Full-fledged affination extractive-crystallizing platform for technology validation of the fast reactor spent fuel reprocessing on fast neutrons – the results of first experiments

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Abstract

Further effective development of fast energy engineering could not be realized without strategy of nuclear fuel cycle closure. Throughout the realization of this strategy combined PH-technology of mixed nitride uranium-plutonium fast reactor spent fuel is proposed.

Keywords: affination extractive-crystallizing platform, mixed U-Pu fuel, spent fuel reprocessing, hydrometallurgy.

INTRODUCTION

Full-fledged affination extractive-crystallizing platform was created for hydrometallurgical processes adjustment and above mentioned technology functional test (Fig.1).

Figure 1 – Boxes and Processing Equipment of the Platform

The platform guarantees the compliance with the radiation and nuclear safety requirements for working processes with hot spent fuel simulator, which main component is U-Pu-Np mixture, including Am, Tc, stable elements and radioactive tracers.

Scientific and engineering solutions provide the conduction of spent fuel reprocessing technology adjustment research on low capacity, which appears to be the boundary between laboratory test equipment and industrial grade equipment, also provide the performance of equipment rerouting for different alternate layouts verification, the performance of computer-assisted control and operating procedure monitoring [1].

Uniqueness of the full-fledged affination extractive-crystallizing platform includes next features:

- Innovative nuclear-safety equipment;
- Prototype equipment of the industrial spent fuel reprocessing module, part of the equipment can be easily scale-adjusted;
- This platform is potential for practice and training use.

EXTRACTIVE UNIT OPERATION TEST

We used simulated nitric acid U solutions and 30 vol. % tributyl phosphate in the Isopar M hydrocarbon solvent in order to test the operation of the extractive and dosing equipment (Fig. 2), the sampling system of the extraction cascade and the refining extraction process analytical support.

Figure 2 – ETsR-33 Extractors and Related Dosing Equipment

During the test, 8 sets of samples were taken in order to analyze for the content of U, HNO_3 and impurities, which simulate fission products.

The extractive platform working results were evaluated according to changes in the composition of product samples, which were taken during the extraction cascade operation (Figure 3).

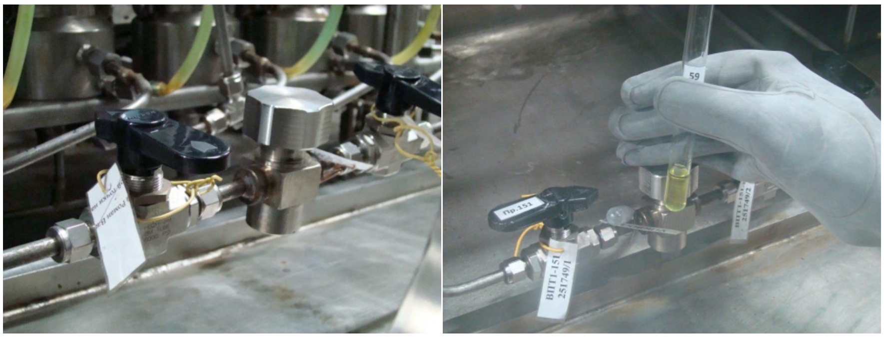

Figure 3 – Sample Collection System

The test run of the extraction cascade using the uranium product the following performance characteristics were demonstrated:

– Stable operation of extraction units and dosing equipment using two-phase system "aqueous solution – 30 % solution of tributyl phosphate in the Isopar M solvent" in the continuous processing of feed stream with the recycling of turnover extractant (stable flow rates in the cascade, effective phase separation in centrifugal extractors at the output of operational units ETsR-33, efficient mass exchange as to uranium and nitric acid);

– Stable speed of dosing the feed supply, recyclable extractant, washing and regenerating solutions used in the process with fixed flow rates;

- Stable running of flow heating circuits process in liquid chromatography columns and in separators for the soda-alkali regeneration of an extractant;

– Appropriate control and shutoff of the equipment through the Automated Process Control System (APCS);

– Rapid response of APCS to process alterations made by operational staff;

– It took approx. 15 hours to reach the steady-state operation for dosing feed solutions of the extraction cascade;

– The continuous running of extraction cascade using U solutions lasted for 35 hours;

– The assessment was made in regard of refining capacities of the extraction process as to the behavior of impurities simulating fission products (Zr, La, Ce, Nd, Mo, Ba) [2].

