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EXPERIENCE OF RECYCLING THE LIQUID RADIOACTIVE WASTE AT THE KOLA NPP

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This article focuses on the issues associated with development and operation of LRW processing complex at Kola NPP completed in 2009. The applied LRW solidification technologies are discussed and the operating installations are presented. Future tasks aimed at upgrading the LRW processing complex and increasing the efficiency of the technologies applied given further RW transfer for disposal have been identified.

Keywords: *radioactive waste (RW), liquid radioactive waste (LRW), LRW processing complex, RW processing, ion-selective sorption, LRW cementation.*

Introduction

Kola NPP is considered as a baseline energy source for the Polar regions of the Russian Federation and is operated in full consistency with the effective norms and rules in the field of atomic energy use. The first NPP unit was commissioned in 1973. To date, 4 power units with a capacity of 440 MW each are being operated at the site.

In the early 1990's it already became evident that further operation of the Kola NPP is impossible without making prompt decisions enabling effective and safe management of the radioactive waste generated. This is viewed as a starting point for further efforts on selecting and implementing relevant RW processing and conditioning technologies and equipment being considered up-to-date at this time. Thus, for example, a decision had been made on upgrading flue gas treatment unit belonging to solid radioactive waste incineration facility successfully implemented in 1996.

Another area considered with relevant activities implemented in cooperation with NUKEM (Germany) was the development of LRW treatment complexes. The technologies proposed by NUKEM were considered standard for that time:

- Cementation of spent ion exchange resins and sludges;
- Cementation of bottom residues (with prior concentration at a unit for strong evaporation).

Project titled Complex for Liquid Radioactive Waste Processing (with relevant NUKEM GmbH technologies applied) was developed in 1994 under joint efforts of three partner companies (Kola NPP, NUKEM and Atomenergoproekt Saint-Petersburg Institute).

At the same time, it became clear that cementation method, along with the obvious advantages it provides (simple technology, reliable immobilization of radionuclides), has an important

