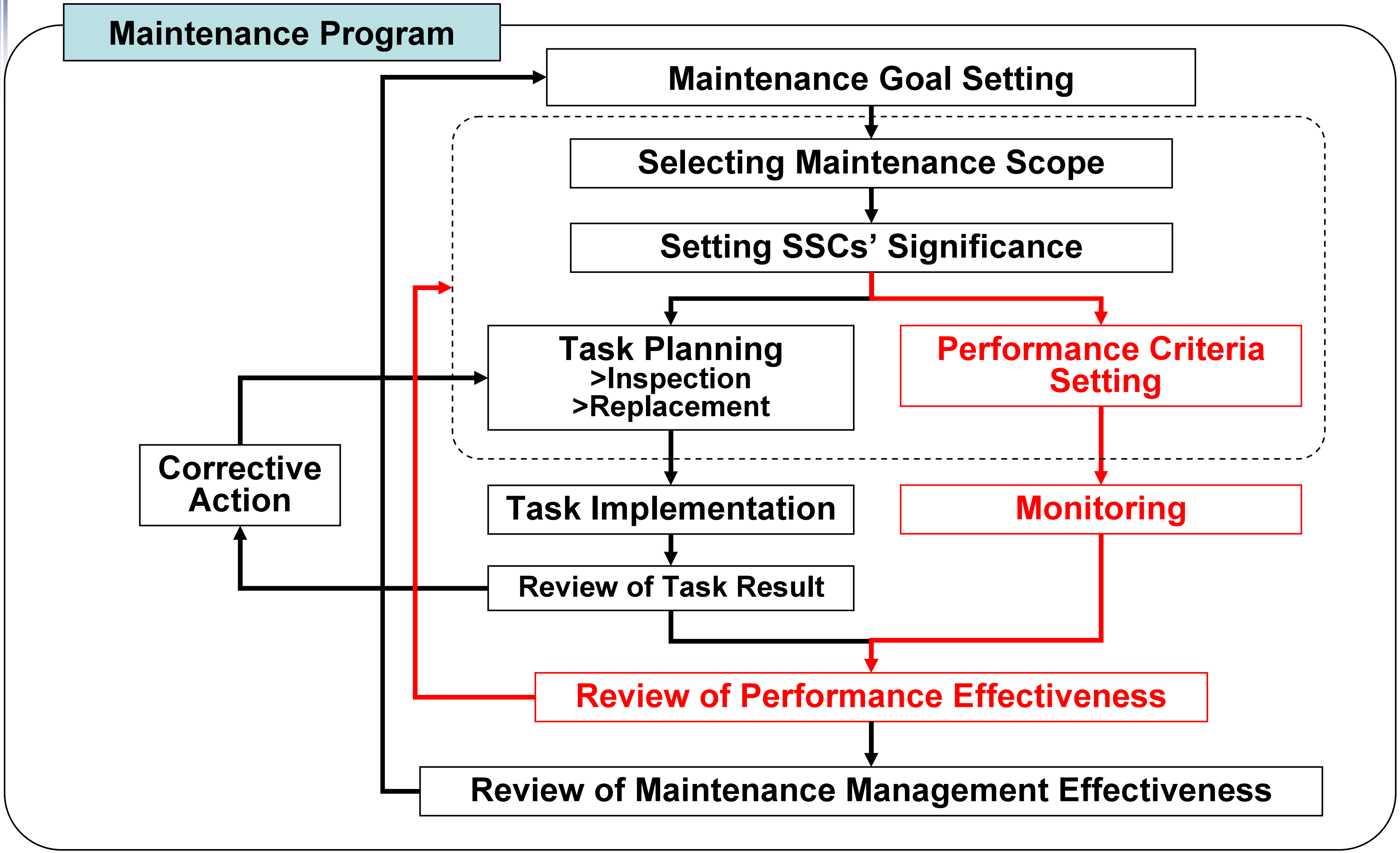
