NEW TREATMENT CENTERS FOR RADIOACTIVE WASTE GENERATED IN NPPS

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ABSTRACT

The most nuclear power plants had been engineered and designed without any wastes treatment facilities. The liquid and solid waste were collected in storage tanks and shelters. After many years of operation, the storage capabilities are exhausted. The treatment of the stored and still generated waste represents a problem of reactor safety and requires a short term solution.

Key Words: Radioactive waste treatment, separation of radionuclides, compaction, incineration, cementation of radioactive waste

I INTRODUCTION

NUKEM has in last years engineered, designed and constructed several new treatment centers to remove and process the stored waste.

The new radioactive waste treatment center (RWTC) includes comprehensive systems to treat both liquid and solid wastes. The process includes:

- treatment of evaporator concentrates
- treatment of ion exchange resins
- treatment of solid burnable waste
- treatment of liquid burnable waste
- treatment of solid decontaminable waste
- treatment of solid compactible waste

To treat these waste streams, various separate systems and facilities are needed. Six major facilities are included:

1 A sorting facility with systems for waste segregation
2 A high-force compactor facility for volume reduction of non-burnable waste
3 An incinerator facility for burning of:
   - solid burnable waste
   - liquid burnable waste
   - low level radioactive ion exchange resins
4 A facility for melting of incineration residue
5 A cementation facility for stabilization of:
   - medium level radioactive ion exchange resins
   - solid non compactible waste
   - compacted solid waste
6 Separation of radionuclides from evaporator concentrates.

This presentation will address the facilities, systems, and lessons learned during the development of the new treatment centers.

The quantities and kind of waste generated annually by a 1000 MW VVER-Type of reactors are shown in Table I.

### TABLE I. Waste Characterization

<table>
<thead>
<tr>
<th>EVAPORATOR CONCENTRATES</th>
<th>Quantity</th>
<th>100 - 300 m³/a</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific activity</td>
<td>E6 to E7 Bq/dm³</td>
<td></td>
</tr>
<tr>
<td>Total salt content</td>
<td>300 - 350 g/dm³</td>
<td></td>
</tr>
<tr>
<td>H_3BO_3 content</td>
<td>100 - 120 g/dm³</td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td>&gt; 11</td>
<td></td>
</tr>
<tr>
<td>IE-RESINS</td>
<td>Quantity</td>
<td>10 m³/a</td>
</tr>
<tr>
<td>Specific activity</td>
<td>E5 to E7 Bq/dm³</td>
<td></td>
</tr>
<tr>
<td>OIL</td>
<td>Quantity</td>
<td>2 m³/a</td>
</tr>
<tr>
<td>Specific activity</td>
<td>E3 - E4 Bq/dm³</td>
<td></td>
</tr>
<tr>
<td>SOLID LOW LEVEL WASTE</td>
<td>Quantity</td>
<td>200 Mg/a</td>
</tr>
<tr>
<td>including:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- burnable waste</td>
<td>50 Mg/a</td>
<td></td>
</tr>
<tr>
<td>- compactible waste</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- insulation materials</td>
<td>50 Mg/a</td>
<td></td>
</tr>
<tr>
<td>- debris</td>
<td>50 Mg/a</td>
<td></td>
</tr>
<tr>
<td>- metal</td>
<td>10 Mg/a</td>
<td></td>
</tr>
<tr>
<td>- filter sand</td>
<td>30 Mg/a</td>
<td></td>
</tr>
<tr>
<td>- decontaminable waste</td>
<td>10 Mg/a</td>
<td></td>
</tr>
<tr>
<td>Specific activity</td>
<td>up to E6 Bq/kg</td>
<td></td>
</tr>
</tbody>
</table>

II WASTE TREATMENT TECHNOLOGIES

In Fig. 1 the waste treatment technologies are shown as a block diagram.
Sorting

If possible, the solid low-level radioactive waste is pre-sorted at the place of origin and transported in a 1 m³ containers to the Waste Treatment Center (WTC) sorting room for control sorting. Here the waste is taken over on the sorting table, unwrapped and conveyed into the sorting box (see Fig. 4). The waste is sorted according to the following criteria:

- compactible
- decontaminable
- burnable.