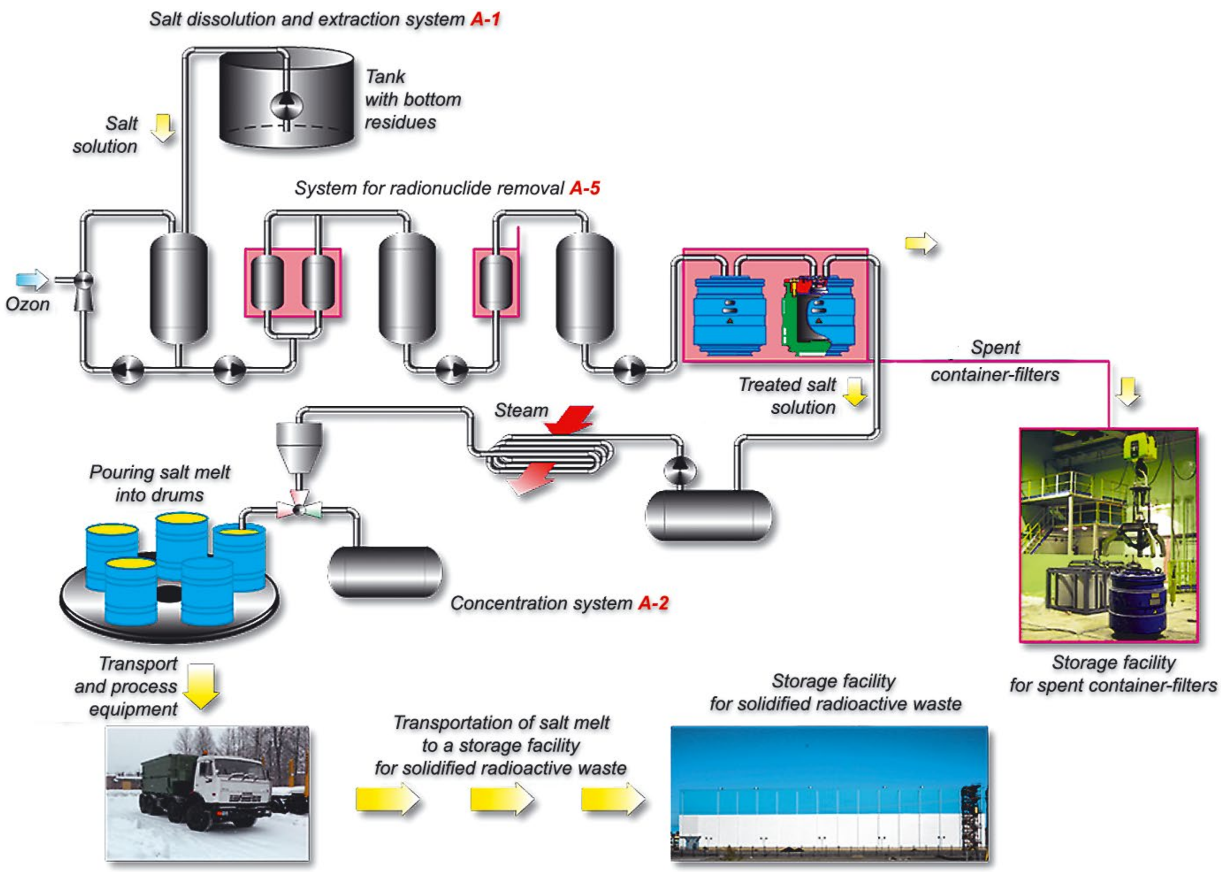

Figure 1. Schematic diagram of bottom residues processing unit

disadvantage suggesting that the volume of conditioned RW is increasing due to insignificant inclusion of LRW into the cement matrix.

For this reason, Kola NPP operator seemed to be very enthusiastic to the implementation of a new LRW processing technology developed in 1995 and based on completely different physical and chemical processes, i.e. ion-selective treatment of bottom residues. The new technology was developed jointly by VNIIAES, MosNPO "Radon", RAOTECH, Alliance-Gamma.

Following relevant laboratory studies, the technology was tested at several Russian NPPs, including Kola NPP, Mangyshlak Nuclear Power combine (Kazakhstan). Pilot-industry unit with a capacity of 100 l/h was tested at the site of the first world NPP (Obninsk). Based on the available data Kola NPP experts working jointly with the Atomenergoproekt Saint-Petersburg Institute have performed a feasibility comparison of different LRW processing options. It enabled the development of new LRW management concept based on LRW ion-selective treatment ensuring radionuclide extraction (figure 1).

In 2013, JSC Rosenergoatom's Strategy was approved [1] providing for a wide range of measures: from reducing the amounts of RW generation to the development of RW processing technologies ensuring that all generated and accumulated RW are processed and comply with the established RW acceptance criteria [2]. Kola NPP LRW processing complex (PC) is consistent with the provisions of the strategy, as well as other PCs [3], including RW PC at the Smolensk NPP [4].

LRW PC operational experience

At Kola NPP, LRW PC was commissioned in two stages:

- 2006 — LRW processing complex building was commissioned including a system designed to retrieve LRW from the first section of LRW storage facility, LRW treatment system allowing radionuclide extraction, conditioning system, auxiliary and control systems. Thus, the first start-up complex designed to reprocess main type LRW was commissioned;
- 2008—2009 — LRW PC was fully commissioned including a storage facility for solidified waste, cementation system, a system designed to retrieve LRW from the second section of the LRW storage facility, pipeline tunnel connecting building No. 2 and LRW PC, radiation monitoring system and etc. (figures 2 and 3).

The following organizations were involved in the development and implementation of the project on

Figure 2. LRW PC construction

Figure 3. LRW PC today

upgrading the LRW management system at Kola NPP:

- Atomenergoproekt Saint-Petersburg Institute — general design contractor;
- RAOTECH — development of ion-selective treatment system designs;
- NUKEM — design development and supply of LRW retrieval and concentration units;
- AREVA and SverdNIIKhimmash — design development and supply of cementation system and transport and process equipment.

Three other organizations, namely, Sovasatom, Alliance-Gamma, RT Soft have contributed significantly at the commissioning stage of the project.

At Kola NPP, bottom residues processing complex includes a number of basic units:

- Unit for salt dissolution and retrieval enabling their further processing;
- Unit for radionuclide extraction from LRW;
- Unit for treated solution concentration (strong evaporation).

All processing stages, as well as auxiliary systems are being controlled using the LRW PC control console (figure 4) with modern software and technical complexes in place. In certain premises, as required, video cameras are fitted for monitoring purposes with the video screened at the console.

Figure 4. General view of the control console

The bottom sediment processing technology is based on selective sorption of ^{60}Co and ^{134,137}Cs accounting for 99.9% of the activity. In terms of chemical composition, bottom residues mainly include such ions as Na^{+}, K^{+}, NH_4^{+}, Fe_3^{+}, NO_3^{-}, SO_4^{-2}, BO_3^{-3} and other.

Ion-selective treatment results in a solution the radionuclide content of which does not exceed the maximum permissible specific activity values set forth by provisions of the Government Resolution of the Russian Federation [5].

These values are considered decisive and are viewed as criteria in making the decision on further transfer of the treated solutions to the strong evaporation unit. In practice, it should be also accounted for if the solution concentration process (strong evaporation) resulting in the generation of a solidified salt product (salt melt) leads to the increase in its specific activity. Resulting salt melt is subject to radiation control enabling to demonstrate that the solid product cannot be for sure regarded as radioactive waste (figure 5).

