# DEVELOPMENT OF A TRITIUM FUEL CYCLE FOR LONG-TERM TOKAMAK OPERATION

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For the conceptual design of controlled fusion reactors, it is necessary to estimate the amount of fuel needed to start the plant and formulate requirements for them at the stage of the technical design [1, 2]. The flows of fuel components that must be supplied to the vacuum vessel/plasma are many times (up to 1000) higher than the burnup rate during a controlled fusion reaction. The standard models used [3] cannot describe most of the processes occurring in the vacuum vessel and technological processes in fuel cycle systems of the facility. Steady-state controlled fusion reactors will require a fuel cycle scheme different from the generally accepted one (for experimental facilities), as well as a stationary operation mode of all fuel cycle systems [1, 2]. The particle flows in the fuel cycle (FC) are determined primarily by the requirements for the parameters of the plasma core provided by the injection system, as well as the flows in the pumping system coming from the vacuum chamber to the control systems [1, 2]. Therefore, the modelling of FC systems and calculations of particle flows should be related to the model of the core and divertor plasma. Simulation of fuel cycle systems with the core and divertor plasma interaction can be implemented using the SOLPS, ASTRA and FC-FNS codes [4-7]. In the presented work, fuel cycle modelling is performed using the FC-FNS code tools [7, 8].

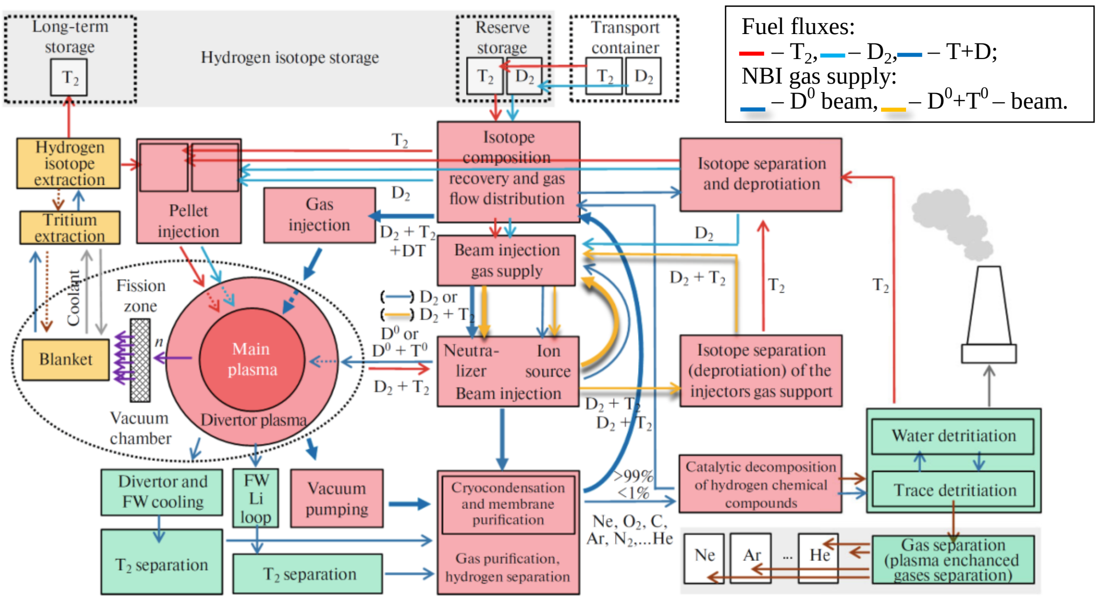
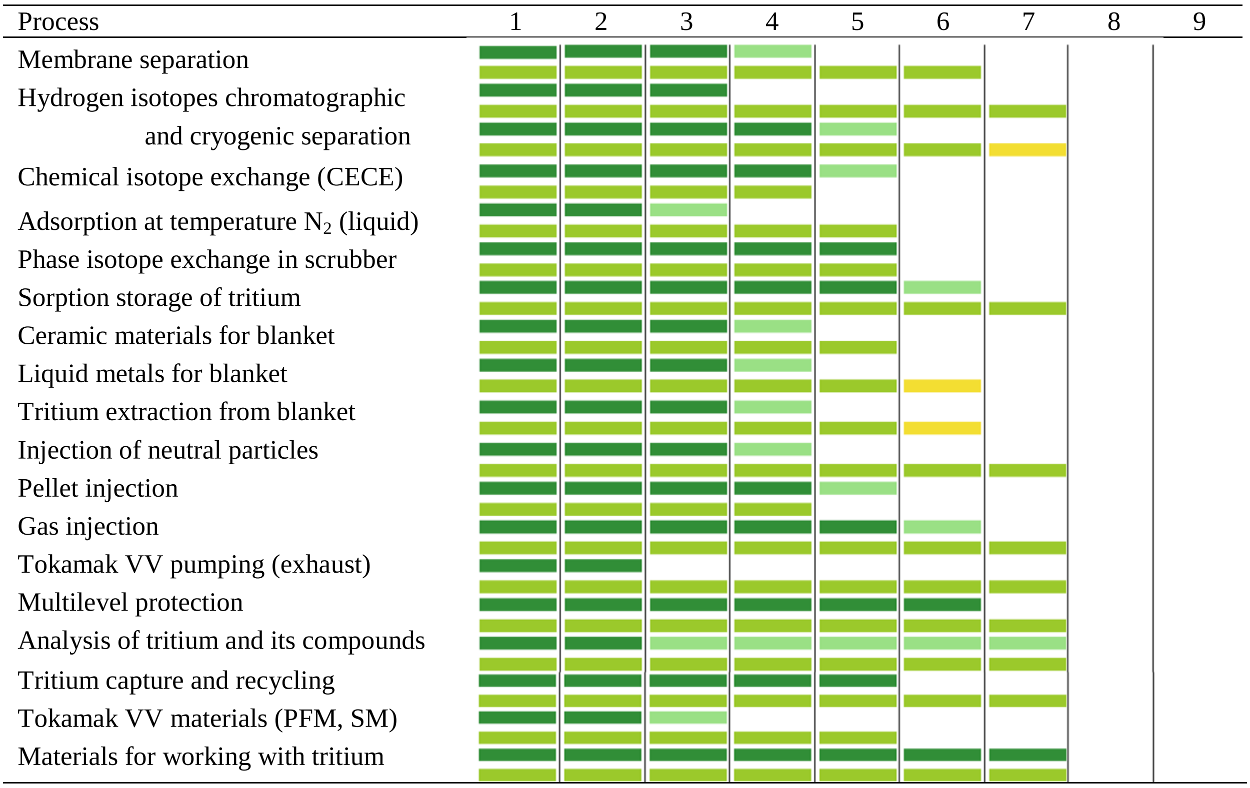



