The treatment of highly radioactive liquid waste originating from a severe accident at a VVER 440 NPP

V. Havlová1, V. Brynych1, L. Szatmáry1, P. Franta1, M. Gajdoš2

1ÚJV Řež, a.s., Waste Management & Fuel Cycle Chemistry Division
2Slovenské elektrárne, a.s., Bratislava, Slovak Republic

Introduction
Requirements surrounding specific post-accident recovery measures come into the focus significantly, following the Fukushima Daichi accident. One of the main challenges concerns the treatment of large volumes of highly radioactive waste waters generated during the severe accident mitigation. Therefore ÚJV Řež, a.s. in cooperation with Slovenské elektrárne, a.s. has started a review process of the concept and design of radioactive contaminated water treatment devices for the VVER 440 P severe accident [1]. The contaminated water treatment apparatus in order to be used in case of damage sustained by the core of VVER-type reactors is being developed as an integral part of a programme aimed at the implementation of post-Fukushima safety measures.

Design basis
The development of a modular system had been commenced at ÚJV Řež, a.s. as early as in the late 1980s [2]. Concerning the post-Fukushima safety measures, previous experience was revaluated and extended by means of the consideration of information concerning both the Three Mile Island and Fukushima Daichi accidents. Moreover, the revision was complemented with short-term experimental research in order to propose the treatment procedure described further. The decontamination apparatus must ensure the following requirements:

- A decrease in radionuclide concentration to the required limit levels or to the levels required for water re-use for reactor cooling purposes following the relevant time period;
- Vitrification of spent sorbent to the desired form for temporal or final storage/disposal;
- Decrease of specific radioactivity of gaseous emissions from decontamination apparatus to levels required for NPP air conditioning;
- Decontamination of approximately 10 m³ liquid waste every 24 hours;
- Equipment of the apparatus according to regulations for nuclear waste handling – manipulators, shielding etc.
- The unit has to consist of several mobile modules so it can be fully assembled on required place. It will be easily scalable if necessary.

Solution composition

Tab. 1: Summary of the major radionuclides in contaminated water 6 months after accident.

<table>
<thead>
<tr>
<th>radionuclide</th>
<th>activity [kBq]</th>
<th>activity [%]</th>
<th>radionuclide</th>
<th>activity [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>90Sr</td>
<td>1.3·10⁶</td>
<td>1.3</td>
<td>137Cs</td>
<td>2.1·10⁶</td>
</tr>
<tr>
<td>134,137Cs</td>
<td>1.6·10⁶</td>
<td>1.6</td>
<td>140Ba</td>
<td>2.6·10⁵</td>
</tr>
<tr>
<td>137Cs</td>
<td>2.1·10⁶</td>
<td>2.1</td>
<td>137Ba</td>
<td>9.3·10⁵</td>
</tr>
<tr>
<td>134Cs</td>
<td>2.2·10⁶</td>
<td>2.2</td>
<td>137Ba</td>
<td>1.0·10⁶</td>
</tr>
<tr>
<td>137Ba</td>
<td>2.3·10⁶</td>
<td>2.3</td>
<td>137Ba</td>
<td>1.2·10⁶</td>
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</tbody>
</table>

Conclusions
The modular treatment system described above takes the form of a design concept only; there remains a very low probability of the occurrence of severe accidents at NPPs. The actual construction of such a modular system and its introduction to NPPs will have to be preceded by additional engineering work mainly in order to pass the relevant regulatory approval processes. Moreover, the long-term storage of such a device and the required sorbent materials may well lower the level of effectiveness due to ageing and potential damage over time. Nevertheless, requirements concerning the implementation of safety measures and overall preparedness coupled with the substantial costs associated with further research open a window of opportunity for potential international cooperation between nuclear operators. In order to comply with requirements set in place following the Fukushima Daichi accident, all nuclear plant operators should be able to have such a device ready for deployment within a specified time following the occurrence of a severe accident (6 month).

Therefore, a potential proposal for future cooperation concerning the development of a waste treatment modular device is set out below:
- VVER + EU NPP operator joint programming and potential research
- the preparation of the treatment module detailed design; the construction of which would be feasible during 6 months following an NPP severe accident
- sorbent database that would be subject to regular updating and which would fully consider the availability of large volumes within acceptable cost limits
- further research on the vitrification and transportation of treatment products

Acknowledgements
The study was conducted with the support of Slovenské elektrárne, a.s.

References