Radiological Characterization of V1 NPP Technological systems & Buildings - Activation

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V1 NPP at Jaslovske Bohunice site

V1 NPP decommissioning:

- 2 WWER type reactor 440/230 units
- Operation: Unit 1 in 1978 – 2006, Unit 2 in 1980 - 2008,
- Since 2001 D&D preparation supported by Bohunice International Decommissioning Support Fund (BIDSF)
- At present: units finally shutdown, since July 2011 under decommissioning license
BIDSF Project B6.4
“Decommissioning Database”

Project purpose: Physical and radiological inventory database development to support V1 NPP decommissioning

Performed by: EWN GmbH, STM Power and AMEC Nuclear Slovakia

Project period: 2008 – 2011

Project tasks:
1. DDB design
2. Historical site assessment
3. Physical inventory – plan and performance
4. Sampling and analysis - plan and performance
5. Hazardous material inventory
6. **Activation inventory** - Characterization of Activated Components Based on Measurement and Sampling
7. Radiological inventory

**Scope of inventory:**
- Nearly 100 civil objects
- 175 technological systems
- Over 40 parameters for each DDB item - identification, physical and radiological properties
Subject of Activation Inventory

Dose Rate Measurement and Sampling

Civil structures from reactor shaft on both units
- stainless steel cladding
- standard concrete, baryte concrete

Reactor internal components placed in V1 NPP HLW storage
- connection rods
- absorbers of control rod assemblies
- neutron flux measurement channels

Reactor
- RPV – both units

Shielding assemblies – both units

Storage grids of spent fuel cooling ponds
- Reactor internals – Unit 2

Works carried out in period from 04/2011 to 12/2011
Radiological Characterization of Activated Components

Scope of services:
1. Categorization of activated components – totally 112 samples planned
2. Development of single working programs for radiological monitoring and sampling
3. Preparation of sampling device & revision of NPP handling equipment
4. Dose rate monitoring and sampling
5. Analyses of samples: gammaspectrometry, radiochemical analyses; γ RA nuclides & limited RA nuclides for Mochovce repository
6. Determination of radiological inventory: activation values (Bq), RNV, dose rates
7. Import of radiological data for activated components into DDB
Sampling of activated civil structures in reactor concrete shaft of Unit 1 and 2

Number of drills: 8
(1-4 at Unit 1, 5-8 at Unit 2)

Sampling depth: 20 – 40 cm

Manual drilling device

Results:
• major activation RA nuclides: Fe-55, H-3, Co-60, Eu-152, Eu-154, Cs-134, Ba-133, Ni-59, Ni-64, C-14

• contamination of concrete by Cs-137

• Division of concrete to 9 layers/unit (along RPV concrete shaft height)
Sampling of activated concrete – results

V1 NPP concrete radiological inventory determined for 1.1.2010:

<table>
<thead>
<tr>
<th>Material</th>
<th>Standard concrete</th>
<th>Baryte concrete</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activity (Bq)</td>
<td>1,58E+09</td>
<td>6,41E+08</td>
<td>2,22E+09</td>
</tr>
<tr>
<td>Mass (kg)</td>
<td>344 166</td>
<td>86 490</td>
<td>430 656</td>
</tr>
</tbody>
</table>

RNV – activated concrete for Unit 1:

Concrete

- Cs-137: 0.02%
- Cs-134: 0.41%
- Ni-63: 1.55%
- Co-60: 3.98%
- Fe-55: 16.33%
- C-14: 0.10%
- H-3: 56.93%
- Eu-152: 18.66%

Baryte concrete

- Fe-55: 91.66%
- Cs-134: 0.13%
- Cs-137: 0.05%
- Eu-152: 1.66%
- H-3: 1.69%
- Eu-154: 0.32%
Sampling of activated components in V1 NPP HLW storage (1)

V1 NPP HLW storage (399 cells):
- 157 absorbers of safety and control rod assemblies (ABS)
- 217 connection rods of safety and control rod assemblies (CR)
- over 330 pc of neutron flux measurement channels (KNI)