FIG.1. Block diagram of fuel cycle systems [8]. Main circuits are divided by colors: ■ – fast processing of the tokamak exhaust, ■ – tritium extraction from the blanket, ■ – processing of tritium-containing waste.

This code was developed and tested for tokamak-based steady-state fusion neutron sources (RF projects FNS-ST and DEMO-FNS) [9]. A range of operating parameters was determined for the core plasma, in which the tritium fraction is regulated by pellets injection with different isotopic composition of T/D (separate injection of D and T pellets). The impact of heating and fuelling by the neutral beams (500 keV/30 MW beams for DEMO-FNS/40 MW fusion power and 130-200 keV/5-10 MW beams for FNS-ST/3 MW – with D/T/D+T composition) recycling and supply of particles from the divertor was also taken into account. The core plasma was simulated and the effect of HFS and LFS pellet injection on the core plasma fuelling and triggering/pacing the ELMs was considered [6, 10]. A method for calculating the hydrogen isotopes fluxes in plasma and the D-T fuel cycle was also developed, taking into account the plasma discharge parameters. The technical characteristics of the FNS fuel cycle systems and selected technologies were also determined. Taking into account the gas flows and isotopic composition in fuelling systems, as well as the technologies selected, taking into account its' technical characteristics, the mutual integration of technological systems and the minimal reserves of tritium in them were determined [11]. The amount of tritium and deuterium in the fuel cycle systems was defined using a computer model of the system, taking into account the technologies used and the design features of the tokamak and technological systems [8].

As a result of the steady-state facility (by FNS as an example) D-T fuel cycle optimization, a design was proposed of systems with gas processing in "real time" without accumulating tritium in the operational storage (see Figure 1). The reduction of fuel gas flows and quantities is achieved via several (up to 13 for FNS projects) DT fuel processing circuits [6, 11]. This made it possible to reduce the tritium inventory required to start and operate the facilities by up to 10 times (less than 0.5 kg for DEMO-FNS/40 MW fusion power and less than 0.1 kg for FNS-ST/3 MW fusion power) compared with estimates from simplified models. An important feature of the described approach is that it allows us to link the plasma discharge parameters with candidate/applied fuel cycle technologies. As a result of the analysis, the level of technology readiness for the FNS D-T fuel cycle systems was determined in order to create a roadmap (TABLE 1).

TABLE 1. TECHNOLOGY READINESS OF A STEADY-STATE TOKAMAK TRITIUM FUEL CYCLE




( ) Russia now; ( ) Russia in the future; ( ) world now; ( ) world in the future.

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