A number of stages can be specified in LRW PC operation history:

- Mastering the technology. At this stage, the efficiency of the selected technology was confirmed. Equipment, as well as technological operations characterized with some issues needed to be addressed was identified.
- Upgrading the equipment. Equipment was upgraded to enhance its efficiency and performance. Thus, for example, oxygen and ozone generators were replaced; additional lines of preliminary and membrane filtration units with higher performance filters were installed.
- Research and development activities aiming to improve the technology itself. The solubility of borates contained in bottom residues was studied

Figure 5. Radiation control of bottom residues processing products

to determine their maximum concentration providing that no crystallization in the pipelines and equipment occurs, but being at the same time sufficient to generate crystalline melt following strong evaporation.

The following results were achieved:

- Investigation of waste from particular (problematic) LRW storage tanks was performed to study physical and chemical properties of the medium and to develop recommendations on the optimization of ozonation modes. Chemical components impeding this process were identified;
- Conditions enabling joint processing of bottom residue decantate and crystalline residue solutions were identified;
- Research on the selective LRW treatment using termoksid-35 as a sorbent was carried out ensuring the required degree of purification;
- Research on technologies suggesting the introduction of additional chemical components to increase the efficiency of cobalt isotope extraction was performed;
- Examined were the issues associated with the development of container-filter with less thick biological protection layer involving relevant calculations on the economic feasibility of its manufacturing and etc.

The results obtained and their partial implementation enabled quite stable operation of the complex. However, the design capacity of 3,600 m^3/year hasn't been yet attained.

LRW PC designs suggests the following annual amounts of LRW processing:

- No less than 936 m^3 of bottom residues' decantate;
- No less than 2,664 m^3 of crystalline residue solutions.

In recent years, LRW PC has reached an average capacity of 2,200 m^3/year, including:

- about 2,000 m^3 of crystalline residue solutions;
- 100—200 m^3 of decantate.

This progress is primarily driven by the following causes: performance assessment for the central complex system, radionuclide extraction unit, was done based on the design documentation available for other systems. Whereas, the given capacity of 0.5 m^3/h was demonstrated following calculations based on such initial LRW characteristic as oxidation (chemical oxygen consumption — COC) and ozone consumption resulting from organics degradation, thus, causing COC decrease. It was showed that complete ozonation of one LRW batch can be performed in one shift, i. e. 8 hours. In reality, this process can last 12—16 hours due to the complex nature of LRW composition. Increase in ozone intake leads to the increase in unreacted ozone amount which is supposed to be a disadvantage for the residual ozone afterburning unit. Moreover, the ambient temperature grows decreasing the ozonation efficiency.

Cementation facility is yet another technological system of the complex. It has been already commissioned. At the pre-commissioning stage, cementation technology was tested to treat spent ion-exchange resins and sludge. The system is currently on stand-by. Drying method is seen as the most efficient one in terms of such media treatment by Kola NPP operator, as well as by many other NPP operators.

On the whole, the treatment complex enabled to address the challenge associated with processing of bottoms residues that had been accumulated during Kola NPP operation and to increase the level of radiation and environmental safety by reducing the amount of stored LRW and converting it into stable forms suitable for safe management and disposal. Over the 12 years of operation, over 2,500 tons of salts originally contained in the bottom residues and initially categorized as "radioactive waste" were treated enabling to no longer consider this waste as radioactive. In December 2008, the LRW LRW project was rated as the Best Environmental Project of the Year by the Ministry of Natural Resources of the Russian Federation.

To enable fully closed LRW processing cycle, Kola NPP has initiated R&D project on the extraction of useful chemical components from the bottom residue reprocessing products.

These efforts were primary aimed at:

- closing the bottom residue processing cycle resulting in a minimal amount of secondary waste;
- meeting the needs of Kola NPP's LRW RC the in treating agents (technical acid and alkali) ensuring water-chemical operating conditions at the facilities;

- extraction of boric acid suitable for commercial use (grade "A" according to GOST 18704-78), i.e. recycling or sale.

During the R&Ds (contractor — Kola Scientific Center's Institute of Chemistry and Technology of Rare Elements and Mineral Raw Materials named after I. V. Tananaev of the Russian Academy of Sciences):

- patent-information testing of technologies enabling to produce treating agents from salt solutions was performed, feasibility study for the chosen field of work was carried out;
- method enabling the extraction of boric acid from molten salt / radionuclide-free solutions was developed, optimal process modes were worked through;
- method enabling the production of treating agents (acids and alkalis) from the salt melt / radionuclide-free solutions was developed, optimal conditions for this process have been identified;
- baseline data were obtained for the design development of a pilot-industrial facility enabling the extraction of boric acid, nitric acid and alkali.

Thus, a project titled Extraction of Boric Acid from Bottom Residue Processing Products at LRW PC was launched at Kola NPP. Relevant contract on design activities was signed.

The project is seen to reduce operation costs with no need to purchase chemical treating agents anymore and some consumable materials to be less purchased as well.

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Bibliographic description

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