Available online at www.sciencedirect.com

ScienceDirect

Procedia Chemistry 21 (2016) 148 – 155

Procedia Chemistry

5th International ATALANTE Conference on Nuclear Chemistry for Sustainable Fuel Cycles

Hydrometallurgical reprocessing of BREST-OD-300 mixed uranium-plutonium nuclear fuel

A.Yu. Shadrin[a*], K.N. Dvoeglazov[a], V.A. Kascheyev[a], V.L. Vidanov[a], V.I. Volk[b], S.N. Veselov[b], B.Ya. Zilberman[c], D. V. Ryabkov[c]

[a] *Institution Innovation and Technology Center by "PRORYV" Project, 2/8 Malaya Krasnoselskaya, 107140 Moscow, Russia*
[b] *JSC A.A. Bochvar VNIINM, 5a Rogova, 123060 Moscow, Russia*
[c] *JSC «VG Khlopin Radium Institute», 28 2-oy Michurinskiy proezd, 194021, St. Petersburg, Russia*

Abstract

The duration of external fuel cycle of BREST-OD-300 reactor with mixed U-Pu nitride fuel (MNIT) including hydrometallurgical reprocessing should not exceed 3 years. An average burnup of the fuel should be 6 % of heavy metal (HM) with the potential increase up to 10 % HM. Therefore, the technology should provide the reprocessing of spent nuclear fuel (SNF) after less than 2 years cooling time and with fissile materials (FM) content of 10 – 15 %. Pellets technology has been chosen for the MNIT fuel production. That means necessity to receive the recycled actinides oxides of high purification coefficient (~ 10^6). Currently on a laboratory scale, the following process stages have been tested on the real products: actinide oxides production and rare-earth and trans-plutonium elements separation. Moreover, on a pilot scale the process of high level radioactive waste (HLW) and intermediate level radioactive waste (ILW) concentration by evaporation has been tested, as well as the Am-Cm separation. In 2015, the design of the MNIT SNF reprocessing facility has been started, placed at the JSC Siberian Chemical Plant site as a part of the pilot demonstration power complex (PDPC) with BREST-OD-300 reactor. MNIT SNF reprocessing plant (RP) should be put in operation after 2020.

Peer-review under responsibility of the organizing committee of ATALANTE 2016

Keywords: uranium plutonium mixed fuel, nitride fuel, SNF reprocessing, hydrometallurgy

* Corresponding author.
E-mail address: shau@proryv2020.ru

1876-6196
Peer-review under responsibility of the organizing committee of ATALANTE 2016
doi:10.1016/j.proche.2016.10.021

1. Introduction

Closed nuclear fuel cycle (CNFC) is a strategic aim of the Russian State Corporation "Rosatom". CNFC prevents spent nuclear fuel accumulation and reduces the volume of the long live radioactive wastes by the minor actinides (MA) transmutation. CNFC can be implemented in a system that combines thermal neutrons (TR) and fast neutrons (FR) reactors, using mixed uranium-plutonium oxide (MOX) fuel for the FR with sodium-coolant (BN) and mixed U-Pu-(Np-Am) nitride (MNIT) fuel for the reactors with lead coolant (BREST).

The developments of BN-1200 with sodium-coolant as well as BREST-1200 with lead coolant are currently under way in Russia. Therefore the reprocessing technology developed should provide an opportunity for MOX and MNIT SNF reprocessing[1].

2. MNIT SNF hydrometallurgical reprocessing

Modern FR SNF reprocessing technologies are imposed to such requirements as a high safety level, reducing the waste impact on the environment as a result of MA burning in the reactor, reducing the risk of nuclear materials proliferation (i.e. excluding the possibility of Pu separation during the reprocessing), resistance to the external influences (earthquake, flood, airplane crash, etc.); economic competitiveness[2,3].

The combined pyro-hydro technology of reprocessing FR SNF (PH-process) proposed for RP PDPC meets these requirements[4-7]. The basic version of the PH-process is designed to MNIT SNF reprocessing in the form of homogeneous neptunium and americium burning, but currently there are no sufficient experimental data for the fabrication of the mixed (U, Pu, Np) nitride fuel containing americium. Therefore a variant of heterogeneous americium burning in the form of U-Am rod containing up to 10% of americium oxide in UO_2 matrix has been developed. For the purpose of U-Am rods hydrometallurgical reprocessing on RP PDPC the voloxidation stage was added to the process for the tritium localization. Voloxidized mixture of oxides is directed to dissolution, whereupon the reprocessing is same as hydrometallurgical reprocessing of PH-process.

In 2015, in connection with the unsuccessful tests of pyro-electrochemical technology on a real MNIT SNF, it was decided to provide the possibility of BREST-OD-300 SNF reprocessing with the burnup up to 6 % HM (the first five years of the reactor lifetime) by completely hydrometallurgical technology and to start a study of high burnup MNIT SNF reprocessing. This decision has caused an increase of voloxidation and oxides dissolution stage capacity from 500 kg/year to 5 tons/year and revise the closed water and acid circulation scheme of RP PDPC. Process flow diagram of MNIT SNF hydrometallurgical reprocessing is shown in Fig. 1.

The following are the individual stages of MNIT SNF hydrometallurgical reprocessing, which research has been carried out in 2013-2015.

3. Off-gas treatment

The feature of the off-gas treatment stage (LSGO from Russian) of the hydrometallurgical variant of MNIT SNF reprocessing, as compared to PH-process, is the necessity to trap some aerosols and compounds of iodine, tritium, carbon, and ruthenium at hydrometallurgical stages. Liquid operation off-gas is passed through the heat exchanger, then after water aerosol injection therein is directed to FSGO (glass fibre rough treatment filter) filter which has aerosol recovery efficiency of 90 - 99 % and nitrogen oxides recovery efficiency up to 70 %, further to FARTOS (aerosol recyclable fine treatment filter) with aerosol treatment efficiency of 99 – 99,9 % and nitrogen oxides recovery efficiency up to 90 %. The gas is then pre-injected with water aerosol and directed to BRUNS (reagent-free capture by the gamma-alumina bed) unit with nitrogen oxides purification efficiency up to 90 % and to the two in-series units SMOG (silica-urea gas treatment) filled with gamma-alumina granules impregnated with the urea - ammonium bicarbonate aqueous solution, which provides a deep nitrogen oxides purification (99.9% or more). A column filled with gamma-alumina granules at the temperature of 150 °C has been proposed to capture the volatile ruthenium tetroxide, wherein RuO_4 decomposition and RuO_2 precipitation occurs. Composite material comprising silver was used to remove iodine. In the hydrometallurgical process an absorption packed column is used for $^{14}CO_2$ capturing, the column is irrigated with aqueous sodium hydroxide in a circulating mode at 20 °C with NaOH regeneration, $CaCO_3$ precipitation and separation followed by conditioning, cementation and storing (disposal)[8-10].