Strategy Maps 2007 for Ageing Management

Technical cooperation among research organizations, utilities and Universities in Japan

- Infrastructure for Ageing Management -
- Domestic and International Research Cooperation -
- Database and Information Basis, Human Resources -

Naoto Sekimura, Prof., Dr.

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Department of Nuclear Engineering and Management
The University of Tokyo
A Coordinating Committee on Ageing Management was established with members from industries, utilities, research organization and regulatory authorities.
R&D Roadmaps for Ageing Management and Safe Long Term Operation

developed by Atomic Energy Society of Japan in 2004-2005

To Keep Safety and Reliability of Nuclear Power Plants for Long Term Operation

1. Establishment of Information Basis
   - Database for Degradation of Materials
     - Systematic Ageing Management Program
     - Database on Regulation Procedures In Other Countries

2. Technical Development
   - Evaluation Technology for Degradation of Components
     - IASCC
     - RPV Radiation Embrittlement

3. Codes and Standards
   - Standardization of Ageing Management Procedures
     - Schemes To Apply New Techniques
     - Performance Index

4. Systematic Maintenance
   - Optimization of Maintenance
     - Risk-based Maintenance
     - Human Resources
Development of Technical Information Infrastructure

Development of Codes and Standards

Systematic Maintenance Improvement

Safety Research & Development

Technical Evaluation Result

Latest Information

Selection of Research Theme

Research result

Latest Information

Maintenance Information
- Case Maintenance
- Operating Experience

Technical Information Infrastructure

Tacit Knowledge

Tools for Education

Human Resources
Strategy of Safety Research and Related Infrastructure for Ageing Management

- Codes and Standards
- Maintenance Engineering of Plant Systems
- Safety Research
- Technological Information Infrastructure

- Regulatory System Infrastructure
- Facility Infrastructure
- Human Resources
- Budget Support

- Strategic training of expertise human resources
- International cooperation

- Ageing technical information database
- Plant operation experience database
- Technical information network
- Knowledge management system
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   - Optimization of Maintenance
   - Risk-based Maintenance
   - Human Resources
Continuous Revision of Strategy Maps for Ageing Management by All the Stakeholders

Strategies Maps for Ageing Management

1. Introduction Scenario
   - Needs
   - Targets
   - Milestones

2. Maps of Technical Issues

3. Roadmaps

Periodic Revision through Latest Knowledge

• R&D projects
• Information Basis
• Hardware Resources
• Human Resources

Publicity

Publication

• Budgetary Actions for Research and Infrastructure
• Regulation Systems with Codes and Standards

Safety Research Sub-Committee in the Coordinating Committee on Ageing Management

Nuclear Safety Regulatory Standard Committee in NISA

2006 -
Major Roles of Industries, Government and Academia for Ageing Management

**Academia**
- Responsibility to contribute to safety research activities
  - to accumulate and expand fundamental knowledge
  - to keep human resources through the safety research

**Government**
- Responsibility to establish and improve safety regulations
  - by conducting safety researches,
  - by keeping infrastructure
- Responsibility to promote nuclear energy for national energy security

**Industries**
- Primary responsibility to keep safe operation of power plants
  - research and development, and
devlopment of the infrastructure for safety and public interests

**Academic Societies**
- To develop, review strategy maps periodically and build a consensus with experts from industries, government and academia
  - by identifying important issues to be solved
  - by discussing roles of stakeholders for rational and efficient implementation of research
- To develop and improve codes and standards based on safety research outcome
### 1. Safety Research to Solve Ageing Issues

