CONCEPT OF DT FUEL CYCLE FOR A FUSION NEUTRON SOURCE

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A concept of DT-fusion neutron source (FNS) with the neutron yield higher than 1018 neutrons per second is under development in Russia. Such a FNS is of interest for many applications: (i) basic and applied research (neutron scattering, etc); (ii) testing the structural materials for fusion reactors; (iii) control of sub-critical nuclear systems and (iv) nuclear waste processing (including transmutation of minor actinides).

The FNS steady-state operation is based on producing the neutrons in a tokamak plasma with temperature of 1÷5 keV due to DT fusion and fast ions maintained by injection of 140 keV neutral atoms (two component tokamak). Thermal fusion reaction is an additional channel for neutrons production but not the major one. Neutron flux in the device is above 0.2 MW/m2s. For the FNS operation the Lawson parameter may be *nτE*~1019 m-3s that is an order of magnitude less than that for a pure fusion reactor [1]. Thus the parameters of tokamak for FNS may be much lower than those of a fusion power plant like DEMO.

For demonstration of FNS capabilities a tokamak with major radius R = 2.5 m, aspect ratio A = 3, superconductive magnetic coils and energy multiplication factor Q ≤ 1 will be used. The plasma heating, current drive and atoms beam for neutron production will be provided by 140 keV (20 MW) and 500 keV (10 MW) NBI as well as 5 MW of ECRH.

Fusion fuel cycle is one of key elements of the FNS. This system provides the fuel mixture with equal fractions of D and T (D:T = 1:1) for all FNS technology systems. Cryopumps of ITER-like type are used for pumping [2]. Gas purification system, getter long-term storage system for hydrogen isotopes and hydrogen isotope separation system provide closed fuel cycle for the tokamak.

Plasma core and edge fueling is provided by neutral atom beams, pellets, supersonic gas jets and gas puffing valves.

The fuel cycle conception is designed to maintain steady state fuel circulation. Less than 2-3 hours should be spent for fuel recycling at the flow rate up to 70 m3Pa⋅s-1. Since all FNS systems (including pellet and neutral beem injectors) use the DT-mixture of equal worth the isotope separation system is used only for removal of protium from the fuel. Protium is produced in the device due to D-D reactions, in reactions of neutrons with elements of structural materials and initially dissolved in the materials. As a result, the isotope separation system should process only 0.5÷5% of the total fuel flow depending on the protium concentration in fuel. This approach allows us to reduce the total amount of tritium in fuel system to 0.75 kg and hence reduce the loss of tritium due to β-decay. The total amount of tritium in the fueling and long-term hydrogen isotope storage systems is equal to the fuel needed for one day operation. The main places for tritium retention in FNS and FNS fueling system are torus and NBI cryopumps, structural materials, plasma-facing materials, dust and flakes in vacuum vessel (VV) and tritium storage bed. The tritium consumption is ~0.3 kg per year including DT fuel burnup in fusion reaction and tritium losses.

Tritium breeding is planned on site in (Li, n) reaction.

References

1. B.V. Kuteev et.al. Nucl. Fusion 51 (2011) 073013
2. Technical Basis for the ITER Final Design Report G A0 FDR 1 01-03-05 W0.2