Japanese Nuclear Industry's Efforts for PWR's Plant Life Management

The Japan Atomic Power Co.

November, 2009

1

Contents

2

History of Japan's PWR

WH 2-loop Design
- Fuel: 10ft→12ft
- New RV Material
- New SG Tube
- New RCP

WH 3-loop Design
- Fuel: 14X14→15X15
- System Improvement
- CV Enclosure

WH 4-loop Design
- Larger Output: 1,170MW
- Ice Condenser CV
- Higher System Efficiency

The first Design Standardization (3-loop plant)
- 870MW
- Standardized Domestic Design
- Partially Mono-Block Turbine

The Second Design Standardization (4-loop plant)
- Integration of Domestic Tech.
- Pre-stressed Concrete CV

The third Design Standardization (APWR: Tsuruga-3,4)
- 1,530MW
- Higher Capacity Factor
- Improvement of Operability & Economic Efficiency

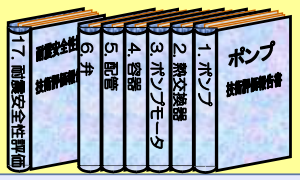
History of PLM/AM at Japanese NPPs

1996 [PART-1]

Basic Policy & Concept of PLM
- Assessed SSC not to be easily replaced
- Policies for long-term & safe operation

1998 [PART-2]

Utilities' evaluation
- SSC which are important to plant safety and operation
- Reviewed by the regulatory body, NISA



Establishment of Long-term Maintenance Program

Incorporation of special maintenance tasks required for long-term & safe operation into the existing maintenance program

NISA Review Completion List

Date of Evaluation	NPPs
2000	1. Tsuruga Unit 1 2. Mihama Unit 1
2001	3. Fukushima Daiichi #1
2002	4. Mihama Unit 2
2004	5. Shimane Unit 1 6. Fukushima Daiichi #2 7. Takahama Unit 1
2005	8. Genkai Unit 1 9. Takahama Unit 2
2006	10. Fukushima Daiichi #3 11. Hamaoka Unit 1 12. Mihama Unit 3
.....	.....
2009	21. Tsuruga Unit 1

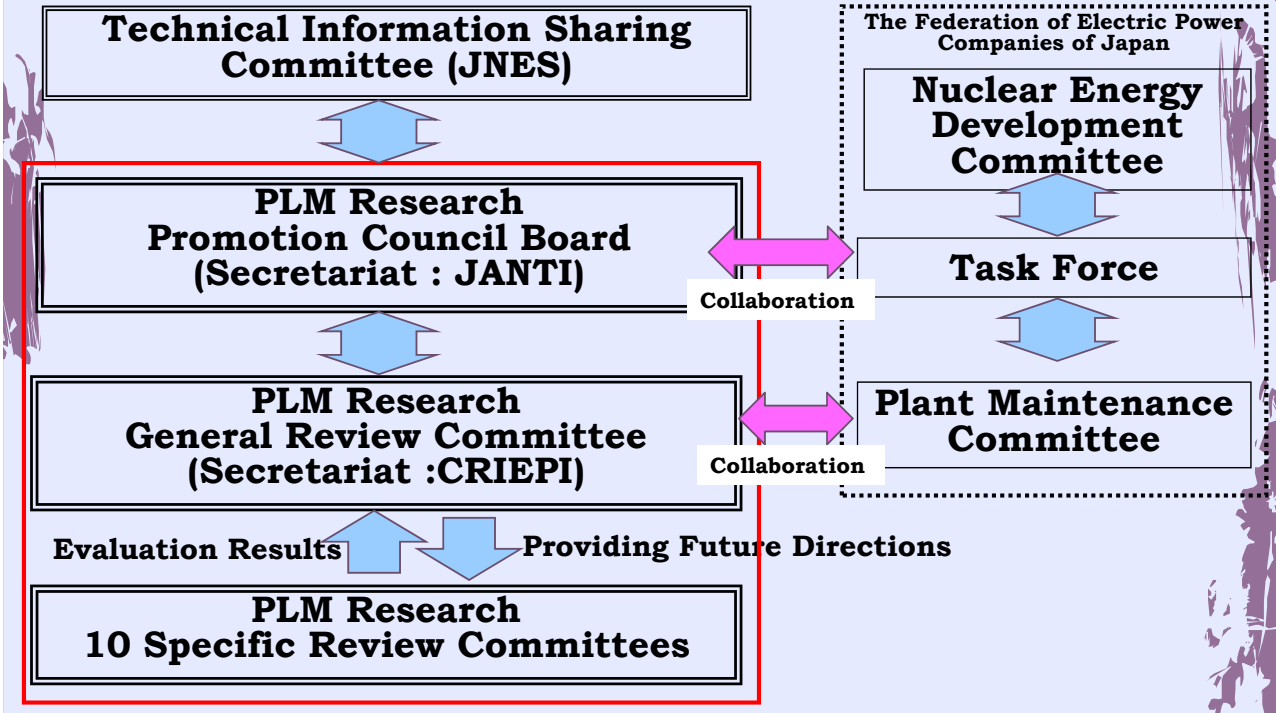
2005

Preparation of the Regulatory Guidance Documents by the Regulatory Body, NISA
- Ageing Management Implementation Guideline for Nuclear Power Plants
- Standard Review Plan for Ageing Management Technical Evaluation of Nuclear Power Plants
- Technical Documents for Ageing Management Implementation of Nuclear Power Plants

2008

Introduction of PLM/AM into the New Regulatory System

Organization in Japan to Promote PLM-related R&D Activities



The nine electric power companies, JAPC, J-Power, CREIPI and JANTI are involved in this organization.

