ARCHITECTURE of the FUEL SYSTEMS for THE FUSIon NEUTRON SOURCE DEMO-FNS

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Simulation of the hydrogen isotope fluxes in fueling systems of a tokamak-based fusion neutron source (DEMO-FNS) with the parameters R/a = 3.2 m / 1 m, B = 5 T, Ipl = 4–5 MA, PNBI = 30 MW and РECR = 6 MW [1] is performed with “FC-FNS” fuel cycle (FC) code [2]. “FC-FNS" describes the D and T particles balance in all the systems that form the fuel cycle consistently. FC systems pump gas from the divertor, pre-purify and separate the impurity gases from the hydrogen isotopes, purify further the chemically-bound hydrogen isotopes, store the isotope reserves and provide fuel injection into the plasma to maintain burning conditions, plasma heating and current generation (by a neutral beam injection system - NB). To supply the plasma DT fuel, in addition to neutral beam injection (we analyze scenarios with a D0 + T0 and D0 beams), pellet injection (PIS) from the side of high and low magnetic fields (HFS/LFS) is foreseen. The gas valve system (GIS), in addition to the impurity injection, provides for injection of the gas mixture that circulates in the FC systems (and exceeds the plasma demand in D and T due to the low efficiency of particles penetration to the core). To ensure the mechanical strength of the fuel pellets, we propose their separate extraction of D2, T2 and DT, followed by different pellet-injectors. Fuel flow separation into the required fractions requires an separation system (ISS) as part of a FC. He fraction in the plasma control occurs in the process of cleaning the gas mixture on a membrane filter in which all of the He from the fuel mixture is released. As a result of this approach, the relative value of the average helium density in the plasma core <nHe> / <ne> is ~0.4%. Control of the H2 fraction occurs due to the removal of H2 and HD fractions from the ISS. Even taking into account the fact that the fraction of HT will remain in the fuel mixture, the proportion of protium in the plasma will be ~0.5%.

The main problem to be solved when designing a FC is to reduce the inventories of hydrogen isotopes in the FC systems. The most critical are systems with a long cycle of gas mixture processing (since they can accumulate the greatest amount of isotopes, including T). "FC-FNS" allows you to calculate the hydrogen isotopes inventories in FC systems as well as the tritium breeding rate (taking into account the needs of the facility) for various types of the additional heating beam (D0 + T0 or D0) and for scenarios with different tritium fraction *fT* of plasma.

The report describes the current architecture of the FC systems that provide all the scenarios considered, and provides an analysis of the operating modes of the key systems. The dependences of the tritium inventory in a FC and T breeding rate were analyzed for various *fT* fraction. The results of modeling various operating modes of injection systems and an analysis of the possibility of ensuring effective gas pumping from the divertor for these modes are given.

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References

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2. S.S. Ananyev, A.V. Spitsyn, B.V. Kuteev, Fusion Engineering and Design 109–111 (2016) 57–60.