Procedure:
1. Categorization of stored components – 40 components selected
2. Remotely controlled sampling equipment used
3. Existing NPP equipment for manipulation – transport containers for components
Sampling of activated components in V1 NPP HLW storage (2)

Sampling procedure in HLW storage:

- Remote-controlled equipment with drilling head on linear guiway, sample suction into carrousel
- **80 samples taken** from selected components (ABS, CR, KNI) – swarfs
- Sample mass from 0.6 mg to 900 mg
- **Dose rate monitoring** along the height of component – up to 30 Sv/h at sampling spot
Sampling of activated connection rod in V1 NPP HLW storage - video
Sampling of activated components in V1 NPP HLW storage – results (1)

<table>
<thead>
<tr>
<th>Category</th>
<th>Dose rate interval [mSv/h]</th>
<th>Assignment of activated component part into category</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>CR A-type</td>
</tr>
<tr>
<td>MOG1</td>
<td>$10^2 - 10^3$</td>
<td>Bottom part 0 – 60 cm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CR B-type</td>
</tr>
<tr>
<td>MOG2</td>
<td>$10^2 - 10^1$</td>
<td>Part 60 – 120 cm from the bottom</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Absorber</td>
</tr>
<tr>
<td>MOG3</td>
<td>$10^1 - 10^{-1}$</td>
<td>CR rest part (360 cm)</td>
</tr>
</tbody>
</table>

CR A-type: from group VI. of controlled rod assemblies – inserted partially in the core

CR B-type: CR from other groups of controlled rod assemblies – occasionally in the core

Absorber

KNI channel
Sampling of activated components in V1 NPP HLW storage – results (2)

Total inventory of CR, ABS and KNI channels placed in V1 NPP HLW storage on due date 1.8.2011:

<table>
<thead>
<tr>
<th>Material</th>
<th>Connection rods</th>
<th>Absorbers</th>
<th>KNI channels</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOG1</td>
<td>1,07E+15</td>
<td>273</td>
<td>1,94E+15</td>
<td>4 023</td>
</tr>
<tr>
<td>MOG2</td>
<td>2,22E+14</td>
<td>1 526</td>
<td>3,65E+13</td>
<td>4 023</td>
</tr>
<tr>
<td>MOG3</td>
<td>8,36E+13</td>
<td>11 717</td>
<td>1,01E+13</td>
<td>10 637</td>
</tr>
<tr>
<td>TOTAL</td>
<td>1,38E+15</td>
<td>13 516</td>
<td>1,99E+15</td>
<td>18 683</td>
</tr>
</tbody>
</table>

RNV valid to date of component unloading from the core and putting to HLW storage
Sampling of reactor and its internals

Subject of sampling:
1. Internals of RPV, Unit 2:
   ▪ Protective tube unit
   ▪ Core basket
   ▪ Reactor cavity
2. Selected shielding assemblies, both units
3. RPV:
   ▪ Basic material sampled from outer side in reactor shafts – bottom part, Unit 1, 2
   ▪ Internal cladding of RPV, Unit 2

▪ In total 34 samples taken – swarf with mass from 0.1 mg to 125 mg
▪ Depth of sampling: 2 – 5 mm
▪ Remote controlled sampling equipment (the same for HLW storage sampling)
▪ Manual drilling with sample capture – only in case of basic RPV material
Sampling of reactor internals, Unit 2

- Container for transport of reactor internals
- Remote controlled sampling carried out on air in refuelling pond above the RPV
- **15 samples taken**

- Dose rate at 50 cm distance:
  - Protective tube unit: 0.44 – 110 mSv/h
  - Core basket: 2400 – 37000 mSv/h
  - Cavity: 0.5 – 4200 mSv/h
# Sampling of reactor internals, unit 2 – results

Total inventory of reactor internals determined on due date 30.9.2011:

<table>
<thead>
<tr>
<th>Component</th>
<th>Parameter</th>
<th>Unit 1</th>
<th>Unit 2</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protection tube unit</td>
<td>Activity [Bq]</td>
<td>5.69E+14</td>
<td>8.37E+14</td>
<td>1.41E+15</td>
</tr>
<tr>
<td></td>
<td>Mass [kg]</td>
<td>27 304</td>
<td>27 304</td>
<td>54 608</td>
</tr>
<tr>
<td>Core basket</td>
<td>Activity [Bq]</td>
<td>5.84E+16</td>
<td>8.59E+16</td>
<td>1.44E+17</td>
</tr>
<tr>
<td></td>
<td>Mass [kg]</td>
<td>22 480</td>
<td>22 480</td>
<td>44 960</td>
</tr>
<tr>
<td>Reactor cavity</td>
<td>Activity [Bq]</td>
<td>7.41E+15</td>
<td>1.09E+16</td>
<td>1.83E+16</td>
</tr>
<tr>
<td></td>
<td>Mass [kg]</td>
<td>61 250</td>
<td>61 250</td>
<td>122 500</td>
</tr>
</tbody>
</table>

## RNV Unit 2

Inventory and RNV for Unit 1 recalculated considering different final shutdown.
Sampling of shielding assemblies, both units (1)

- **Shielding assemblies** = 36 replaced fuel assemblies in peripheral core position – reduced RA impact on RPV
- **Refuelling machine for transport** of shielding assemblies used
- **Remote controlled sampling** carried out on air in spent fuel storage pool
- **Selected 3 assemblies/unit** based on their position in the core
- **6 samples taken**

- **Dose rate at 50 cm distance**: 3.1 – 110 Sv/h
- **Confirmed measured dose rates** carried in 2008, dose rate at 1cm distance: > 2000 Sv/h
Sampling of shielding assemblies - video
Sampling of shielding assemblies – results

Total inventory of shielding assemblies determined on due date 30.9.2011:

<table>
<thead>
<tr>
<th>Component</th>
<th>Parameter</th>
<th>Unit 1</th>
<th>Unit 2</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shielding assemblies</td>
<td>Activity [Bq]</td>
<td>4,63E+16</td>
<td>4,63E+16</td>
<td>9,27E+16</td>
</tr>
<tr>
<td></td>
<td>Mass [kg]</td>
<td>10 800</td>
<td>10 800</td>
<td>21 600</td>
</tr>
</tbody>
</table>

Unit 1

- Fe-55: 61.207%
- Mn-54: 0.222%
- Co-60: 27.514%
- Ni-63: 11.025%
- C-14: 0.002%
- Ni-59: 0.019%

Unit 2

- Fe-55: 68.011%
- Mn-54: 0.749%
- Co-60: 23.791%
- H-3: 0.001%
- C-14: 0.001%
- Ni-59: 0.013%
- Ni-63: 7.428%
Sampling of RPV – basic material & cladding

Sampling of RPV basic material, both units:
- Manual drilling - 6 taken samples
- Average dose rate: 100 – 300µSv/h

Sampling of RPV internal cladding, Unit 2:
- Concrete container inside RPV
- Remote controlled equipment – 7 taken samples
- Dose rate at 50 cm: 1 – 1010 mSv/h
Sampling of RPV – results

Total inventory of RPV material determined on due date 30.9.2011:

<table>
<thead>
<tr>
<th>Component</th>
<th>Parameter</th>
<th>Unit 1</th>
<th>Unit 2</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>RPV basic material</td>
<td>Activity [Bq]</td>
<td>3,36E+14</td>
<td>3,97E+14</td>
<td>7,33E+14</td>
</tr>
<tr>
<td></td>
<td>Mass [kg]</td>
<td>247 800</td>
<td>247 800</td>
<td>495 600</td>
</tr>
<tr>
<td>RPV internal cladding</td>
<td>Activity [Bq]</td>
<td>1,23E+14</td>
<td>1,76E+14</td>
<td>2,99E+14</td>
</tr>
<tr>
<td></td>
<td>Mass [kg]</td>
<td>17 300</td>
<td>17 300</td>
<td>34 600</td>
</tr>
</tbody>
</table>