PLM related R&D Items

Specific Issues

1. SCC
2. Irradiation Embrittlement
3. Fatigue
4. Seismic Safety
5. Concrete Degradation
6. Cable Insulation Degradation
7. Pipe Wall Thinning
8. Inspection/Monitoring Technologies
9. Preventive Maintenance & Repair Techniques
10. Enhancement of Maintenance Activities

R&D focus

① **Fundamental Research Projects**
Clarify ageing mechanisms, identify potential consequences, and develop new materials

② **Develop. of Advanced Technologies**
Technologies required for evaluation, inspection and repair

③ **Application of Technologies in field**
Technical approaches, demonstration tests, making standards and their approval by the government

④ **Construction of Database Required for PLM Technical Evaluations**

⑤ **Development of Alternative inspection/monitoring methods instead of ones by the conventional overhaul**

⑥ **Proposals for Improving the Current Regulatory system and Rules**

⑦ **Securing of human resources by establishing the system to promote it**

Next Generation LWR Development

By utilizing the results of the PLM related R&D

Project based on the Japan's Nuclear Energy National Plan

Objective: (1) Develop the next generation LWRs which could be recognized as the world standard (1,700～1,800MW-class BWR and PWR)
(2) The government and electric power companies should promote the R&D projects with the help of the plant vendors.

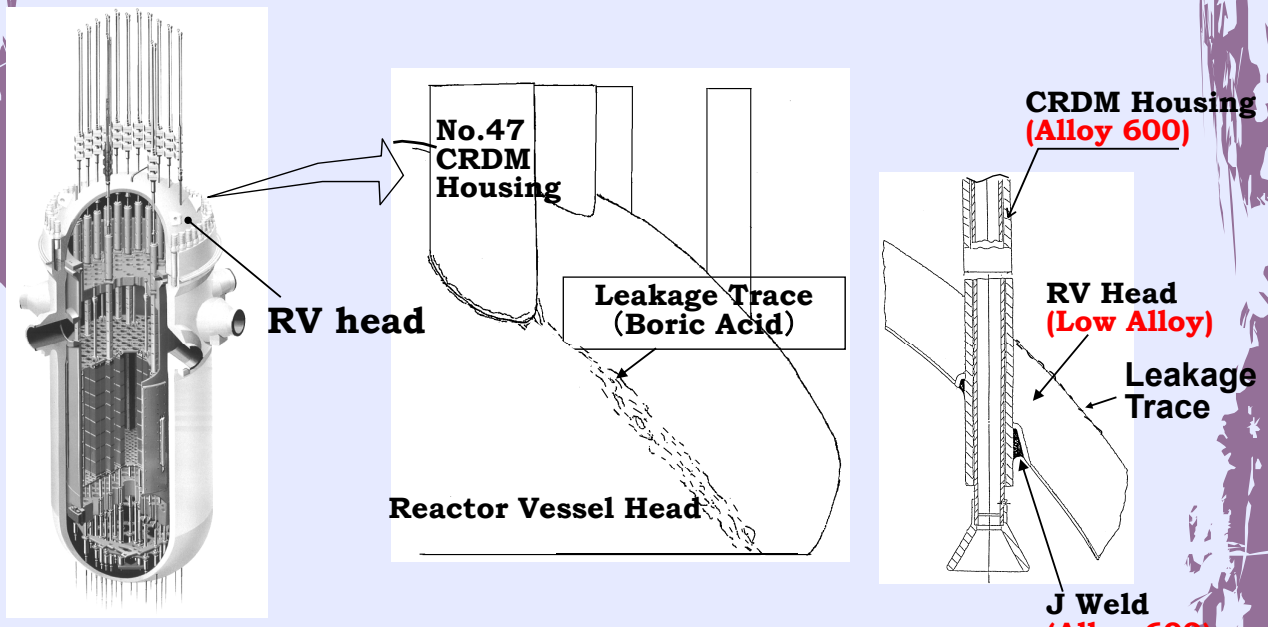
Project Term: 2008～2015 (8 years)

Development Targets of The Project (6 Core Items)