<table>
<thead>
<tr>
<th>Aging phenomenon</th>
<th>Current Status</th>
<th>40th to 50th year</th>
<th>Long-life, next-generation reactor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irradiation embrittlement</td>
<td>* Countermeasures are being taken by rule of thumb based on plant data.</td>
<td>* Predication methods and monitoring technology will be upgraded.</td>
<td>* Advanced designs will be developed based on past operating experience.</td>
</tr>
<tr>
<td>Stress corrosion crack</td>
<td>* Countermeasures suited to materials in use are being taken.</td>
<td>* Use of SCC-resistant materials will be ensured.</td>
<td>* Simulation methods will be established.</td>
</tr>
<tr>
<td></td>
<td>* Database is being constructed.</td>
<td>* Database will be constructed.</td>
<td>* ISI technology will be upgraded.</td>
</tr>
<tr>
<td>Fatigue</td>
<td>* Countermeasures suited to materials in use or environment are being taken,</td>
<td>* Countermeasures suited to materials in use or environment will be taken, and database will be constructed.</td>
<td>* Countermeasures suited to materials in use or environment will be taken, and database will be constructed.</td>
</tr>
<tr>
<td></td>
<td>and database is being constructed.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wall thinning</td>
<td>* Countermeasures suited to materials in use are being taken, and database is being constructed.</td>
<td>* Mechanism-based predication methods will be established.</td>
<td>* Monitoring technology will be upgraded.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>* Risk-based maintenance methods will be established.</td>
<td></td>
</tr>
<tr>
<td>Deteriorated cable insulation</td>
<td>* Countermeasures suited to materials in use are being taken.</td>
<td>Deterioration diagnosis technology will be upgraded.</td>
<td>* Monitoring technology will be upgraded.</td>
</tr>
<tr>
<td></td>
<td>* Database is being constructed.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Decreased strength of concrete</td>
<td>Intensive study is being made on scarcely known fields.</td>
<td>The reliability of integrity evaluation methods will be improved or enhanced.</td>
<td>* Past records of performance will be reflected in the maintenance technology and durability designs for new plants.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CCV integrity evaluation methods will be established.</td>
<td>* Recycling methods will be established for replaced structures and materials.</td>
</tr>
</tbody>
</table>

### 2. Establishment of Codes and Standards

### 3. Establishment of Information Basis

### 4. Systematic Maintenance
**Strategy Maps 2007 for Ageing Management**

**Roadmaps for Stress Corrosion Cracking**

### 1. Integrity Evaluation : IASCC

<table>
<thead>
<tr>
<th>Fiscal Year</th>
<th>Phase I (until 40 year operation of early stage NPPs)</th>
<th>Phase II (until 50 year operation)</th>
<th>Phase III (until 60 year operation)</th>
</tr>
</thead>
</table>

- **Preparation and refinement of initiation data and crack growth data on IASCC**
- **Extended IASCC crack initiation data and its refinement**
- **Extended IASCC crack growth data and its refinement**
- **Correlation between laboratory data and field events**
- **Obtaining of crack growth data for ex-plant materials**
- **In-core IASCC initiation and growth evaluation**
- **Refurbishment of laboratory facility including JMTR**
- **Understanding of IASCC mechanism**
- **Study of accelerated irradiation validity**
- **Understanding and modeling of IASCC crack initiation and growth mechanism**
- **Study of IASCC mechanism at high fluence region**
- **Development of simulation technology of IASCC initiation and growth**
- **Establishment of code and standards, and regulatory criteria**
- **IASCC integrity evaluation guide**
- **Establishment of CS for fitness-for-service**
- **Coding of IASCC initiation and growth simulation**
- **SCC long term integrity evaluation guide**

### 2. Integrity Evaluation : IGSCC

### 3. Integrity Evaluation : NiSCC

### 4. Inspection Technologies on SCC

### 5. Monitoring Technologies on SCC

### 6. Repair & Replacement Technologies
### Strategy Maps 2007 for Ageing Management

#### Roadmap of Research and of Code Development for IASCC

<table>
<thead>
<tr>
<th>Fiscal Year</th>
<th>Phase I (until 40 year operation of early stage NPPs)</th>
<th>Phase II (until 50 year operation)</th>
<th>Phase III (until 60 year operation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>IASCC initiation test methods</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2006</td>
<td>Extended IASCC crack initiation data and its refinement</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2007</td>
<td>Preparation of infrastructure for IASCC research</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2008</td>
<td>Preparation and refinement of initiation data and crack growth data on IASCC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2009</td>
<td>In-core IASCC initiation and growth evaluation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2010</td>
<td>Extended IASCC crack growth data and its refinement</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2011</td>
<td>Correlation between laboratory data and field events</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2012</td>
<td>Obtaining of crack growth data for ex-plant materials</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2013</td>
<td>Refurbishment of laboratory facility including JMTR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2014</td>
<td>Study of accelerated irradiation validity</td>
<td>Study of IASCC mechanism at high fluence region</td>
<td></td>
</tr>
<tr>
<td>2015〜2019</td>
<td>Understanding and modeling of IASCC crack</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2020〜2029</td>
<td>Study of IASCC mechanism at high fluence region</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2021</td>
<td>Establishment of CS for fitness-for-service</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2022</td>
<td>Development of simulation technology of IASCC initiation and growth</td>
<td>Establishment of CS for fitness-for-service</td>
<td></td>
</tr>
<tr>
<td>2023</td>
<td>IASCC integrity evaluation guide</td>
<td>Coding of IASCC initiation and growth simulation</td>
<td></td>
</tr>
<tr>
<td>2024</td>
<td>Establishment of CS for fitness-for-service</td>
<td>SCC long term integrity evaluation guide</td>
<td></td>
</tr>
<tr>
<td>2025</td>
<td>Establishment of CS for fitness-for-service</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2026</td>
<td>Establishment of CS for fitness-for-service</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2027</td>
<td>Establishment of CS for fitness-for-service</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2028</td>
<td>Establishment of CS for fitness-for-service</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2029</td>
<td>Establishment of CS for fitness-for-service</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Strategy Maps 2007 for Ageing Management Scenarios(1)