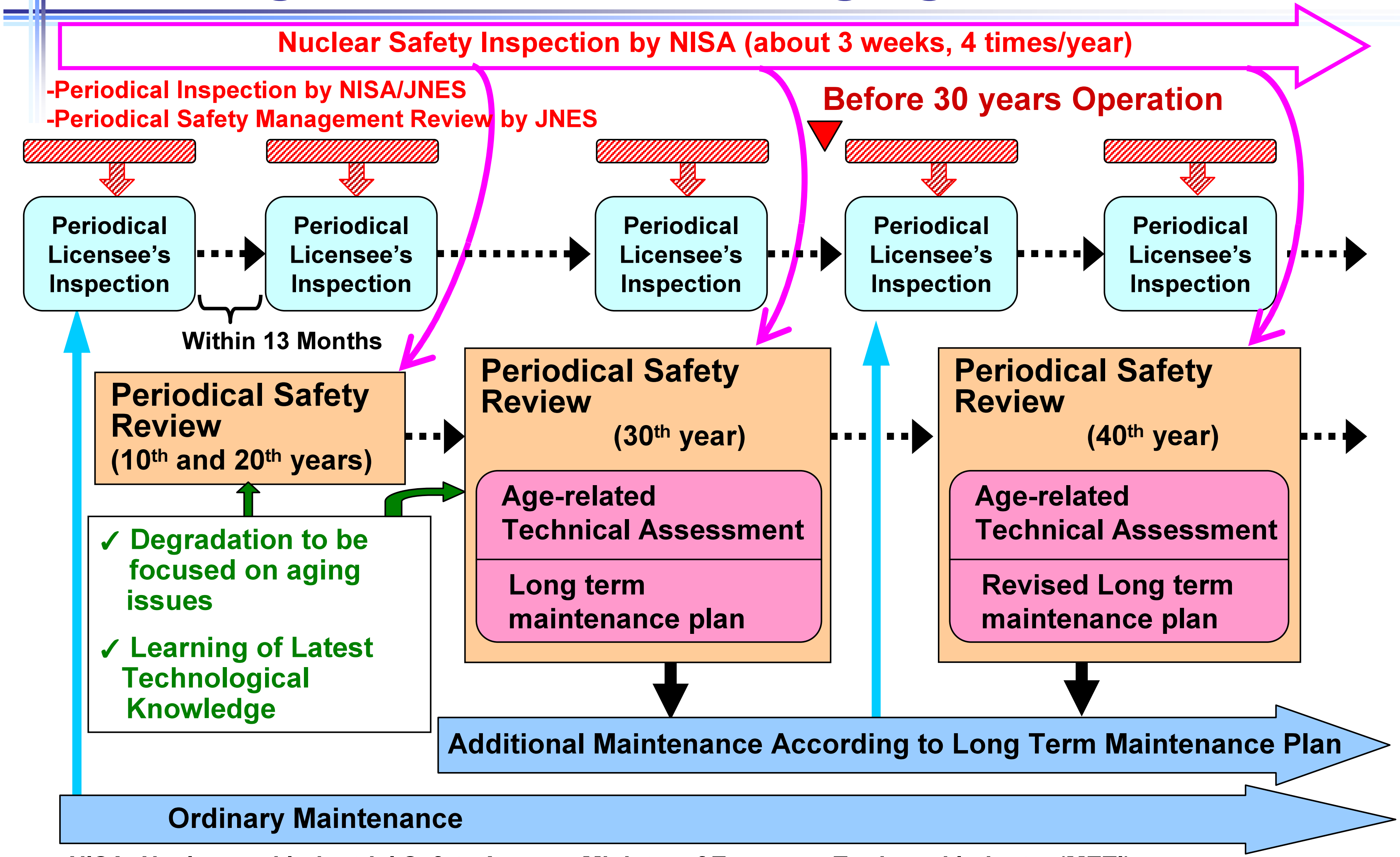