RPV internal cladding, Unit1

<table>
<thead>
<tr>
<th>Element</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Co-60</td>
<td>10,643%</td>
</tr>
<tr>
<td>Ni-63</td>
<td>30,287%</td>
</tr>
<tr>
<td>Fe-55</td>
<td>58,916%</td>
</tr>
<tr>
<td>Mn-54</td>
<td>0,038%</td>
</tr>
</tbody>
</table>

RPV basic material, Unit1

<table>
<thead>
<tr>
<th>Element</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mn-54</td>
<td>0,3%</td>
</tr>
<tr>
<td>Ni-63</td>
<td>14,9%</td>
</tr>
<tr>
<td>Co-60</td>
<td>5,8%</td>
</tr>
<tr>
<td>Fe-55</td>
<td>20,5%</td>
</tr>
<tr>
<td>others below MDA</td>
<td>58,40%</td>
</tr>
</tbody>
</table>
Sampling of storage grids in spent fuel cooling pond, Unit 1

- Manual drilling with sample capture on air
- 3 taken samples
- Average dose rate: 350μSv/h
- RNV, Unit 1

Total inventory of storage grids determined on due date 30.9.2011:

<table>
<thead>
<tr>
<th>Component</th>
<th>Parameter</th>
<th>Unit 1</th>
<th>Unit 2</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Storage grids of spent fuel cooling pond</td>
<td>Activity [Bq]</td>
<td>4,61E+11</td>
<td>7,63E+11</td>
<td>1,22E+12</td>
</tr>
<tr>
<td></td>
<td>Mass [kg]</td>
<td>4 700</td>
<td>4 700</td>
<td>9 400</td>
</tr>
</tbody>
</table>

Graph showing distribution of elements:
- Fe-55 93,9%
- Mn-54 0,4%
- Nb-94 0,1%
- Pd-107 0,1%
- Co-60 2,6%
- Ni-63 2,5%
- Sr-90 0,1%
Radiological Characterization of V1 NPP - Activation

- Same approach for all activated components:
  - Working program
  - Work implementation: dose rate measurements, sampling, analyses
  - Report - evaluation of working program (including DVD)
  - DDB import: 1130 modified or new items
- Total number of samples: 125
- Total inventory: 2,61E+17 Bq
- Analyses:
  - All samples – gamma-spectrometry
  - 13 samples – analysis of hard-to-detect radionuclides:
    C-14, Ca-41, Ni-59, Ni-63, Fe-55, Se-79, Sr-90, Mo-93, Zr-93, Nb-94, Tc-99, Pd-107, Sn-126, I-129, Cs-135, Sm-151, Pu-238, Pu-239+240, Am-241, Cm-244 (RA nuclides limited for RAW repository in Mochovce)
Radiological inventory results – activation (1)

Final list of 19 RNV for activation:

- RPV cladding – Unit1, Unit 2
- RPV basic material, water biological shielding - Unit1, Unit 2
- RPV internals - Unit1, Unit 2
- Shielding assemblies - Unit1, Unit 2
- RPV Serpentine - Unit1, Unit 2
- RPV Thermal insulation - Unit1, Unit 2
- Activated standard concrete - Unit1, Unit 2
- Activated baryte concrete - Unit1, Unit 2
- Grids of spent fuel storage pool, stainless steel cladding of reactor shaft - Unit1, Unit 2
- High level waste storage (Mogilnik) – control rods, absorbers, neutron flux measurement channels
Radiological inventory results – activation (2)

Percentage contribution of radionuclides to the NPP V-1 activation:

Other identified activation products:

<table>
<thead>
<tr>
<th>Radionuclide</th>
<th>Contribution (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ba-133</td>
<td>4,24E-09</td>
</tr>
<tr>
<td>Cs-134</td>
<td>4,23E-09</td>
</tr>
<tr>
<td>Eu-152</td>
<td>1,10E-07</td>
</tr>
<tr>
<td>Eu-154</td>
<td>1,08E-08</td>
</tr>
</tbody>
</table>
Thank you for your attention.

Any questions?