Reductions in Occupational Dose

INPRO Dialogue Forum

November 19-23, 2013

Kenichi Yasuda
Senior Engineer, Hitachi GE
Indicator IN3.1.1: *Occupational dose values*

**User requirement UR3.1:** INS installations should ensure an efficient implementation of the concept of optimization of radiation protection for workers through the use of automation, remote maintenance and operational experience from existing designs.

**Acceptance Limit of IN3.1.1:**
Less than limits defined by national laws or international standards and so that the health hazard to workers is comparable to that from an industry used for a similar purpose.
1. Basic Concept of Dose Reduction
2. ABWR Design Feature for Dose Reduction
3. Source Term Reduction
4. Radioactive corrosion product concentration reduction
5. Automatic equipment for maintenance and inspection
6. Latest ABWR experience
7. Summary
1. Basic Concept of Dose Rate Reduction
(Formation and Migration of Radioactivity in BWR)

Generation
Structural Material

Radioactivation
Fuel Rod

Deposition
RRS piping

Feed water

Corrosion (heater, valve)

Dissolution

Corrosion (Component, Fuel)

Dissolution

Removal in CUW

59Co crud

59Co ion

Fe

59Co crud

59Co ion

59Co crud

59Co ion

60Co crud

60Co ion

Iron acts as "glue" for Co deposition on fuel cladding

Corrosion

Activation

Dissolution

Deposition

oxide film

piping and component

Removal in
CUW

Iron acts as "glue" for Co deposition on fuel cladding

Radiation

Exposure
1.2 Basic Concept of Dose Rate Reduction

Occupational Exposure

Person-Sv = S(Dose rate × Number of workers × Working time)

Dose Rate-Governing Equation

Radioactivity deposition rate on piping and components
= Radioactivity in reactor water × Deposition rate coefficient

Requirement for Dose Rate Reduction

• Reduce radioactivity in reactor water
• Diminish deposition rate coefficient of piping and components
• Remove deposited radioactivity at beginning of outage
2. ABWR Design Feature for Dose Reduction (1)

• RIP and FMCRD adopted in ABWR contribute improvement of maintenance and reduction of occupational dose.
2. ABWR Design Feature for Dose Reduction (2)

Recirculation Internal Pump (RIP)

Improvement of maintenance and reduction of occupational dose are achieved by adopting RIP

- Dose source of recirculation system piping removed
- In Service Inspection for recirculation piping weld eliminated
- No high activity Recirculation System valves to maintain and test
2. ABWR Design Feature for Dose Reduction (3)

Fine Motion Control Rod Drive (FMCRD)

Two piece design in mechanical portion (Upper components & spool piece)

- Improved maintainability reduces personnel dose (Components to be maintained are limited at spool piece only)
- If FMCRD main body is dismounted, FMCRD is dismounted by handling machine and water inside FMCRD is drained by it.

Clean water purge flow

- Radiation exposure is less than conventional BWRs driven by reactor coolant
3.1 Source Term Reduction  
(Implementation of Low Co Materials and Effectiveness of Co Reduction)

Corrosion production reduction by water quality control and material selection

- Water Chemistry Control
- Material Selection

Diagram labels:
- Alternate material for Stellite\(^{(R)}\)
- Low cobalt content stainless steel (Co<0.05%)
- HP turbine
- LP turbine
- Generator
- Condenser
- Oxygen Injection
- Water chemistry control
- Low cobalt content stainless steel (Co<0.05%)
- Moisture separator
- Fe control
- Dual condensate polishing system
- Corrosion resistant steel

Notes:
- HP: high pressure
- LP: low pressure
3.2 Source Term Reduction
(Implementation of Low Co Materials and Effectiveness of Co Reduction)

<table>
<thead>
<tr>
<th>Material</th>
<th>Inconel(^{(R)})</th>
<th>Stainless</th>
<th>Stellite(^{(R)})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional</td>
<td>0.22%</td>
<td>0.25%</td>
<td>45-64%</td>
</tr>
<tr>
<td>Low Co</td>
<td>≤0.05%</td>
<td>≤0.05%</td>
<td>≤1.0%*</td>
</tr>
</tbody>
</table>

*: alternate material

<table>
<thead>
<tr>
<th>Material</th>
<th>Component</th>
<th>Applied</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inconel</td>
<td>Spacer spring in fuel</td>
<td>○</td>
</tr>
<tr>
<td></td>
<td>Others</td>
<td>○</td>
</tr>
<tr>
<td>Stainless</td>
<td>CR sheath</td>
<td>○</td>
</tr>
<tr>
<td></td>
<td>CR tube</td>
<td>○</td>
</tr>
<tr>
<td></td>
<td>HP feedwater heater tube</td>
<td>○</td>
</tr>
<tr>
<td></td>
<td>LP feedwater heater tube</td>
<td>× (Small contribution)</td>
</tr>
<tr>
<td>Stellite</td>
<td>CR pin, Roller</td>
<td>○</td>
</tr>
<tr>
<td></td>
<td>Valve etc</td>
<td>△ (Partial)</td>
</tr>
</tbody>
</table>

Low Co materials are applied to the large contribution parts of the plant.