Fig2: Maintenance program

1-3. Regulation Related to Aging



NISA: Nuclear and Industrial Safety Agency, Ministry of Economy, Trade and Industry (METI)
JNES: Japan Nuclear Energy Safety (Incorporated Administrative Agency)

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2. Development of RI-ISI approach

Background

- Maintenance program for which passive components are in consideration is mainly for active components.
- Uniform maintenance including aging countermeasure is desirable for piping.
- Reduction of radiation exposure by efficient piping inspection with maintaining plant safety is desired.
- No concrete assessment measures related to RI-ISI applicable to domestic plant.

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Practice

- Study on RI-ISI assessment approach applicable to domestic plants.
- Implementation of trial evaluation for studied assessment approach.

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2-1. RI-ISI introduction purpose

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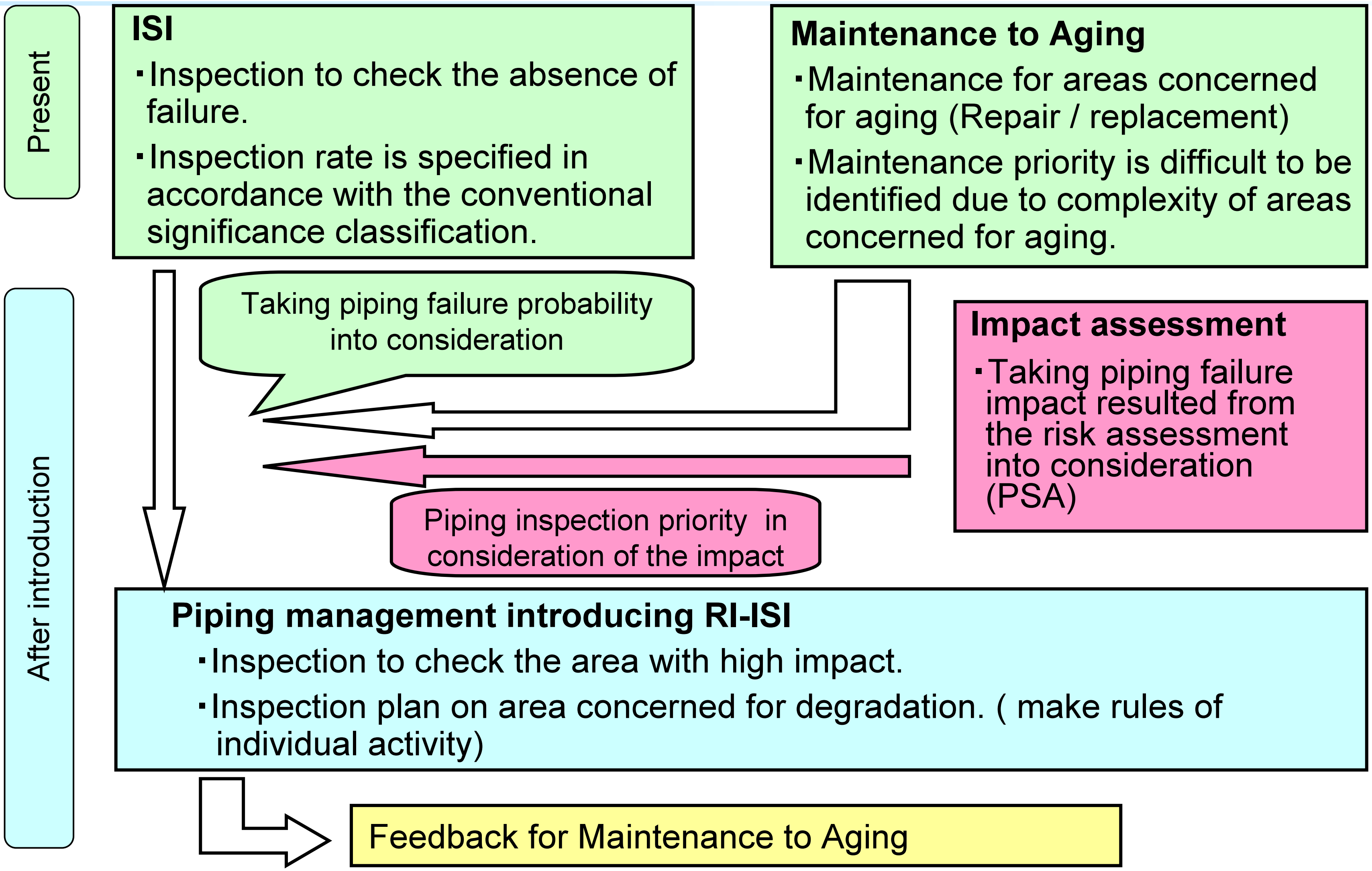