- Ageing Management Technical Evaluation for Every 10 Years -

- Increase in number of plants
- From initial plants to standardized plants

Note: This figure is drawn assuming that all of the plants currently in service will continue their operation.

First plant to exceed 40 years of operation
First plant to exceed 50 years of operation
### JNES Projects for Ageing Management

<table>
<thead>
<tr>
<th>Category</th>
<th>Major Projects</th>
<th>JFY</th>
<th>Prids</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety Research on evaluation of NPP</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Environmental Fatigue Tests of NPP</td>
<td></td>
<td>1994-2006</td>
</tr>
<tr>
<td></td>
<td>Materials for Reliability Verification (EFT)</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Integrity Assessment of Flawed Components with Structural Discontinuity (IAF)</td>
<td></td>
<td>2001-2007</td>
</tr>
<tr>
<td></td>
<td>Assessment of Cable Aging for Nuclear Power Plant (ACA)</td>
<td></td>
<td>2002-2008</td>
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<tr>
<td></td>
<td>Evaluation Methodology of Crack Growth Rate for Ni-based Alloys (NISCC)</td>
<td></td>
<td>2000-2009</td>
</tr>
<tr>
<td></td>
<td>Evaluation of Irradiation Assisted Stress Corrosion Cracking (IASCC)</td>
<td></td>
<td>2000-2008</td>
</tr>
<tr>
<td></td>
<td>Intergranular Stress Corrosion Cracking of Nuclear Grade Stainless Steel (IGSCC)</td>
<td></td>
<td>2003-2007</td>
</tr>
<tr>
<td>Maintenance &amp; Repair</td>
<td>Repair Welding Technology of Irradiated Materials (WIM)</td>
<td></td>
<td>1997-2010</td>
</tr>
<tr>
<td></td>
<td>Nuclear Power Plant Material Improvement Technology (PMT)</td>
<td></td>
<td>1996-2003</td>
</tr>
<tr>
<td>Inspection and Monitoring</td>
<td>Nondestructive Inspection Technologies for Core Shroud Integrity Assessment (NSA)</td>
<td></td>
<td>2003-2006</td>
</tr>
<tr>
<td></td>
<td>Nondestructive Inspection Technologies on Ni-based Alloy Welded Joint (NNW)</td>
<td></td>
<td>2002-2008</td>
</tr>
<tr>
<td></td>
<td>Nondestructive Inspection Technologies for the Narrow Penetrations on Reactor Vessel (NPV)</td>
<td></td>
<td>2005-2008</td>
</tr>
<tr>
<td>Seismic Safety</td>
<td>Development of Seismic Safety Evaluation Method on Aged Nuclear Facilities</td>
<td></td>
<td>2004-2006</td>
</tr>
</tbody>
</table>
Examples of the results obtained from ACA project

Simultaneous aging characteristics of the XLPE insulator made by A company

Simultaneous aging characteristics of the FR-EPR insulator (black core) made by A company

Major results obtained from ACA project

- Progress of degradation may be significantly different among various manufacturers, even for the same kind of insulator.
- There were some cables that indicated significantly rapid progress of degradation at low dose during simultaneous aging, and many other cables also indicated relatively rapid progress of degradation during simultaneous aging.
Industrial Efforts to Promote PLM-related R&D Activities *

Technology information coordination committee

Chairman and deputy chairman of promotion council board participate in the committee.