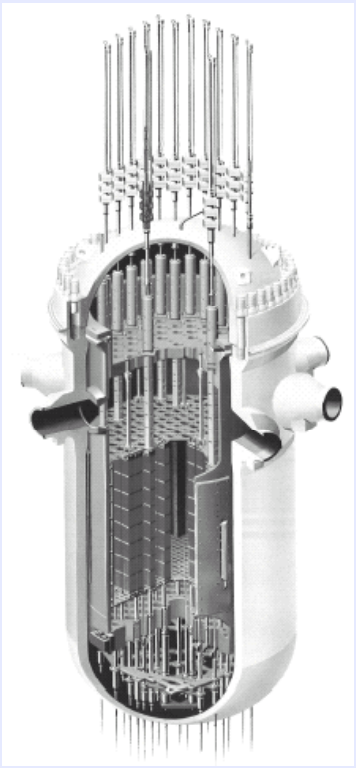
- Achieve significant reduction of spent fuels and the highest availability in the world by developing NSSS utilizing 5% or higher enrichment fuel.
- Realize the standardized plant design regardless of site conditions by adopting the seismic isolation technology.
- Introduce new materials and improved water chemistry aiming at 80 years plant design life and significant reduction of radiation exposure received during maintenance work.
- Reduce the construction schedule significantly by introducing the radial construction technologies.
- Achieve both the highest safety and economic efficiency in the world by optimized combination of passive and active systems.
- Adopt the most advanced digital technology to improve the availability and safety simultaneously.

PWSCC in RV Head Penetration

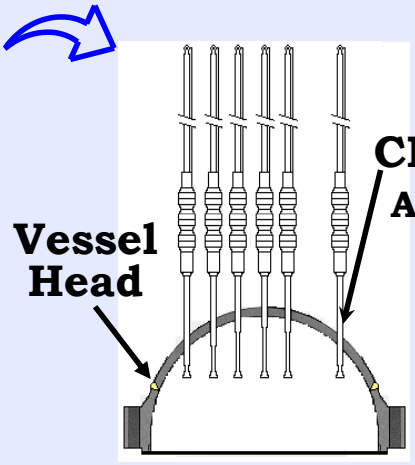
Sketch of Leakage Trace in the Case of a Japanese Plant



PWSCC in RV Head Penetration

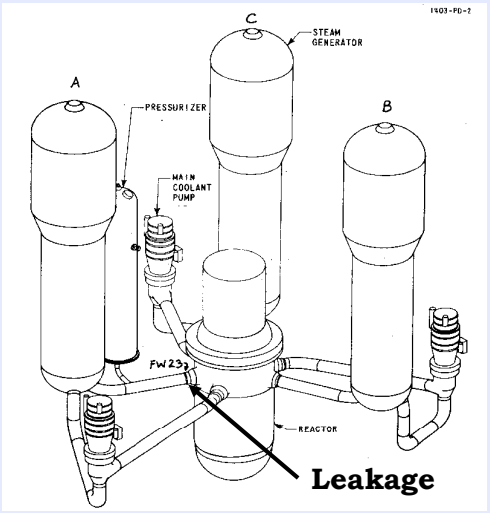


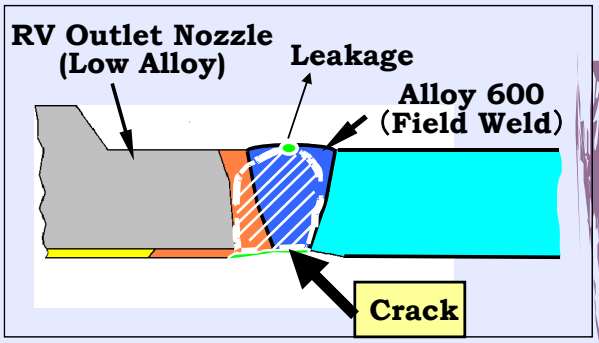
Replacement of Material from Alloy 600 to Alloy 690

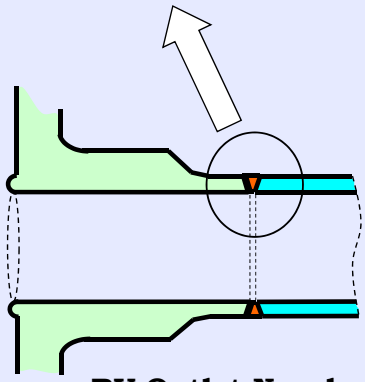


PWSCC in RV Nozzle Welds (1/2)

Leakage from the Main Loop in V.C.SUMMER(Oct. 2000)



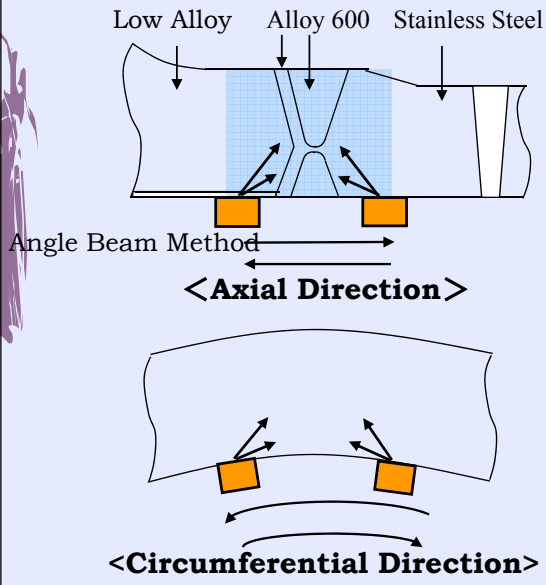




<Root Cause>
- PWSCC in Alloy 600 Weld
- High Tensile Residual Stress Generated by Weld Repair