The compactible waste is filled in 170 dm³ drums which are docked to the sorting box. In order to better utilize the drum volume, pre-compacting takes place by means of an in drum compactor integrated in the sorting box. The filled drums are closed by means of a lid and transported to the compaction facility. Decontaminable waste is collected in a carriage lined with foil, which also is docked to the sorting box and transported to decontamination outside of the WTC. In the sorting box, the burnable waste is wrapped in plastic bags and transported to the incineration plant.

Compaction

In the compaction facility (Fig. 7), sorted waste contained in 170 dm³ drums is compacted by means of a high force compactor. The compacted waste is filled in 200 dm³ drums and transported to the cementation facility for purpose of grouting. The compacting room is designed as a first barrier to avoid any contamination. During the compacting of 170 dm³ drums the high force compactor is additionally closed by means of integrated lifting bulkheads. Generated dust is exhausted at place.

Technical data of the high force compactor:
- Force of pressure: 16 MN
- Throughput: 12 drums/hour.

Incineration

The incineration and flue-gas cleaning systems are shown in Fig. 5 and Fig. 6. The waste composition of the burnable waste is as follows:

- Cellulose, textiles: approx. 65 % by weight
- Plastic (without PVC): approx. 20 % by weight
- Rubber: approx. 3 % by weight
- PVC: up to 5 % by weight
- Non burnable material (glass, metal): approx. 7 % by weight

Burnable liquid waste (oil) is also incinerated. The solid waste is delivered in bags of 5 - 8 kg and via box B105 put into the incinerator D201. The liquid burnable waste is homogenized in the mix tank B101 and transported via a pump and preheating station A101 into the burner.

In the incinerator (see Fig. 5) solid waste - fed more or less continuously - is burned understoichiometrically. In the burning zone the waste is transformed with air and steam into gaseous carbon hydrides, carbon monoxide, carbon dioxide and soot. This gas mixture is transported together with soot and still nonburned particles into the after burner chamber D203. The flue gas from the afterburner chamber D203 is cooled by adding of cool air in the static mixer (see Fig. 6). The following reverse jet scrubbers K401 and K402 remove the harmful substances. If the salt concentration in the scrubbers solution is in the range of 10 - 15 weight per cent, it is pumped into the cementation facility.

The off-gas leaving the second reverse jet scrubbers is saturated by water vapours in order to avoid condensation of water in the following parts of the plant it is heated up to about 20 °C higher than the dew point. The filters F501A and B serve to hold back the finest solid particles. The draught blower V601 generates the low negative pressure which is necessary during the operation. The residues of combustion ashes and nonburnable material accumulated in the furnace D201 and in the afterburner chamber D203 are discharged every 24 hours via the ash discharge boxes B801 and B802 into a connected 170-dm³ drum and conveyed to the ash melting system.

Technical data of the incineration facility:
- Throughput:
  - 60 kg/h (c. v. 20,000 kJ/kg) of solid waste
  - 40 kg/h (c. v. 20,000 kJ/kg) of solid waste and 10 kg/h of oil.

Incineration temperature:
- in the incinerator 850 - 950°C
- in the afterburner chamber 1050 - 1200°C.

Cementation

The following waste is treated by means of cementation (see Fig. 3):
- Resins (medium active)
- Filter sand from the biological waste water cleaning
- Scrubbing water from the flue gas cleaning of the incineration facility.

The cemented waste is filled in 200-dm³ drums and after the curing a solid block is formed. The cementation of the waste comprises the following essential process steps:
- Instructions and programming of all quantities and weights according to the cementing recipe
- Metering of the waste into the slanting mixer R101 and starting of the mixer R101
- Conveyance of the premetered quantity of cement by means of the conveyor H201 from the primary tank B202 into the slanting mixer R101
- Draining off, free from contamination, of the homogeneous cement mixture from the slanting mixer R101 into the 200-litre drum, alternatively filling-up of the void volume between the compacted waste in the
200-litre drum.

The resins are dewatered before the cementation in the primary tank B401.

Technical data of the cementation facility:
Throughput: 14 Mg/day of cemented product
Content of dry resins: up to 14 % by weight
Content of salts: up to 35 % by weight.