Fig. 3: Change of the piping inspection due to introduction of RI-ISI

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2-2.Study on evaluation approach

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Step1:Plant impact assessment and segment classification

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Step2:Pipe failure potential evaluation and segment classification

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Step3:Risk categorization

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Step4: Inspection element selection

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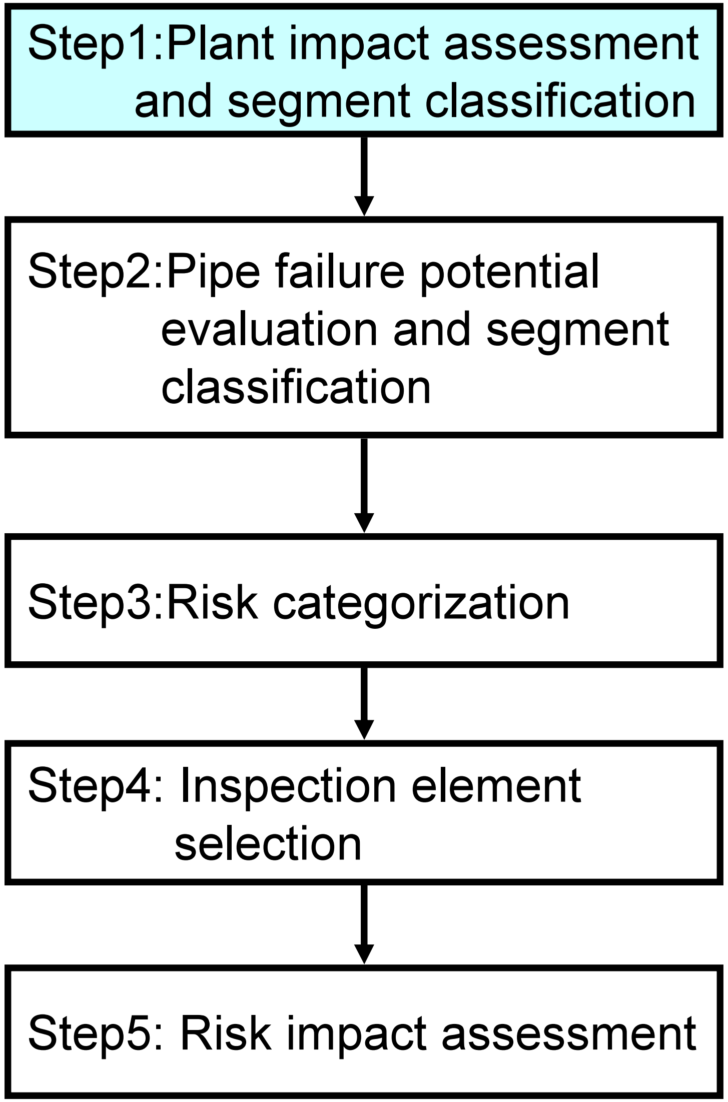
Step5: Risk impact assessment

Fig. 5: RI-ISI evaluation steps

2-2.Study on evaluation approach



▪**Step 1**

- 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.

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2-2.Study on evaluation approach

- Step1:Plant impact assessment and segment classification
- ↓
- **Step2:Pipe failure potential evaluation and segment classification**
- ↓
- Step3:Risk categorization
- ↓
- Step4: Inspection element selection
- ↓
- Step5: Risk impact assessment

▪Step 2

- Degradation probability for each classified segment in Step1 is assessed by use of degradation check sheet.

- In accordance with the piping isometrics, the classified segments in Step 1 are further divided such that one segment has the same degradation probability.

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2-2.Study on evaluation approach

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- Degradation probability classification is implemented by taking account of piping materials and environmental conditions.
- Degradation probabilities are classified into five categories.