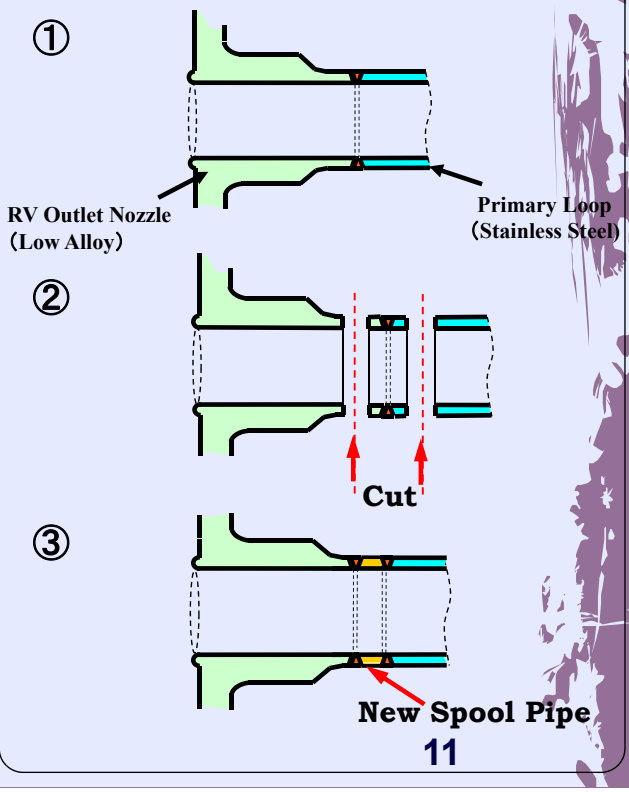
PWSCC in RV Nozzle Welds (2/2)

Improved Inspection Method

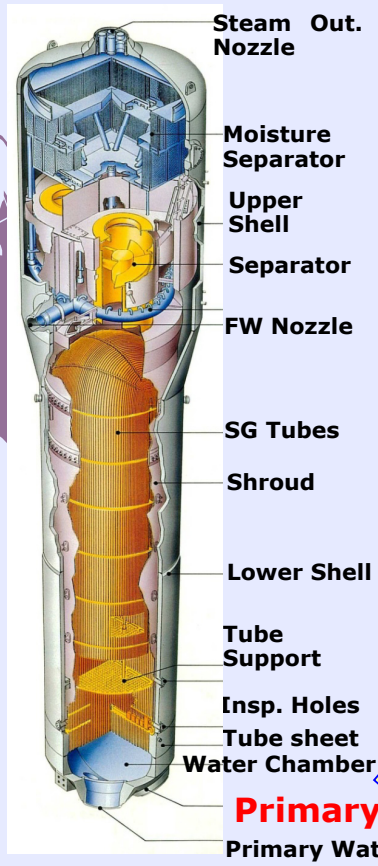


Before	Current
Straight Refracted (Shear : Axial)	Straight Refracted (Longitudinal : Axial & Circum.)

Repair Technique

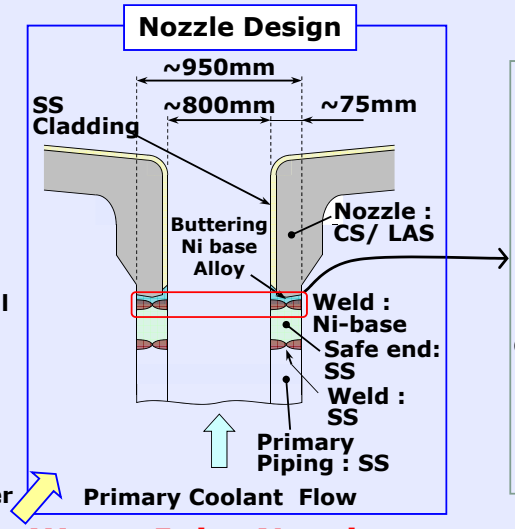


PWSCC on DMW of SG Nozzle

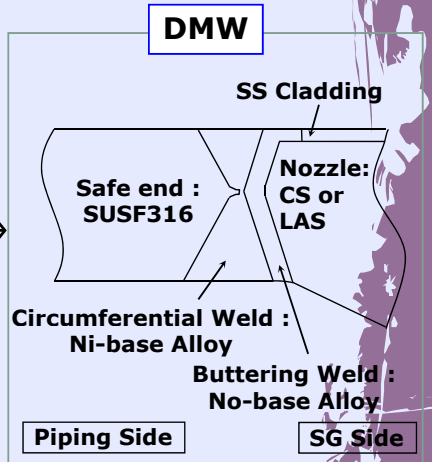


- **PWSCC cracks were found on DMW of SG inlet nozzle at some PWR plants in Japan since September 2007.**
- **Mihama-2, Tsuruga-2 etc.: Cracks were found by ECT as the check prior to shot peening.**