PLM research promotion council board
【Policies regarding research promotion】
[Secretariat: JANTI (FEPCO)]

PLM research administrative review meeting
【Discussing research strategies】
[Secretariat: CRIEPI]

Evaluation results
Providing future directions

10 Sub Group (SG): Examination team
【Individual Issues.】

* Kamada et al; this Symposium

Electric power companies, manufacturers and organizations that are involved in the support system

Nine electric power companies, JAPC, Electric Power Development CO., CRIEPI and JANTI
Research Project on Fundamentals of Ageing Management (NISA funds)

NISA (Nuclear and Industrial Safety Agency) in METI

Tohoku Cluster ICR

Fukui Cluster INSS

East Japan Cluster MRI

Ibaraki Cluster JAEA

Technical Information Coordination Committee Safety Research WG In JNES

Information Exchange

Progress Report Advice

Outcome

General Review Session on Ageing Management Infrastructure Improvement

General Review Session WG

Review Session on Ageing Management Database and Knowledge Base

Review Session on Seismic Effects on Piping Thinning

Review Session on Condition Monitoring and Safety Preservation Technology

Review Session on Irradiation Embrittlement

Review Session on Cable Degradation

Review Session on Stress Corrosion Cracking

Academic Societies etc.

Information Exchange

Progress Report Advice
Development of New Embrittlement Correlation

• Fundamental study on the embrittlement mechanisms
  – Nano-structural characterization by experiments
  – Multiscale computer simulation of microstructural evolution

• Mechanism-guided embrittlement correlation
  – Surveillance data in Japan
  – New approach using rate equations in predicting microstructural changes
Hierarchical Structure of Degradation of Materials for Light Water Reactors

Effects of Radiation in Nuclear Materials and Ageing Management of Nuclear Systems

Radiation Damage Processes

- Nuclear Reaction Phase
- Collisional Phase
- Cooling Phase
- Thermal Phase
- Diffusional Phase
- Microstructure
- Property Changes
- Lifetime Optimization

Evaluation Methodologies

- NPRIM Code
- Binary Collision Approximation
- Molecular Dynamics
- Monte-Carlo Simulation
- Analytical Diffusion & Reaction Rate Equations
- Dislocation Dynamics
- Post Irradiation Tests

N. Sekimura (1994)
Multi-scale Computer Simulation

Molecular Dynamics
Displacement cascade

Kinetic Monte Carlo
Microstructural evolution during irradiation

~10^{-11} \text{sec}
~10^{-8} \text{m}

Point defect production

Molecular Dynamics
Vacancies
Cu atoms

Detailed analysis of microstructure

Dislocation Dynamics
Dislocation behavior during deformation

~10^{9} \text{sec}
~10^{-7} \text{m}

Radiation damage

Dislocation Dynamics
Interaction between dislocation and damage

~10^{9} \text{sec}
~10^{-4} \text{m}

Dislocation loop

Dislocation Dynamics
Prediction of mechanical property

~10^{9} \text{m}

Stress (MPa)

Irradiated

Unirradiated

Strain (%)
Nano-structural Characterization

3-Dimensional Atom Probe

Cu-enriched clusters formed by neutron irradiation

LEAP (Local Electrode Atom Probe)

~40 nm

~300 nm

Normalized counts of gamma rays

Electron momentum

Positron Annihilation (Coincidence Doppler Broadening)

thermally aged

Irradiated

unirradiated
\[ \Delta T = \sqrt{\left(\Delta T_{SC} \right)^2 + \left(\Delta T_{MD} \right)^2} \]

\[ \Delta T_{SC} = \xi_{17} \cdot \sqrt{V_f} = \xi_{17} \cdot \sqrt{\xi_{16} \cdot f \left( C_{Cu}^{\text{mat}}, C_{SC} \right) \cdot g \left( C_{Ni}^0 \right) + h \left( \phi t \right) \cdot \sqrt{C_{SC}}} \]

\[ \frac{\partial C_{SC}}{\partial t} = \xi_4 \cdot \left( \left( C_{Cu}^{\text{mat}} + \xi_1 \right) \cdot D_{Cu} + \xi_2 \right) \cdot C_{MD} + \xi_9 \cdot \left( C_{Cu}^{\text{avail}} \cdot D_{Cu} \cdot \left( 1 + \xi_8 \cdot C_{Ni}^0 \right) \right)^2 \]

\[ \frac{\partial C_{MD}}{\partial t} = \xi_5 \cdot F_t^2 \cdot \left( \xi_6 + \xi_7 \cdot C_{Ni} \right)^2 \cdot \phi - \frac{\partial C_{SC}}{\partial t} \]