Category	Condition	Degradation mode (Example)	Required action
Ⅰ+	Possibility for rupture.	FAC	Maintenance and repair is desired
Ⅰ	Possibility for leakage.	O2SCC(304SS), SCC from outer surface (Unidentified area)	
Ⅱ	Possibility for crack (degradation) occurrence.	Valve sheet leak type thermal stratification, Thermal fluctuation (RHR heat exchanger bypass line), Operating type thermal ratification	Periodical inspection is desired
Ⅲ	Slight possibility for degradation.	O2SCC(316SS),Thermal fluctuation (MCP charging nozzle)	Randomly inspected by the ISI
None	No possibility for degradation.	No possibility for degradation, SCC from outer surface (identified)	

Table 1: Degradation probability classification

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2-2.Study on evaluation approach

Step1: Plant impact assessment and segment classification

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Step2: Pipe failure potential evaluation and segment classification

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Step3: Risk categorization

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Step4: Inspection element selection

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Step5: Risk impact assessment

▪Step 3

- Risk category is assessed by combing impact and degradation probability categories obtained in Step1 and Step2 and clarify inspection demand.

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2-2.Study on evaluation approach

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- 100% inspection demand is assigned to piping with high degradation probability and high impact on the plant .

Impact assessment

Degradation probability assessment

Degradation category			Impact category			
			None	Low	Middle	High
	I +	Possibility for rupture.	(10%)*	(25%)*	(100%)*	(100%)*
	I	Possibility for leakage.	(0%)*	(0%)*	(25%)*	(100%)*
	II	Possibility for crack (degradation) occurrence.	0%	0%	10%	25%
	III	Slight possibility for degradation.	0%	0%	5%	10%
	None	No possibility for degradation.	0%	0%	0%	10%

(note)*:Rank I + and I are basically desired to be maintained or be repaired.

Table 2: Risk categorization and inspection demand

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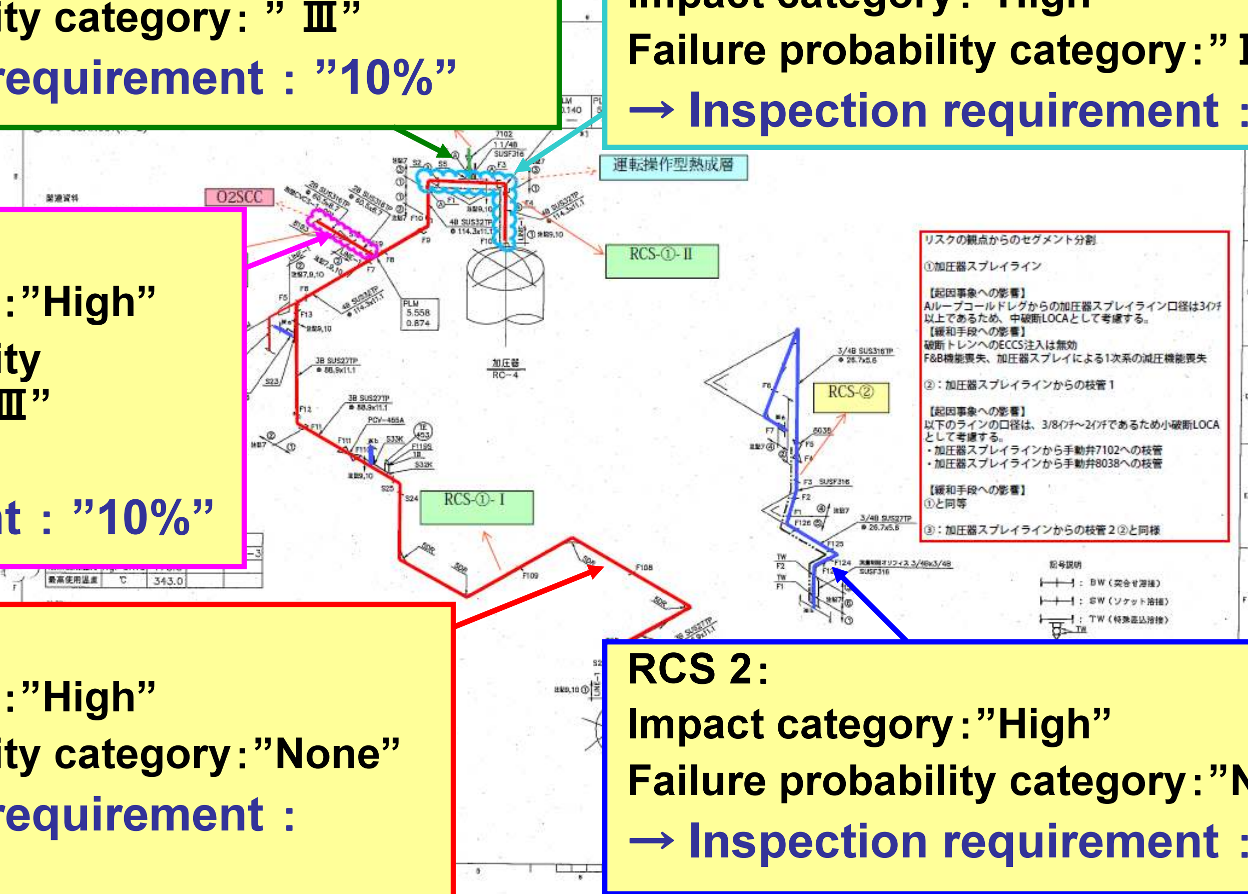
RCS 3 :
Impact category:"High"
Failure probability category: " Ⅲ"
→ Inspection requirement : "10%"