Nozzle Design

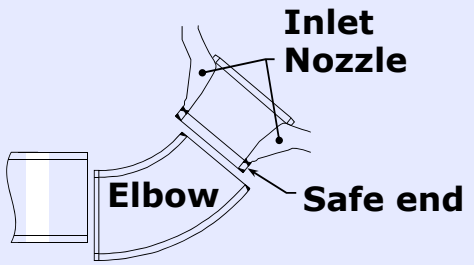


DMW

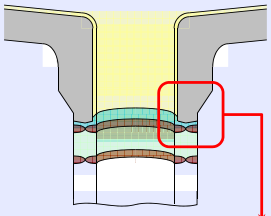


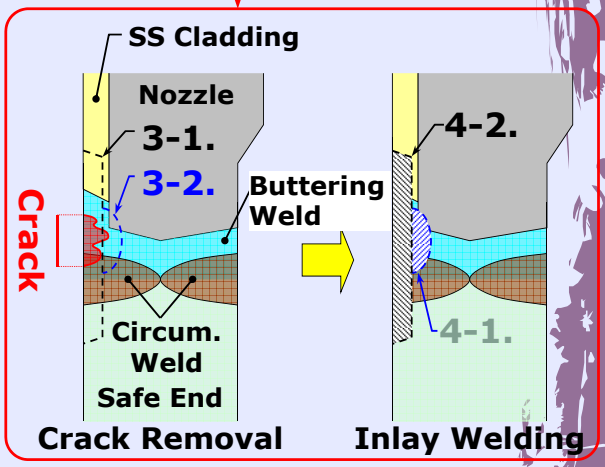
Primary Water Inlet Nozzle

Repair Process Overview For Deep Cracks



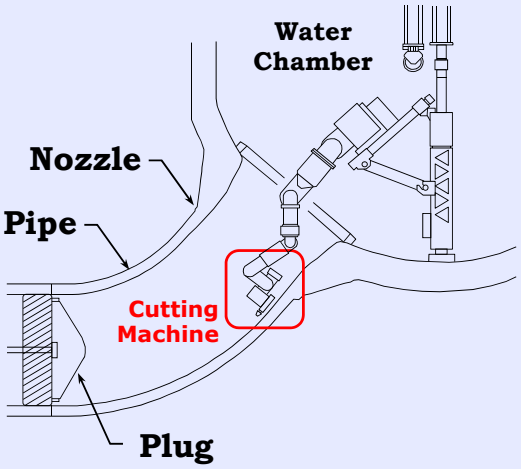
1. Remove the existing elbow
2. Decontamination
3. Crack removal
   - ●All around shallow cutting
   - ● Local deep cutting
4. Inlay welding
   - ●Local cladding weld using alloy 600
   - ● All around inlay weld using alloy 690
5. Install new elbow

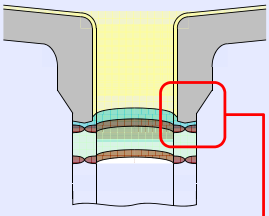


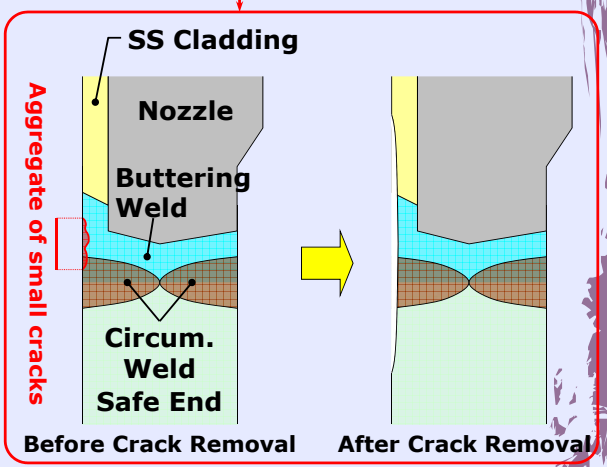


Repair Process Overview For Shallow Cracks

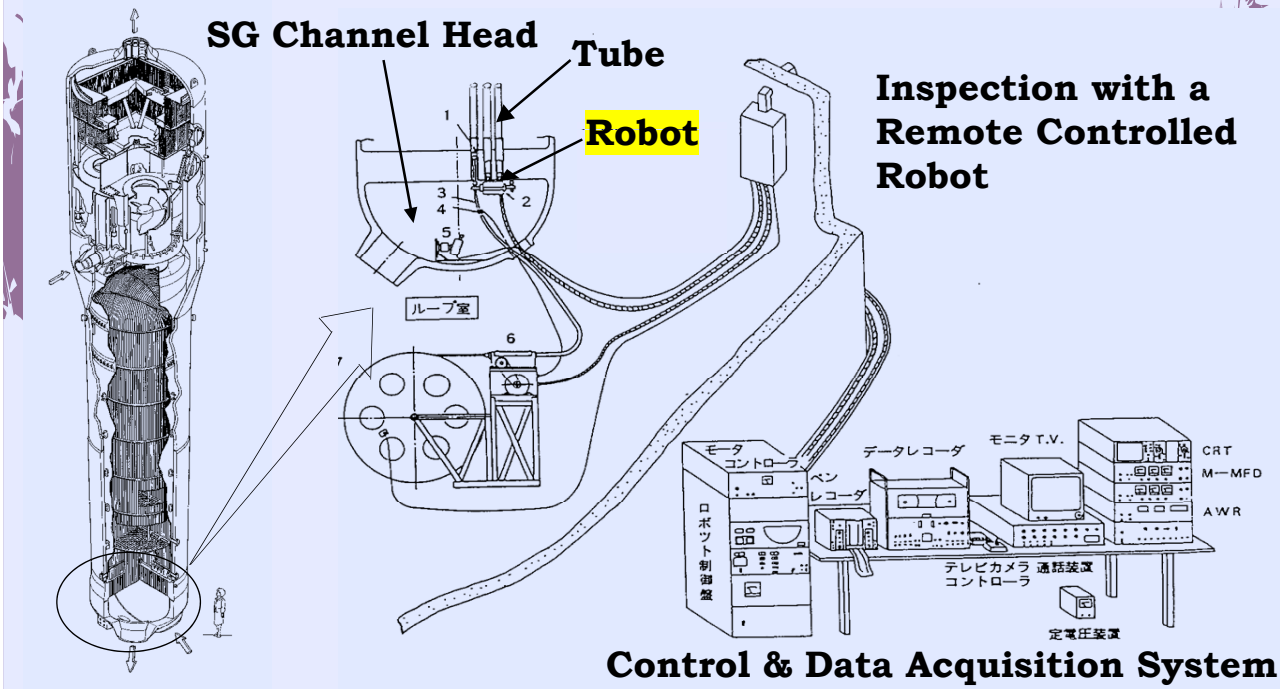
1. Install the cutting machine
2. Crack removal
3. Inspection by ECT
4. Wall thickness measurement
5. Perform ultrasonic shot peening



