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Thorium based Molten Salt Fuel Cycle

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In 2011, Chinese Academy of Sciences (CAS), after discontinuing the research and development activity in nuclear energy for decades, started to implement Strategic Priority Research Program "Future Advanced Fission Nuclear Energy (FANE)". To perform this program, two sub-bases, the north and the south, were deployed in CAS. Shanghai Institute of applied physics (SINAP), as the south sub-base, is taking in charge of research and development of "Thorium-based Molten Salt Reactor Nuclear Energy System (TMSR)". According to this research plan, two kinds of molten salt nuclear reactors, i.e. 2MW pebble bed fluoride salt-cooled high temperature reactor with solid fuel (TMSR-SF1) and 2MW molten salt reactor with liquid fuel(TMSR-LF1), will be designed and developed. Three fuel cycle models will also be implemented orderly, one-through fuel cycle on TMSR-SF, modified open fuel cycle on TMSR-SF and TMSR-LF, and closed fuel cycle on TMSR-LF.
Compared with 239Np (half-life 2.35 days), an intermediate product in U-Pu fuel cycle, 233Pa, an intermediate product in the conversion of 232Th to fissionable 233U) has β decay with half-life 27days that is almost an order of magnitude longer, which indicates that the equilibrium concentration of 233Pa in reactor is almost ten times of that of 239Np. 233Pa has relatively high thermal neutron capture cross section, and neutron capture of 233Pa accumulating in reactor will reduce conversion ratio by consuming pioneer nuclide of fissionable 233U and reactivity of the reactor which negatively influents the formation of 233U indirectly. The operation of reactor at high efficiency and high breeding ratio requires the isolation of 233Pa and rare-earth frequently, even continuously, which is the key issue in design and operation of thorium molten salt reactor (TMSR).
The frequent fuel processing is feasible for MSR, and just feasible for MSR. Compared with other GIV reactors, the feasibility of on-line fuel processing is an unique merit for MSR. Therefore MSR is an optimal type to implement Th-U fuel cycle. Pyrochemical processing methods are judged to be the only technologies for the fuel of MSRs with integrated reprocessing technologies. Because the liquid fuel for MSR is a mixture of molten fluorides, the fuel processing and reprocessing technologies planned are pyrochemical or pyrometallurgical techniques, which are based on separation of 233U and fission products in molten fluoride salt. Considering the special advantages of fluoride volatility and electrometallurgical techniques, a preliminary protocol based on closed fuel cycle has been proposed for the treatment of fuel from TMSR. The recycling techniques of fuels proposed in this protocol include fluoride volatilization, distillation of molten salt carriers, electrochemical deposition. The simple experimental devices for above techniques have been established, and the feasibility studies are ongoing in SINAP.

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