RCS 1-Ⅱ :
Impact category:"High"
Failure probability category:" Ⅱ "
→ Inspection requirement : " 25%"

RCS 1-Ⅲ :
Impact category:"High"
Failure probability category: " Ⅲ"
→ Inspection requirement : "10%"



RCS 1-Ⅰ:
Impact category:"High"
Failure probability category:"None"
→ Inspection requirement : " 10%"

RCS 2:
Impact category:"High"
Failure probability category:"None"
→ Inspection requirement : " 10%"

Fig. 4: Risk categorization and inspection demand example

RCS (Reactor Cooling System) isometrics

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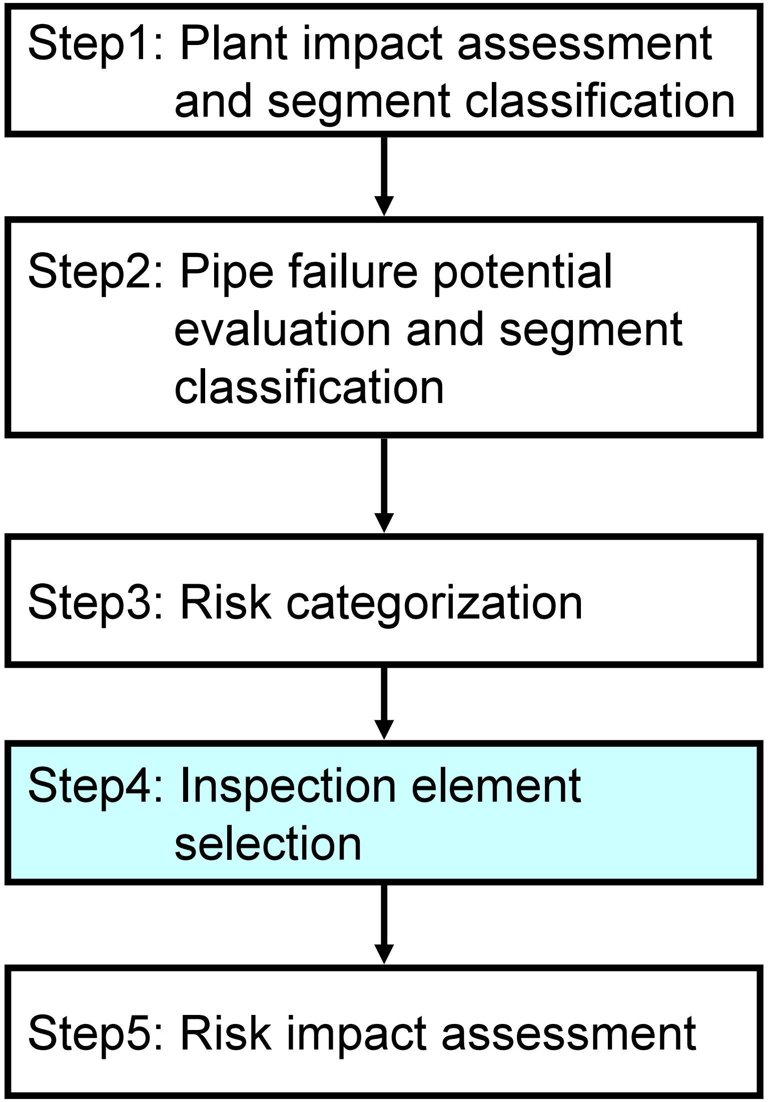
2-2.Study on evaluation approach