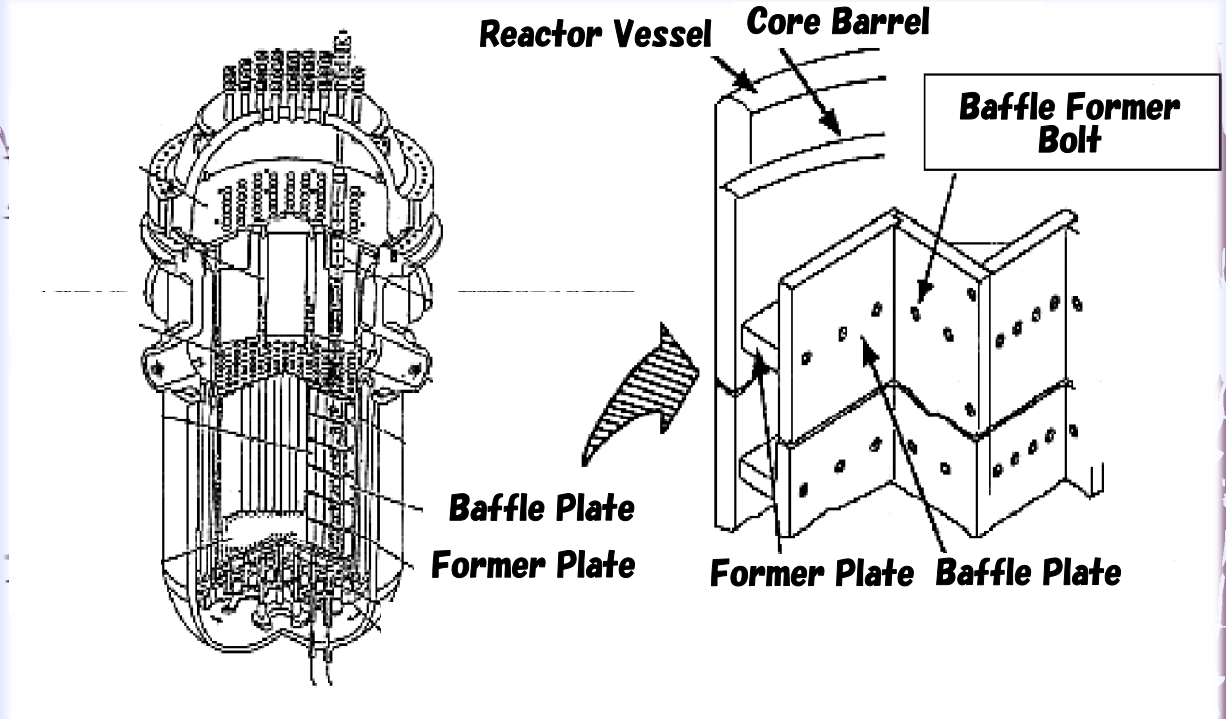




ECT System for PWSCC in SG Tubes



IASCC in Baffle Former Bolts



IASCC in Baffle Former Bolts

Identification of IASCC Susceptible Components ↔ **Neutron Irradiation Threshold of IASCC Susceptibility**

↓

Understanding of Degradation Mode & Fracture Mode ↔ **Structural Margin against Failure**

