Monitoring of Tritium Internal Exposure Doses In TQNPP

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1. Qinshan Nuclear Power Base

- **Qinshan I**
  - 300MW × 1

- **Qinshan II**
  - 650MW × 4

- **Qinshan III**
  - 720MW × 2

- **Fangjiashan**
  - 1000MW × 2
### 1. Qinshan Nuclear Power Base

<table>
<thead>
<tr>
<th>Unit</th>
<th>Construction</th>
<th>Commercial Operation</th>
<th>Capacity (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1-1</td>
<td>Mar.20,1985</td>
<td>Apr. 01,1994</td>
<td>350</td>
</tr>
<tr>
<td>Q2-1</td>
<td>Jun.02,1996</td>
<td>Apr. 15,2002</td>
<td>650</td>
</tr>
<tr>
<td>Q2-2</td>
<td>Apr.01,1997</td>
<td>May.03,2004</td>
<td>650</td>
</tr>
<tr>
<td>Q3-1</td>
<td>Jun.08,1998</td>
<td>Dec.31,2002</td>
<td>728</td>
</tr>
<tr>
<td>Q3-2</td>
<td>Sep.25,1998</td>
<td>Jul.24,2003</td>
<td>728</td>
</tr>
<tr>
<td>Q2-3</td>
<td>Apr.28,2006</td>
<td>Oct.25,2010</td>
<td>660</td>
</tr>
<tr>
<td>QF-2</td>
<td>Jul.17,2009</td>
<td>Feb.12,2015</td>
<td>1089</td>
</tr>
</tbody>
</table>
2. Third Qinshan Nuclear Power Plant

Coolant: ~200T heavy water; Moderator: ~260T heavy water
3. Tritium

\[ n + ^2_1 H \rightarrow ^3_1 H + \gamma \]

1.04 \times 10^3 \text{TBq/y in Coolant}

5.40 \times 10^4 \text{TBq/y in Moderator}
HTO and TDO can cause internal exposure by inhale and by skin penetration. Generally, when exposed without any protection, tritium intake by inhale and by skin penetration will be 2:1.

According to the operation experience of heavy water reactors around the world, the internal tritium exposure dose takes 20%-40% of CRE in the heavy water reactor plant.
4. Tritium Internal Dose Monitoring

LSC:
PerkinElmer Tricarb 2900TR/2910TR

Scintillation Solution:
PerkinElmer Ultima GOLD LLT (10L)

Urine Sample Direct Analysis:
Urine Sample(2ml) + Scintillation Solution(10ml) darkened for 30 min, measured directly by LSC.
4. Tritium Internal Dose Monitoring

Routine Monitoring:
Workers who have the tritium internal exposure risk.

Monitoring Period:
14 days and 30 days

\[
E = \frac{(C_i + C_{i+1})}{2} \frac{(t_{i+1} - t_i)}{\ln2/10} \times 4.8 \times 10^{-5} \times 110\%
\]

\[
E = \frac{4.8 \times 10^{-5}C_n}{\ln2/10} \times 110\% = 7.6 \times 10^{-4}C_n
\]
4. Tritium Internal Dose Monitoring

**Monitored Workers**

- The graph shows the number of monitored workers from 2003 to 2017.
- The y-axis represents the number of monitored workers, ranging from 0 to 2000, with intervals of 200.
- The x-axis represents the years from 2003 to 2017.
- The red line indicates a threshold level.
- The number of monitored workers fluctuates over the years, with notable changes in 2005, 2007, 2009, and 2016.
4. Tritium Internal Dose Monitoring

Annual tritium internal collective dose

Proportion of tritium internal collective dose
Since 2004, the average annual collective dose of tritium internal exposure has been **149.62 person·mSv**, accounting for **19.07%** of the total annual collective dose. The collective dose of tritium internal exposure is closely related to the tritium concentration in the moderator and coolant, operating conditions of units, and tritium-related workload. As running time increases, the collective dose of tritium internal exposure grows with the tritium concentrations in the moderator and coolant. Since 2008, radiation protection technical and management measures in plant have been increasingly optimized to protect against tritium internal exposure. The trend of a continuous increase in tritium internal exposure collective dose has been controlled and is currently stable. Since the second half of 2012, plant started a special ALARA project to reduce the collective dose, focusing on the high radiation risk activities, encouraging the frontline workers’ involvement to optimize the work process, to develop the more effective protection measures internal exposure, to implement timely detection and response procedures for heavy-water leakage. Based on these policies, the collective dose of tritium internal exposure has decreased each year.
4. Tritium Internal Dose Monitoring

Max individual tritium internal dose

Average individual tritium internal dose
Since 2003, the annual average personal internal exposure dose has been less than 0.16 mSv. A total number of workers whose annual personal internal exposure doses exceeded 2 mSv, of which 5 workers' internal exposure doses in a single intake exceeded 2 mSv.

2011, an unexpected tritium intake event was occurred when the work group were cutting and wielding heavy water pipes. A wielder received 14.53 mSv tritium internal exposure dose.
4. Tritium Internal Dose Monitoring

Number of monitored workers from 2003 to 2017

- ≥0.5 mSv: 927 workers
- ≥0.3 mSv: 1999 workers
- ≥0.2 mSv: 3169 workers
- ≥0.1 mSv: 5457 workers
- ≤0.1 mSv: 18036 workers

Total monitored workers: 23493
### 4. Tritium Internal Dose Monitoring

<table>
<thead>
<tr>
<th>Category</th>
<th>Worker Number</th>
<th>Average Internal Collective Dose(person-mSv)</th>
<th>Average Individual Internal Dose(mSv)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintenance</td>
<td>852</td>
<td>64.22</td>
<td>0.08</td>
</tr>
<tr>
<td>Fuel Handling</td>
<td>122</td>
<td>29.37</td>
<td>0.24</td>
</tr>
<tr>
<td>Radiation Protection</td>
<td>146</td>
<td>19.68</td>
<td>0.14</td>
</tr>
<tr>
<td>Operation</td>
<td>246</td>
<td>6.63</td>
<td>0.03</td>
</tr>
<tr>
<td>Engineering</td>
<td>225</td>
<td>8.07</td>
<td>0.03</td>
</tr>
</tbody>
</table>
Fuel Handling is unique to heavy-water reactor plants. Fuel handling operators are facing the highest radioactive risk in the heavy water reactor plant. In TQNPP, the average annual individual dose of fuel handling operators is 2.85 mSv, and the average annual tritium internal individual dose is 0.24 mSv.

Regardless of whether the reactor units were being overhauled or operating normally, the radiation protection personnel had a relatively balanced workload throughout the year. Radiation protection personnel may be exposed to plant-wide radiation because their coworkers and workplaces are distributed across the plant, and their work is related to the entire plant.
5. Conclusion

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