Copyright 2013 Hitachi GE Nuclear Energy, Ltd - All rights reserved
4.1 Radioactive corrosion product concentration reduction (Fe Control Methods Adopted in ABWR)

<table>
<thead>
<tr>
<th>Item</th>
<th>① CF Bypass</th>
<th>② LPHD mixed in CD Downstream</th>
<th>③ Fe injection into Feedwater</th>
</tr>
</thead>
<tbody>
<tr>
<td>Method</td>
<td>Easy to operate after stabilizing of CD iron removal efficiency</td>
<td>Effective for increasing small amount of Fe - Rigid</td>
<td>Flexible, Easy - Short term, Auxiliary</td>
</tr>
<tr>
<td>Feature</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Range of Fe conc. control</td>
<td>0.3-1ppb</td>
<td>0.4-0.5ppb</td>
<td>0.1-1ppb</td>
</tr>
</tbody>
</table>

- Flexible, Easy
- Short term, Auxiliary
4.2 Radioactive corrosion product concentration reduction

\((^{58}\text{Co} \& ^{60}\text{Co Conc. in Reactor Water})\)

Lower \(^{58}\text{Co}\) and \(^{60}\text{Co}\) concentration was experienced under optimum iron concentration control in feedwater.

5.1 Automatic equipment for maintenance and inspection (1)

• To reduce radiation exposure, Hitachi-GE has developed many remote-automatic maintenance and inspection equipment based upon proven robotic technologies.
• As an example, CRD handling equipment and in-service inspection equipment are introduced below.

CRD Handling Equipment

• During the outage, FMCRD is inspected and maintained.

• FMCRD handling work is performed with the CRD handling Equipment installed under vessel for its assembling and disassembling.

• Then, the disassembled FMCRD is inspected and maintained with the Maintenance Equipment.
In-Service Inspection Equipment

- This equipment is used to detect defects on the outer RPV (body, support skirts, flanges, nozzles and their corners), pipes and RIP nozzles by using ultrasonic probes.
5.1 Latest ABWR experience
(Comparison of Dose Rate in PCV)

Latest ABWR showed extremely low dose rate in PCV.

5.2 Latest ABWR experience
(Occupational exposure of ABWR)

- Additional modification or replacement
- Standard inspection (BWR-5)
- Standard inspection (ABWR)

**Estimated equilibrium levels of ABWR**

Expected ABWR occupational exposure of equilibrium state has been estimated to be around 0.5 person-Sv.

6. Summary

- RIP and FMCRD adopted in ABWR contribute improvement of maintenance and reduction of occupational dose.

- Corrosion production reduction by material selection and water quality control.
  - Low Co materials are applied to the large contribution parts of the plant.
  - Lower $^{58}$Co and $^{60}$Co concentration was experienced under optimum iron concentration control in feedwater in latest ABWR.

- To reduce radiation exposure, Hitachi-GE has developed many remote-automatic maintenance and inspection.

- The occupational dose expected at the outage after reaching equilibrium state has been estimated to be around 0.5 person-Sv in latest ABWR. This value is sufficiently low level compared with the worldwide statistics.

- In conclusion, ABWR is evaluated to meet AL3.1.1.
Supplement: Small Radiation Exposure in BWR Turbine

Actual dose rate at Turbine Building operating floor under normal operation is as low as that of non-controlled areas.

Dose Rate Classification

<table>
<thead>
<tr>
<th>Classification</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-controlled Area</td>
<td>A ≤ 0.006 mSV/h</td>
</tr>
<tr>
<td>Controlled Area</td>
<td>B &lt; 0.01 mSV/h</td>
</tr>
<tr>
<td></td>
<td>C &lt; 0.05 mSV/h</td>
</tr>
<tr>
<td></td>
<td>D &lt; 0.25 mSV/h</td>
</tr>
<tr>
<td></td>
<td>E &lt; 1 mSV/h</td>
</tr>
<tr>
<td></td>
<td>F ≥ 1 mSV/h</td>
</tr>
</tbody>
</table>

Through N-16, that is a radiation product of oxygen, go to turbine with steam, it’s half life of 7.1 seconds. ⇒ *Dose rate is negligible small*

The above classification is established in accordance with shield design reference dose rates assuming frequency of access to and time spent in each area.