Contribution ID: **150** Type: **Unsolicited Poster**

CONCEPTUAL DESIGN, SYSTEM MODELING AND OPTIMIZATION OF TRITIUM FUEL CYCLE IN A STEADY-STATE OPERATING TOKAMAK

Wednesday 11 June 2025 14:05 (1 minute)

Controlled fusion reactors with steady-state operation (SSO) will require a fundamentally new approach to the organization of the fuel cycle and the use of other innovative solutions for technological systems, since all existing and planned facilities were designed for a pulse-periodic mode in which the gas mixture is processed between discharges. Switching to long-term pulses will require stable operation of all fuel cycle systems with coordination of operating modes and fuel flows, while the total supply of tritium at the facility should be reduced as much as possible. The creation of steady-state facilities with a fuel cycle similar to the existing experimental one will lead to an unjustified accumulation of tritium.

As part of the conceptual design of controlled fusion reactors, it is necessary to estimate the amount of fuel required to start the project/facility and formulate requirements for technological systems at the technical design stage. Existing fuel cycle models for the DEMO plant predict high reserves of tritium (more than 5 kg for DEMO-FNS project with 40 MW fusion power) and do not take into account the processes inside the plasma and vacuum vessel (and oriented towards a D:T=1:1 mixture in the plasma and in all systems). A conceptual design of the fuel cycle was carried out for two FNS projects with fusion power 40 MW based on the classic JET scale tokamak and 3 MW based on a spherical tokamak FNS-ST. An effective simulation model and new codes have been developed to describe the partial flows of D and T in a vacuum vessel, as well as the processes of fuel nuclides injection, pumping in gases'processing systems, and estimating the tritium amount in the fuel cycle systems of these plants.

A new structure is proposed of a SSO fuel cycle for FNS with "real time" processing gases without accumulating in the operational storage. It provides separate flows of fuel components and plasma isotope composition. Due to organization of several circuits (up to 13 in FNS projects), the structure provides minimal possible tritium reserves in the FNS complex. The proposed structure maintains stationary control of the plasma isotopic composition by means of a separate D/T supply using pellets (HFS, LFS - to stimulate ELMS) and heating beams. The gas puffing into a vacuum vessel without changing its isotope composition after pumping can reduce the flow rate in the hydrogen isotope separation system. This will reduce the tritium reserves required to start the facilities (less than 0.5 kg for DEMO-FNS/40 MW and less than 0.1 kg for FNS-ST/ 3 MW) by almost 10 times compared with the estimates obtained in the DEMO configuration.

As a result, a draft design of the fuel cycle of the FNS-ST and DEMO-FNS complexes was proposed and developed, being based on new technical and technological solutions. The FC composition and readiness level of tokamak technological systems realizing the D-T FNS fuel cycle have been determined. The proposed and realized approach is capable to solve the D-T fuel cycle design problems of SSO fusion devices.

Country or International Organisation

Russian Federation

Affiliation

NRC Kurchatov institute

Speaker's email address

ananevss@gmail.com

Author: ANANYEV, sergey (nrc Kurchatov institute)

Co-author: KUTEEV, Boris (NRC Kurchatov Institute)

Presenter: ANANYEV, sergey (nrc Kurchatov institute)

Session Classification: Posters

Track Classification: Tritium Fuel Cycle