\[ \frac{\partial C_{Cu}^{\text{mat}}}{\partial t} = -v_{SC} \cdot \frac{\partial C_{Sc}^{\text{enh}}}{\partial t} - v'_{SC} \cdot C_{SC} \]

\[ D_{Cu} = D_{Cu}^{\text{thermal}} + D_{Cu}^{\text{irrad}} = D_{Cu}^{\text{thermal}} + \eta_1 \cdot \phi^{\eta_2} \]

\[ \Delta T_{MD} = \xi_{18} \cdot \sqrt{C_{MD}} \]

\[ \frac{\partial C_{MD}}{\partial t} = \xi_5 \cdot F_t^2 \cdot \left( \xi_6 + \xi_7 \cdot C_{Ni} \right)^2 \cdot \phi - \frac{\partial C_{SC}}{\partial t} \]
Comparison of DBTT shift between the measured value and the prediction

<table>
<thead>
<tr>
<th>Method</th>
<th>Std. Dev.</th>
<th>Mean Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>JEAC4201</td>
<td>11.9</td>
<td>-1.3</td>
</tr>
<tr>
<td>RG1.99r2</td>
<td>15.4</td>
<td>-1.9</td>
</tr>
<tr>
<td>EWO</td>
<td>10.4</td>
<td>2.8</td>
</tr>
<tr>
<td>E900-02</td>
<td>11.7</td>
<td>2.3</td>
</tr>
<tr>
<td>CRIEPI</td>
<td>9.4</td>
<td>0.7</td>
</tr>
<tr>
<td>CRIEPI adj</td>
<td>5.4</td>
<td>0.1</td>
</tr>
</tbody>
</table>
RVH nozzle environmental shielding weld (seal welding over cracking)

Applying corrosion resistant Inconel 690 overlay weld directly over through-wall cracking

RVH nozzle penetration repair technique

The structure and application of Inconel 690 repair weld have been approved by the verification committee, RTTW committee and CRT committee.

Repair welding machine

Repair weld applied to through-wall cracking in J-groove weld
# History of Troubles and Preventive Maintenance of RVH

<table>
<thead>
<tr>
<th>1980</th>
<th>1990</th>
<th>2000</th>
<th>Present</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Trouble</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Preventive Maintenance</strong></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>R/V</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;head penetration nozzle&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;BMI nozzle&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ECT of R/V head penetration nozzle</td>
<td>Replacement of R/V head</td>
<td>Replacement of R/V head (Takahama3.4,Ohi3.4)</td>
<td></td>
</tr>
<tr>
<td>Reduction of R/V head top temperature (Takahama3.4,Ohi3.4)</td>
<td></td>
<td>WJP of BMI nozzle (weld metal)</td>
<td></td>
</tr>
<tr>
<td>UT (angle beam,longitudinal wave) of safe-end welds of nozzle (R/V,Pressurizer,S/G)</td>
<td></td>
<td>WJP / ECT of BMI nozzle (base metal)</td>
<td></td>
</tr>
<tr>
<td>R/V,Pressurizer,S/G</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;Safe-end welds of nozzle&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R/V</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;Safe-end welds of nozzle&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

S/G

|        |            |                               |                   |
| <Tube> |            |                               |                   |

| Replacement of S/G(MA600→TT690) | | Intelligent ECT of tube of S/G (TT600) |                   |

| Shot-peening of tubes of S/G (TT600) | | |                   |
# Reactor Vessel Head Nozzle Maintenance

<table>
<thead>
<tr>
<th>Year</th>
<th>Older Plants</th>
<th>New Plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995</td>
<td>▼Bugey 3 Leak (1991) (France)</td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td>▼Davis-Besse Leak (2002)</td>
<td></td>
</tr>
<tr>
<td>2010</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2015</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Older Plants**
  - Mihama 1,2,3
  - Takahama 1,2
  - Ohi 1,2

- **New Plants**
  - Takahama 3,4
  - Ohi 3,4

Preventive maintenance (T-Cold) has been conducted at new plants with a lower possibility of PWSCC in order to mitigate PWSCC susceptibility.

ECT had been conducted at old plants with a relatively high possibility of PWSCC.

VH had been replaced at old plants with a relatively high possibility of PWSCC.

Replacement of VH is also planned for new plants.

