ADVANCED AND SUSTAINABLE FUEL CYCLES FOR INNOVATIVE REACTOR SYSTEMS

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ABSTRACT

The key objective of nuclear energy systems of the future as defined by the Generation IV roadmap is to provide a sustainable energy generation for the future. It includes the requirement to minimize the nuclear waste produced and thereby notably reduce the long term stewardship burden in the future. It is therefore evident that the corresponding fuel cycles will play a central role in trying to achieve these goals by creating clean waste streams which contain almost exclusively the fission products. A new concept based on a grouped separation of actinides is widely discussed in this context, but it is of course a real challenge to achieve this type of separation since technologies available today have been developed to separate actinides from each other.

In France, the CEA has launched extensive research programs in the ATALANTE facility in Marcoule to develop the advanced fuel cycles for new generation reactor systems. In this so-called global actinide management (GAM) concept, the actinides are extracted in a sequence of chemical reactions (grouped actinide extraction (GANEX)) and immediately reintroduced in the fuel fabrication process is to use all actinides in the energy production process.

The new group separation processes can be derived as in this case from aqueous techniques but also from so-called pyrochemical partitioning processes. Significant progress was made in recent years for both routes in the frame of the European research projects PARTNEW, PYROREP and EUROPART, mainly devoted to the separation of minor actinides in the frame of partitioning and transmutation (P&T) studies.

The fuels used in the new generation reactors will be significantly different from the commercial fuels of today. Because of the fuel type and the very high burn-ups reached, pyrometallurgical reprocessing could be the preferred method. The limited solubility of some of the fuel materials in acidic aqueous solutions, the possibility to have an integrated irradiation and reprocessing facility with improved economics and the higher radiation stability of the molten salt media are some of the arguments in favour of pyro-reprocessing.

Adaptations of this technology exist for the treatment of both oxide and nitride fuels. The flowsheet for the treatment of nitride fuels is similar to that of metal fuel. In the case of oxides a head-end reduction step is needed. It can be performed by direct electroreduction, where the heat generating fission products are removed and the fissile materials are recovered as an alloy, which can be again directly reprocessed by electrorefining.

The present paper describes the progress made at ITU – mainly in the frame of the network projects mentioned above - in developing the grouped actinide recycling concept with a view to the sustainability goals described above for innovative reactor systems.

In the frame of these projects, reprocessing of EBRII type metallic alloy fuel with 2% of Am and 5% of lanthanides ($U_{60}Pu_{20}$-$Zr_{10}Am_2Nd_{3.5}Y_{0.5}Ce_{0.5}Gd_{0.5}$) is being carried out by electrorefining at ITU. An excellent grouped separation of actinides from lanthanides (An/Ln mass ratio = 2400) had been obtained. The high neutron capture of lanthanides and their possibly detrimental interaction with the cladding material implies that they must be separated. In this sense the choice of the cathode material for the actinide recovery is essential and it could be shown that aluminium is an excellent material for a pyrochemical partitioning process. The results are confirmed in conditions simulating the scaling up (multiple run) of the process, with an accumulation of Ln in the salt. One of the major goals is the minimization of actinide losses and to thereby reduce significantly the radiotoxicity of the waste produced.

The results shown here represent the first demonstration of an efficient grouped actinide recovery from realistic metallic fuels and are therefore an important step in achieving the sustainability goals of future reactor systems.