Contribution ID: **16** Type: **Contributed Poster**

Assessment of fuel purification requirements in a DEMO Reactor

Wednesday 12 October 2022 14:50 (20 minutes)

The minimization of the Fuel Cycle inventory in a pulsed DEMO-like power reactor can be provided in the Direct Internal Recycling (DIR) concept by adding an additional short-cut between the pumped torus exhaust gas and the fuelling systems [1]. The Fuel Cycle which includes plasma fuelling and exhaust, as well as several exhaust processing and isotope separation processes, is one of the key elements on which the successful operation of a Fusion Power Plant (FPP) will depend.
For steady-state FPP operation it is necessary to remove the reaction products from the tokamak chamber and to compensate for burned-out components of the working mixture of deuterium and tritium. The consumption of fresh fuel is determined mainly by the reactor power and the amount of gas pumped off depends on various factors like reaction-product enrichment or purification conditions. Simple balance considerations can provide estimates and relations to optimize the fuel cycle loads.
In this work the limiting fuel burnup fraction is estimated as a function of the fraction of hydrogen isotopes and helium in the total plasma pressure for different values of the helium-enrichment factor in the mixture pumped off. It is also discussed the required purity of incoming fuel with respect to helium as a function of the allowable concentration of protium in the working chamber for different values of fuel burnup fraction. The required fuel purity with respect to protium, which is virtually independent of the burnup fraction, and the relative helium concentration in the working chamber are estimated.
Calculations show that for DEMO operation a relatively deep purification of the fuel mixture to remove helium is required, while as far as purification from protium is concerned it is sufficient to remove only a small portion of it.
[1] Ch. Day and T. Giegerich, The Direct Internal Recycling concept to simplify the fuel cycle of a fusion power plant, Fusion Engineering and Design 88 (2013) 616-620.

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Session Classification: Posters

Track Classification: Interface btw Plasma Burn Control & Fuel/Exhaust Actuator