▪**Step 4**

- Areas to be inspected are selected from each segment based on the number of areas required to be inspected. In this case, parts to be inspected, inspection volume and inspection method are set corresponding to anticipated degradation mechanism.

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2-2.Study on evaluation approach

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Step1: Plant impact assessment and segment classification

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Step2: Pipe failure potential evaluation and segment classification

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Step3: Risk categorization

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Step4: Inspection element selection

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Step5: Risk impact assessment

▪**Step 5**

- To check that plant safety (PSA evaluation) of the inspection area is equal to or decrease by transferring from existing ISI to RI-ISI inspection.

- Evaluation is implemented by means of following equation.

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

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 existing 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.

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3-1.Trial evaluation study (condition)

Condition 1: Selection of representative system

- RCS (Reactor Cooling System) and CVCS (Chemical & Volume Control System) are set as representatives by studying following items.
  - Systems for which many degradation modes are selected to be evaluated are selected by priority
  - Systems with many areas to be inspected are selected by priority to check effects on area to be newly subject for ISI by application of RI-ISI.

Condition 2：Evaluation case

- Trial evaluation is performed for following two cases to compare presence or absence of effect of significant degradation mechanism.

Case1 ： Assumed that all area with concern for SCC from outer surface has been already inspected.

Case2 ： Assumed that areas with concern for SCC from outer surface have yet to be identified.

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3-2.Trial evaluation study (Result)

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Study result 1: Number of area to be inspected

	Number of area to be inspected		
	Case 1 (Identified SCC from outer surface)	Case 2 (Unidentified SCC from outer surface)	Existing ISI
RCS	34	61(27)	62
CVCS	1	30(29)	19
Total	35	91(66)	19

Table 3 :Comparison of number of areas to be inspected by existing ISI and RI-ISI

( ) brackets means number of SCC area from the outer surface among number of areas to be inspected.

RCS :Reactor Cooling System、CVCS : Chemical & Volume Control System

3-2.Trial evaluation study (Result)

Study result 2：Risk category evaluation

ΔCDF	Case 1 (Identified SCC from outer surface)	Case 2 （Unidentified SCC from outer surface）
RCS	-4.43E-5	-2.45E-7
CVCS	-7.63E-9	-5.95E-10
Total	-4.43E-5	-2.45E-7

Table 4: Evaluation result of risk impact

RCS :Reactor Cooling System、CVCS：Chemical & Volume Control System

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4.Conclusions

- Degradation probability assessment is performed such that each segment is classified through 5 steps in consideration of piping materials and environmental conditions. 5-step assessment permits highly accurate assessment comparing with the existing method.
- A part with high degradation probability and high impact on plant seems to be a critical part which requires maintenance such as repair and replacement, therefore 100% inspection demand is assigned to. This permits to ensure reduction of plant risk.
- This trial evaluation is implemented on RCS and CVCS. It is confirmed that number of areas to be inspected and risks can be reduced with increasing maintenance of plant.

To be studied further

Utilization of the risk information permits the uniform piping management including maintenance to aging.

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