Separation of radionuclides from evaporator concentrates

Evaporator concentrates are the main waste stream generated in nuclear power plants. The usually used treatment methods are bituminization or cementation. In both cases the achievable volume reduction factor (1 to 1.5) is very low. Because of the continuously increasing cost for final storage and because of the large volume of the evaporator concentrates (100 - 300 m³ annually generated by a 1000 MW VVER-Reactor) it is necessary to introduce new treatment methods which give a significant volume reduction of waste which should be stored as radioactive one.

In international co-operation (NUKEM-Russian research institutes) a new process for treatment of evaporator concentrates has been developed and tested in a pilot scale unit using evaporator concentrates generated in Kalinin NPP and others NPP’s. According to the achieved results, it possible to reduce the volume of the waste which should be stored as radioactive waste by a factor of 30 to 50.

The single process steps of the new process for treatment of evaporator concentrates are shown in Fig. 2. A typical industrial unit has a throughput of approx. 500 dm³/h of evaporator concentrates. In the first process step organic compounds (oil, EDTA, oxalates) are removed. The removing of organics occurs by ultrafiltration and by oxidizing. The oxidizing is performed by means of chemicals (KMnO₄), by means of ozone or by electrochemical oxidizing. After removing of the organics, cobalt exists in ion form and can be separated by filtration in form of hydroxide. The achievable DF (decontamination factor) is in the range of 100 to 3000.

The separation of the main radionuclide Cs137 is performed by means of selective sorbent. As sorbent nickelferrocyanide using aluminum silicate as a carrier material has been tested (NShA-Sorbent). The hourly throughput is equal 2 to 3 volumes of the sorbent. The loading capacity of the sorbent is in the range of 200 to 300 time the volume of the sorbent. The decontamination factor for Cs137 is in the range of E3 to E5. The sorbent is placed in 120 dm³ column which is inserted in 200 dm³ drum. In this 200 dm³ drum the used sorbent can be disposed. The radiation resistance of the sorbent excess E7 Grey. For treatment of 1000 m³ of evaporator concentrates about 1m³ of sorbent has to be used.

Melting of Incineration Residues

The radioactive residues from the incineration facility are transported to the melting facility in 170 dm³ shielded containers. The feeding of the homogeneous residues/additives mixture into the melting furnace occurs batchwise (4 kg/batch) by means of a star feeder and a specially designed feeding device. Five feeding sequences (20 kg of residues/additives mixture) are necessary for the production of one melt discharge.

The melting furnace is of the chamber furnace type and is equipped with a brick lined swivelable melting crucible. The feeding of the residues/additives mixture occurs sidely and directly into the melting crucible, at one position. Heating up and melting operation of the furnace (Temperature between 1200°C and 1700°C) occurs with two fuel/air plasma burners both installed on the top.

After one hour of operation, the crucible containing the melted mass is swiveled and the melt flows into a 50 dm³ container which is fitted to the bottom outlet of the furnace. After five melt discharge, corresponding to the processing of approx. 100 kg residues/additives mixture, the container is full and is allowed to cool down in the discharge box. After cooling down, the container is removed out of the discharge box and put into a 200 dm³ drum. An empty container can now be fitted to the bottom outlet of the furnace.

The flue-gases leaving the melting furnace by temperatures up to 1200°C contains hazardous constituents, like heavy metals or radionuclides - as gas or in form of solid dust particles and aerosols - and have to be cleaned before release to the stack. The cleaning of the flue-gasses is integrated in the incineration facility, both facilities can use a common off-gas cleaning system.

Technical data of the melting facility:
Throughput: 20 kg/h of residues
Melting Temperature: 1300 - 1700°C
Leaching rate of the product: E-6 g/cm² day for Cs
Fig. 1  Block Diagram
Treatment of radioactive waste generated in NPP's

- LL Liquid Waste
- LE Aqueous
- LL Solid Waste
- Recycling
- Decontamination
- Sorting
- LSS
- LL
- Burnable
- Separation of Radioelements
- Evaporator Concentrates
- Pellets, Scataloging, Solution
- Cementation
- Container
- Incineration
- Container
- Melting
- Container
Fig. 2  Block Diagram
Treatment of Evaporator Concentrates
Separation of Radionuclides

Cod-Mac/med/2804/0308/396bgm
Fig. 4: Sorting

- Empty Drums
- Empty Carriage
- Empty Back

Waste from Storage
Waste for Compaction
Waste for Decommissioning
Waste for Incineration
Fig. 6 Flue gases cleaning system