↓

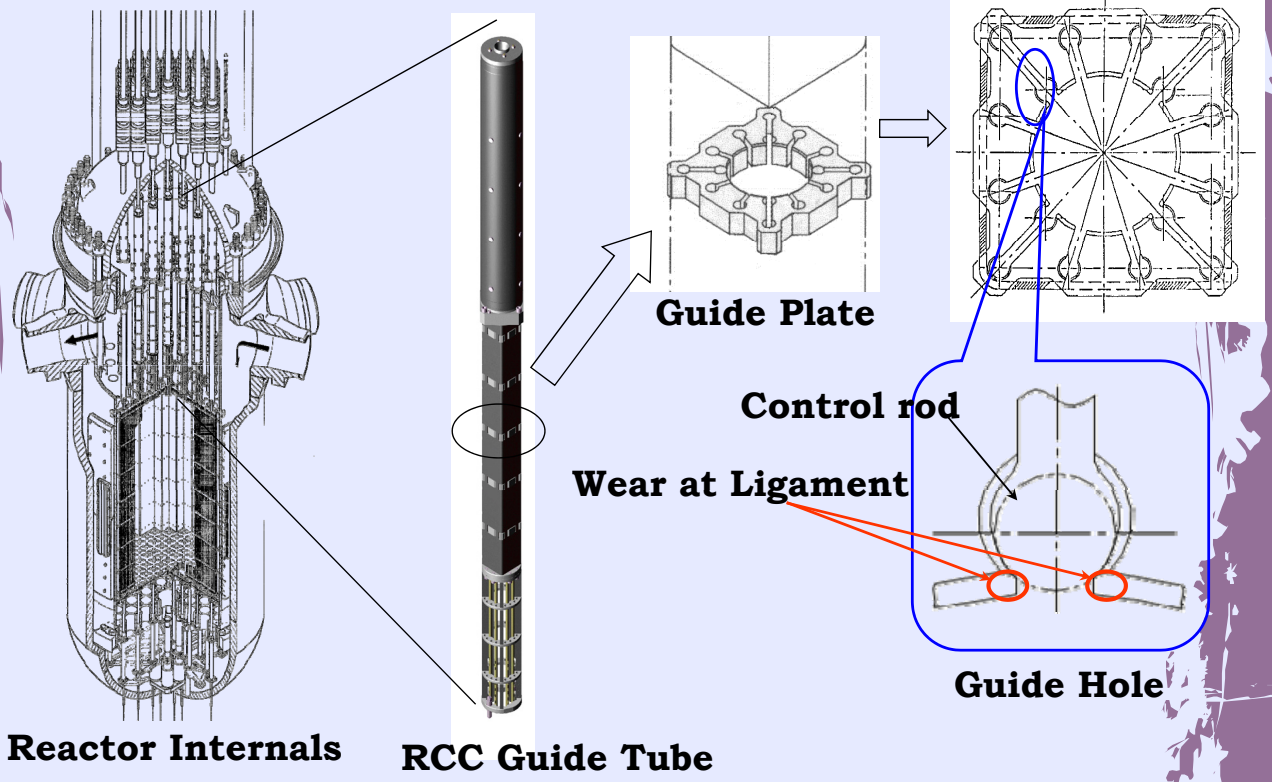
Establishment of Criteria to maintain Component Function ↔ **Structural Integrity Evaluation**
*IASCC Growth Rate
*Residual Stress
*Fracture Toughness
*Environment Condition

↓

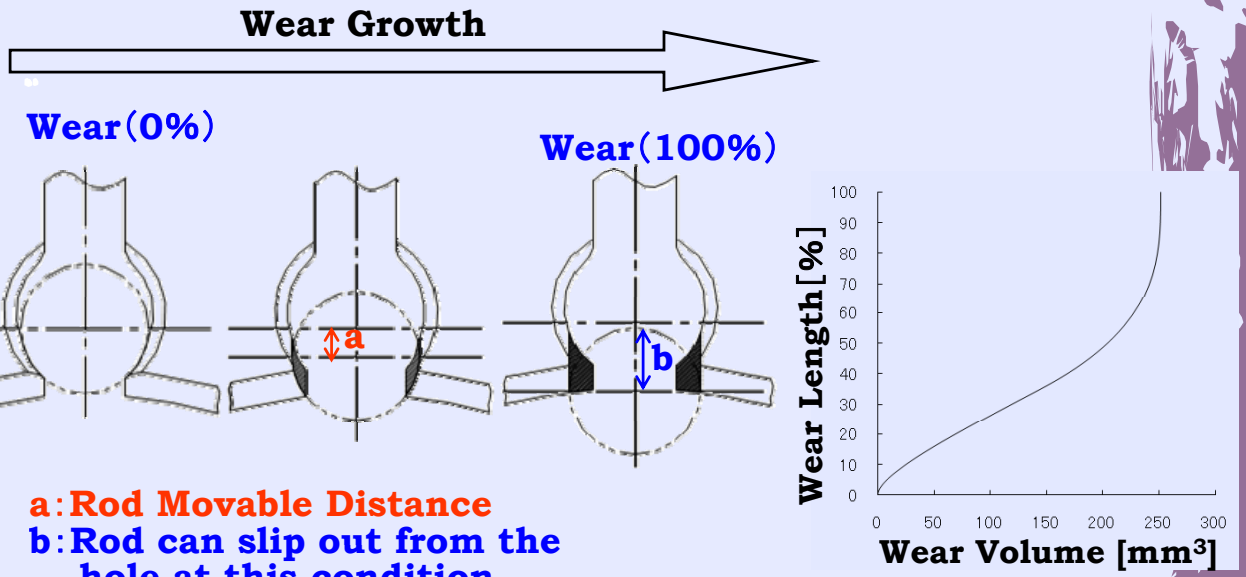
Evaluation of Acceptable Crack Size & Inspection Interval

