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Purification of irradiated beryllium from radioactive nuclides using ”dry” chlorination method

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In these studies, the task of beryllium purification from radioactive nuclides from neutron flux during operation as a plasma facing materials of the fusion reactor first wall was solved 1. ITER requires at least 50 t of beryllium for the first wall of the vacuum chamber, it must be replaced every 5 years of operation when the reactor is operating at the nominal power. Currently, the total global production amount is only about 300 tons per year 2, so the return of beryllium to the fusion production cycle is a necessity.
The paper presents the results of decrease a beryllium radiation activity after the conducted studies and gives recommendations for using the “dry” chlorination method [3] for the fusion industry. To implement the “dry” method chlorination of irradiated beryllium, an experimental installation was designed. Methods for controlling the composition of beryllium chlorination reaction products and measuring the chlorine concentration using a non- destructive method based on processing the light intensity signal in the reaction chamber have been developed.
An automated control system for the process of irradiated beryllium purification has been developed for increase the technology efficiency and creating safe operating conditions for the installation. This information and control system allows remote controlling the technological process, excluding the possibility of people interaction with harmful substances.
The experimental work was carried out to convert beryllium into chloride and purify it from the main radionuclides based on the thermophysical and neutronics calculations of the characteristics of the process [4].
The object of the research was beryllium of JMTR (Japan) research materials science reactor, which was irradiated from 1968 to 1975 with power generation a 24017.4 MW/day in the reactor [5]. As a result, the flux density of thermal neutrons was 8.0*1013 n/(cm2•s) and fast neutrons ~ 7.5•1012 n/(cm2•s) for 7 years. The beryllium contamination is determined by radionuclides of tritium 3H, cobalt 60Co, silver 108Ag, and cesium 137 Cs (Figure 1).

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Fig.1 –Irradiated beryllium rod in JMTR Core

Figure 2 shows the process of “dry” chlorination method [6] of irradiated beryllium. A beryllium (Be) sample 2 was heated in the quartz glass reaction chamber 1 to a temperature of 730 ℃, where chlorine (Cl2) was fed. A hot stream of beryllium chlorides (BeCl2) and cobalt chloride (CoCl2), as well as tritium (3H) entered the gas mixer 3, which was supplied with hydrogen, which binds the tritium and free chlorine in the form of hydrogen chloride. A filter cobalt chlorides 4 was heated to a temperature of ~500 ℃, where it was deposited on the surface of nickel (Ni) filter elements. Then the heat exchanger 5 was used to cool and maintain the required temperature of the gas mixture by feeding and adjusting the nitrogen (N2) flow rate in the circuit. Then the gas mixture is fed to the bottom of the beryllium chloride (BeCl2) collection tank 6, heated to a temperature ~500 ℃, there are two sieves that ensure dispersion and thus decrease the gas velosity. The gases (HCl, 3HCl, H2) released from the beryllium chloride collection tank passed through the cooling heat exchanger and entered the tritium chloride collection tank 7 (Figure 2). This container is filled with water in which HCl and 3HCl were dissolved. A small stream of hydrogen was released into the atmosphere.

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1 –reaction chamber; 2 –irradiated beryllium (3H, 60Co, 108Ag, 137Cs); 3 –gas mixer (3HCl);
4 –filter for 60Co; 5 –heat exchanger; 6 –tank for BeCl2; 7 –tank for 3HCl.
Fig. 2 –The scheme of chloride production and separation

The interaction of hydrogen with chlorine residues in the gas stream made it possible to create a carrier for radioactive tritium and eliminate a chemically toxic substance in the emissions.

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