- Change of nozzle Base & J-Weld material: Alloy 600 → Alloy 690 (Improved corrosion resistance)

Increased plug hole diameter
1. Purpose

- Mitigation of SCC for pipes or cylindrical equipments

2. Effect

- Residual Stress Improvement for weld joints and HAZ on the inner surface

3. Experiences

- BWR Plants in Japan

HAZ : Heat Affected Zone
Development of a laser peening system for core shroud.

Application for Japanese nuclear reactors (BWR) since 1999.

Development and application of a fiber-delivered system since 2002.

Experiences in BWRs: 8 plants.
- CRD Stub Tubes: 4 plants
- Core Shroud: 5 plants

PWR Applications since 2004: 2 plants.

Fiber-delivered Laser Peening System Application for CRD Stub Tubes (BWR)
## Road Map: Examples of R&D and Good Practices

### Experiences and Countermeasures of SCC in PLR Piping

<table>
<thead>
<tr>
<th>Major Events</th>
<th>‘70</th>
<th>‘80</th>
<th>‘90</th>
<th>‘00</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Materials Improvements</strong></td>
<td>Type 304</td>
<td>Type 304L</td>
<td>Type 316(LC)</td>
<td></td>
</tr>
<tr>
<td><strong>Stress Improvements</strong></td>
<td>Induction Heating Stress Improvement, Heat Sink Welding, Corrosion Resistance Cladding</td>
<td></td>
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<tr>
<td><strong>Environment Improvements</strong></td>
<td>Start-up deaeration Operation, Hydrogen injection, Noble metal chemical addition</td>
<td></td>
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<tr>
<td><strong>Replacement Repair</strong></td>
<td>Except main piping, Main piping, To expand whole type 316L</td>
<td></td>
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</tr>
<tr>
<td><strong>Major R&amp;D</strong></td>
<td>Development of low carbon SS, Development of Countermeasures to SCC, Development of Hydrogen injection, PMT, WIM (JAPEIC/JNES projects)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- SCC of type 304 piping, oversea & domestic NPP
- SCC of type 316L piping, domestic NPP
- SCC of type 304L shroud, oversea NPP
- UT indication ▼ at PLR Piping, H-3 NPP
- After NP 2F-2

Experiences and Countermeasures of SCC in PLR Piping

Proprietary Information
Cooperation with International Organizations

- **IAEA**
  Ageing Management Guideline (for aged NPP)

- **OECD/NEA**
  SCAP SCC and Cable Ageing Project
  IAGE Metal-Concrete-Earthquake Resistance-HF Steering Group
  OPDE OECD Pipe failure Data Exchange Project

- **USA**
  NRC PINC Project
  ASME Sec.XI Code Committee
  IEEE Cable Environmental Qualification Test

- **IEC**
  Radiation Effect Interpretation (Judgment) Criteria
U.S. Nuclear Regulatory Commission (USNRC) proposed international cooperative research Project for the Inspection of Nickel-alloy Components (PINC).

And Five country eight organizations are participating in PINC to address common problem.

**Project Organization**

- **TG-Atlas**
  - Develop an electronic Atlas (database) of NDE and metallography information

- **TG-NDE**
  - Round Robin of NDE techniques on PWS CC and simulated cracks

Davis-Besse Reactor Vessel Head Degradation
Round Robin Test in TG-NDE

Performance to detect PWSCC will be clarified and the results will be reflected to regulatory guidelines and process qualifications by NDI test of CRDM, BMI, Safe-end dissimilar metal welds.

Sample of CRDM TPs

Sample of BMI TPs

Sample of DMW TPs
OECD/NEA SCAP Project *

SCAP: Stress Corrosion Cracking and Cable Ageing Project

- The main objectives of SCAP are to:
  - Establish a complete database with regard to major ageing phenomena for SCC and degradation of cable insulation through collective efforts by OECD/NEA members
  - Establish a knowledge-base by compiling and evaluating collected data and information systematically, with regard to major ageing phenomena for SCC and degradation of cable insulation
  - Perform an assessment of the data and identify the basis for commendable practices which would help regulators and operators to enhance ageing management

*This project is being financed through Japanese voluntary contribution*
Management of the SCAP

Management Board

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(Japan)

SCC WG

SCC Chair
Mrs. Gott (Sweden)

Clearing House
ERIN (U.S)

Cable WG

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Clearing House
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IFE (Norway)

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- Canada
- Czech Republic
- Finland
- France
- Germany
- Japan
- Korea
- Mexico
- Norway
- Slovak Republic
- Spain
- Sweden
- U.S

(Observers)
IAEA, EC