CRYSTALLIZATION UNIT OPERATION TEST

We used simulated melt (uranyl nitrate – nitric acid – water) in order to test the operation of the refining crystallization equipment and related analytical support of the crystallization process. (Fig.4)

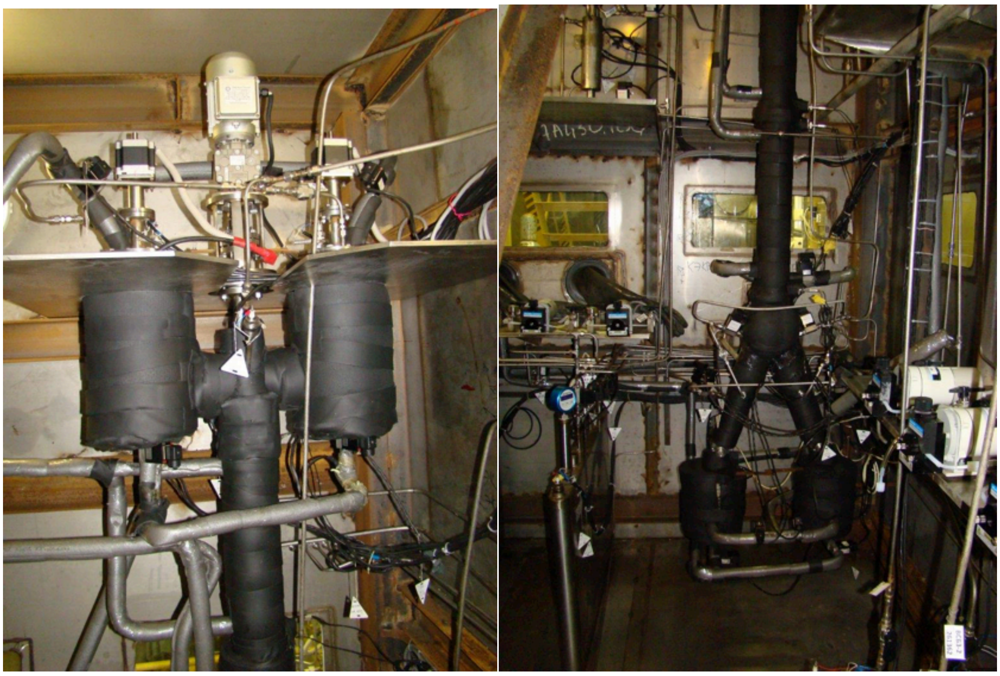

Figure 4 – Mockup Full-Fledged Crystallizer View Installation

Before the melt was supplied into the process and during its processing, work was done to record the temperature trend (variation) in the column and inlet-outlet chambers of the crystallizer using temperature gages installed at the beginning and at the end of each thermal section of the crystallizer and in its inlet-outlet chambers.

In each test, we measured amounts of process products withdrawn (fed) in the working cycle of inlet-outlet chambers (stuffing chamber with crystals, drainage, dissolution of dried crystals, and withdrawal of the product batch), i.e.:

– mother washing solution (MWS) produced during the time when the chamber is connected to the crystallizer column;

– aqueous phase (APh) separated in the drainage of crystals;

– solution, which is supplied into the chamber to dissolve dried crystals;

– withdrawn end product.

Crystallizer running-in with using the uranyl nitrite melt demonstrated the stability of the following performance parameters:

– Adequately stable feed stream dosing with a fixed temperature as judged from the readings by the mnemo of the automated process monitoring and control station on the operation of dosers (the dosing speed fluctuated doesn’t exceed an average of ±5 % relative to the set value, based on the feed rate trend shown by the dosers);

– Steadily operating circuits for cooling and heating process zones of the crystallizer (the feed stream inlet in the crystallizer column, the crystallization zone, the crystal washing zone in the crystallizer column, zones (assemblies) of crystals collection-drainage and end product withdrawal). Temperature fluctuations observed in the research did not go beyond ±4 rel. %;

– Steady rotational speed of the mixer in the crystallizer column;

– Stable dosing of the auxiliary washing solution with a fixed rate that falls within the design value;

– Stable control of the aqueous phase level in the crystallizer column that was defined from acceptable lowering of the level in the crystallizer column at the moments of shifting the crystals feeding stream;

– Required temperature trend in the crystallizer column was determined from temperature sensors installed at the beginning and at the end of each thermal section of the crystallizer [3].

CONCLUSION

The result of the above-described research using spent fuel simulators concludes in finding out the optimum process conditions for operating extraction cascades, separators, the liquid chromatography column (LCC) and the crystallizer, and obtaining coefficients for the purification of uranium and plutonium from simulated fission products.

In addition, we determined specific characteristics of operating the crystallization unit and came up with recommendations to enhance the quality and reliability of its performance.

It was also demonstrated that specifications and design solutions for the equipment employed in the full-fledged affination extractive-crystallizing platform can be applied to the equipment for the extractive-crystallizating purification of U-Pu-Np products as part of the spent fuel reprocessing module of the BREST-OD-300 reactor.

REFERENCES

[1] Report “Test Run of the Process and Checkout of Individual Stages of the Extraction-Crystallization Refining for Reprocessing SNF from the BREST-OD-300 reactor” dated November 11, 2016, Reg. No. 110-106/39OUO, 220 p., OUO.

[2] Act of Testing the Extraction Cascade Using the U Product Including the Checkout of the Analytical Support and Sampling System dated October 21, 2016, Reg. No.110/09-25/3543, 14 p.

[3] Act of Testing the Mockup Crystallizer Using Uranyl Nitrite Solutions Including the Checkout of the Analytical Support and Sampling System dated October 31, 2016, Reg. No. 110/09-25/3679, 15 p.