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PAREX, A Numerical Code in the Service of La Hague Plant Operations

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Abstract

The PAREX code developed by the CEA is able to simulate the PUREX process in steady or transient state. From an operator point of view, this numerical code for simulation of liquid-liquid extraction operations is an outstanding tool as an aid for plant operation through process flow sheet optimization, troubleshooting and safety analysis calculations. This paper focuses on two examples. The first concerns the evaluation of the available operating margin of the extraction zone of the first purification cycle flowsheet. The second example concerns a uranium-plutonium splitting operation where the code was used to explain a shift of plutonium concentration in the solvent outlet.

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1. Introduction

Liquid-liquid extraction operations conducted in the PUREX process at La Hague reprocessing plant must meet strict requirements. A high degree of performance is indeed desired with respect to finished product purity and the recovery yield of these products. Other requirements must be guaranteed such as safety and operational longevity.

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To allow the optimization of the process and face with the exhaustive approach required in the analysis of criticality risk, a major effort has been made by the CEA and AREVA at an early date to model the PUREX operations. A digital code named PAREX has thus been developed.

The methodology adopted to develop the code was to experimentally study the main governing phenomena like the distribution data for the relevant species, their mass transfer kinetic, and the kinetics of redox reactions when a change of oxidation state is needed to perform a separation. Contactor hydrodynamics were also studied in order to take their specific features into account to simulate their transfer efficiency. The elementary models, addressing each of the phenomena mentioned above were then implemented in the PAREX code.

Prior to any application, PAREX code was qualified by comparing models predictions to experimental data (laboratory scale or industrial scale). Comparison of experimental data with PAREX show that main extraction operations of the PUREX process are effectively calculated by the PAREX code either in steady or in transient state[1-4].

This digital code for the simulation of the liquid-liquid extraction operation is an outstanding tool for a plant operator. At La Hague reprocessing plant, PAREX code is indeed widely used for different purposes like support to safety demonstration, process flowsheet evolution (new fuels), troubleshooting, procedures improvement or operators training.

This paper provides an overview of the use of the code as an aid for plant operation and focuses on two application examples. The first concerns the support to safety demonstration with the available margin evaluation of the extraction zone of a first cycle flow sheet. The second example concerns a uranium-plutonium splitting operation, where the code was used to explain a shift of plutonium concentration into the solvent recorded at the outlet, leading to curative recommendations.

2. Sensitivity analysis of solvent extraction purification flowsheet

Any flowsheet for the treatment of a specific fuel in a solvent extraction unit systematically undergoes a sensitivity analysis to determine the impact of any operating parameter deviation from the nominal value on the process behavior, especially as regards of the risk of plutonium leakage and build-up. This analysis performed using the PAREX code, consists of two steps.

2.1. Operating margin determination

The first step, known as operating margin determination, is aimed at determining for each of the operating parameters (feed, flowrates, feed composition…) the maximum admissible misadjustement level with respect to plutonium accumulation and leakage into equipment which is not safe by geometry (conventional tanks or mixer-settlers). Parameters sensitivity is determined by modifying each of the process parameters stepwise and calculating for each step the new equilibrium with PAREX code. When the maximal admissible plutonium concentration is reached in an item of equipment, the operating margin is reached.

To illustrate these calculations, we consider the extraction-scrubbing zone of the first purification cycle at La Hague Plant. Flowsheet is given in Fig.1.

The feed solution containing the dissolution solution is introduced in the extraction column (AX). Then the loaded solvent is treated in the scrubbing column (AS). This loaded solvent is further treated in the technetium scrubbing column (ASS). Uranium and plutonium in the aqueous outlet of the latter are recovered in the complementary extraction operation (AXX), which is a mixer-settler bank. The solvent outlet of AXX is directed back to the extraction column. Unlike AX, AS and ASS columns, AXX mixer-settlers and raffinates tanks are not safe by geometry. Plutonium concentration must not exceed 7.7 g/l in raffinate tanks and 10 g/l in AXX mixer-settlers.

Fig. 2 shows the results of the calculation carried out to determine the operating margin available for the solvent flowrate introduced in the extraction column (AX). Beyond the operating margin shown in Fig. 2, the plutonium concentration in AX raffinate increases significantly.

These calculations also help to identify the most reliable indicators that are worth monitoring to evaluate the process status and efficiently control the extraction operation. Fig 2 shows that plutonium concentration evolution in