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PLASMA PROCESSING OF CLOSED NUCLEAR FUEL CYCLE WASTE

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Abstract: The work proposed the plasma method of processing closed nuclear fuel cycle wastes in the form of a water-salt-organic composition. This method has several advantages and allows recycling such material safely. The optimal composition for recycling in plasma was determined. Equilibrium compositions showed that in the process of plasma processing N_2, CO_2, H_2O and also $FeCl_3$ и Fe_2O_3 in the condensed phase were formed. Lack of soot is an indicator that the recycling process is environmentally safe.

Аннотация. В работе предложен плазменный метод переработки отходов замкнутого ядерного топливного цикла в виде водно-солеорганической композиции. Этот метод имеет несколько преимуществ и позволяет безопасно перерабатывать такой материал. Определен оптимальный состав для утилизации данного отхода в плазме. Равновесные составы показали, что в процессе плазменной обработки образуются N_2, CO_2, H_2O, а также $FeCl_3$ и Fe_2O_3 в конденсированной фазе. Отсутствие сажи является показателем того, что процесс переработки является экологически безопасным.

Keyword: waste, plasma, closed nuclear fuel cycle.

Ключевые слова: отходы, плазма, закрытый ядерный топливный цикл.

For the development of nuclear energy, namely, to create a closed nuclear fuel cycle (NFC), the final stage is important - reprocessing of spent nuclear fuel (SNF), its non-combustible (NC SNF) and combustible reprocessing waste (C SNF). The problem of SNF management is not new; in search of a solution to this problem, a tremendous amount of work has been done, many different technologies have been created [1].

The basis of modern technology for spent nuclear fuel processing at radiochemical plants (including Russian ones) is the PUREX process (Plutonium-Uranium Recovery by EXtraction), which is preceded by cutting (fragmentation) of spent fuel assemblies (SFA), as well as the dissolution of spent fuel in nitric acid.

Most often, the extractant material in this process, with which it is possible to extract uranium and plutonium purified from fission products, is tributyl phosphate (TBP), which is diluted with kerosene, carbon tetrachloride or hexachlorobutadiene (HCBD), etc.

SNF reprocessing waste (RW SNF) after uranium and plutonium was extracted from them, are water-salt solutions of metals with a certain model composition, which is given in [3].

A sufficiently high concentration in the solution of fission products, as well as plutonium nuclides, significantly reduces the efficiency of the extractant due to radiation exposure, thus, the extractant is converted to C SNF. During the extraction process, waste is also formed in the form of water contaminated with radioactive isotopes, which is drained into quarries at radio engineering factories and drainage lakes enclosed by dams.

A significant reduction in energy costs for the process is possible with the plasma processing of SNF wastes in the form of combustible water-salt-organic compositions (WSOC).

The experiments showed that the complete combustion of liquid combustible waste is observed when they have a combustion temperature of about 1200 °C [4]. Figure 2 shows the effect of the content of the NC SNF and TBP (in the C SNF) on the adiabatic combustion temperature of different compositions of the WSOC based on them.

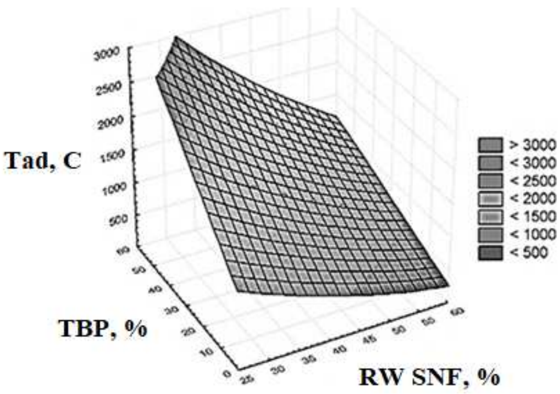

Fig. 1. Graph of the effect of the content of TBP in the extractant and the spent fuel on the adiabatic combustion temperature Tad of different woks

Analyzing the dependence, it is obvious that in order to create a combustible WSOC with an adiabatic combustion temperature of ≈ 1200 ° C, as well as a maximum content of OP SNF, the following composition of the WSOC is required: 34% RW SNF: 20% TBP: 46% HCBD.

Figure 2 shows the compositions of the main gaseous (a) and condensed (b) products formed during the plasma processing of NC SNF and C SNF in the form of the optimal composition of the WSOC (the share of the plasma coolant is 70% by weight).

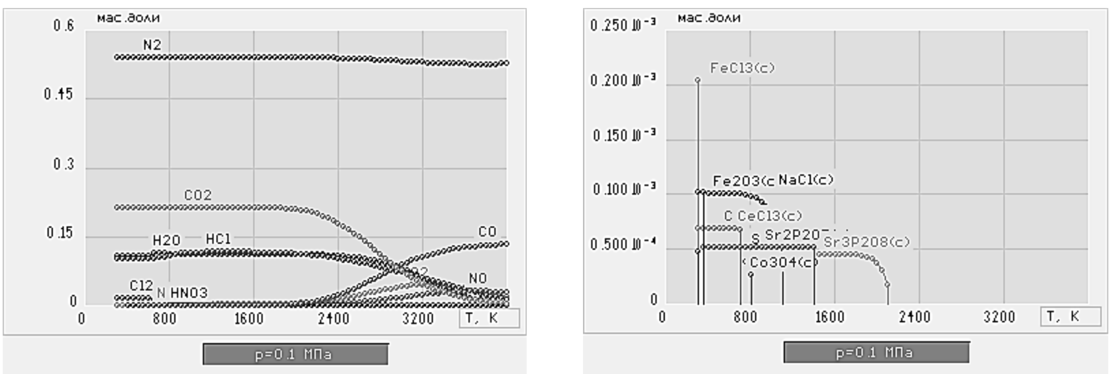

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Fig. 2. The composition of the gaseous (a) and condensed (b) products of the plasma utilization of combustible waste from the reprocessing of spent nuclear fuel in air plasma (70% air: 30% WSOC)

An analysis of the compositions (Fig. 2) shows that mainly N_2, H_2O, CO_2 are formed in the gas phase, and simple oxides and chlorides form in the condensed phase. The absence of soot and toxic gases among the products is an indicator that the plasma reprocessing of NC SNF and C SNF is in an environmentally friendly, and therefore optimal mode.

Conclusions. Plasma utilization of nuclear fuel cycle waste in the form of the optimal composition of the WSOC allows avoiding evaporation and chemical treatment, and reduces energy costs for the process. Taking into account the obtained results, we can recommend the following modes for practical implementation of the process:

- temperature range 1200 ± 100° C;
- composition of WSOC (34% RW SNF: 20% TBP: 46% HCBD);
- fraction of plasma coolant: 70%.

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