JNES Project
Japan OG Project
JAEA Project
NISA Project

RCC Guide Tube Wear



Guide Tube Wear Growth

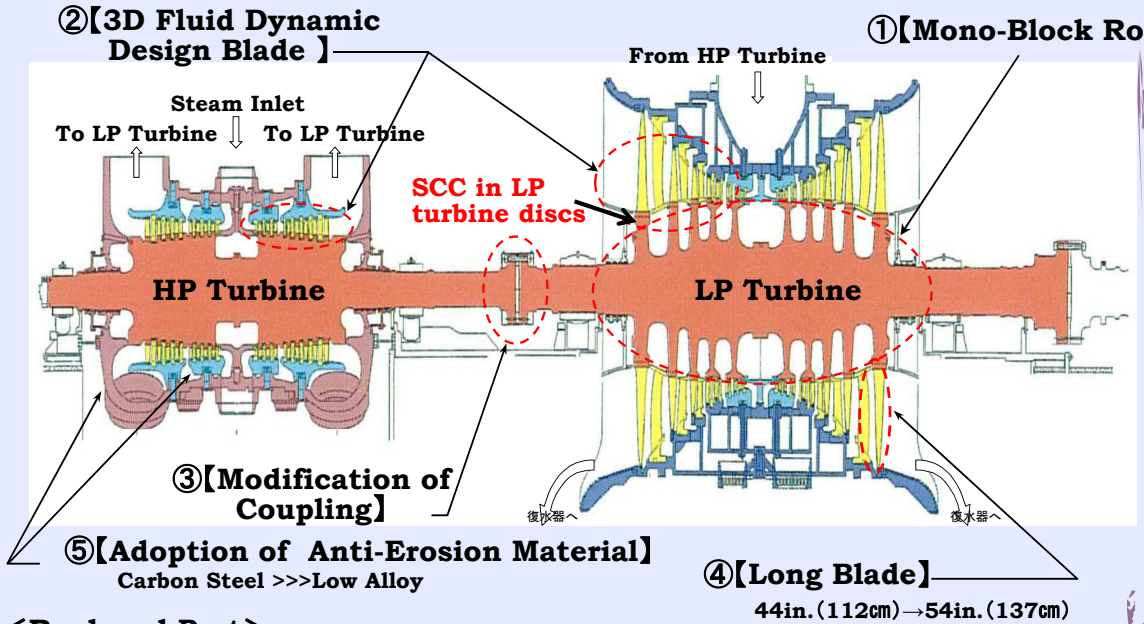


a:Rod Movable Distance
b:Rod can slip out from the hole at this condition

$$\text{Wear Length} := \frac{a}{b} \times 100\ [\%]$$

Wear Volume ∝F× S × T
F : Thrust Force
S : Sliding Speed
T : Time

SCC in LP Turbine Discs



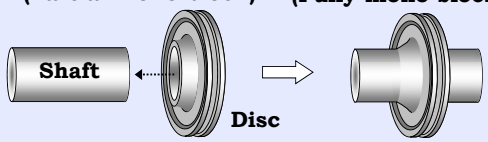
<Replaced Part>

: LP Rotor, HP Rotor
:LP Turbine Inner Casing
:Blade
:Blade Ring
:HP Turbine Outer Casing

SCC in LP Turbine Discs

① Mono-Block Rotor

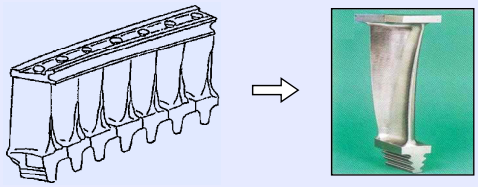
Before Replacement (Partial mono-block) | After Replacement (Fully mono-block)



Interference Fit

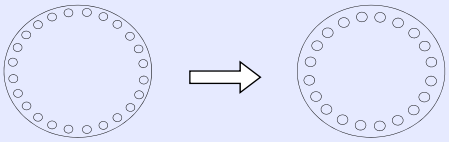
② 3D Fluid Dynamic Design Blade

Before Replacement (Parallel Blade) | After Replacement



③Modification of Coupling

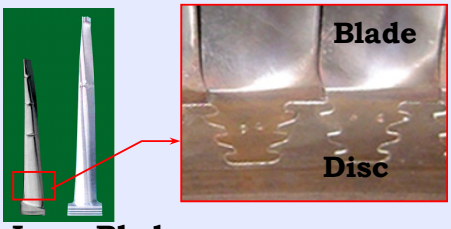
Before Replacement | After Replacement



Adoption of Bolt Tightening & Loosening by Hydraulic Pressure for Higher Maintenability

	Before Replacement	After Replacement
Bolt Hole Dia.	60mm	73mm
No. of Bolts	24	20

④Long Blade



L0 Long Blade
44in.(112㎝)⇒54in.(137㎝)

Conclusion

- It is very important to perform proactive maintenance for a long-term safe operation
- Understanding the actual condition of plant components and R&D are essential for performing the proactive maintenance in aged plants