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Tritium migration pathway and role of the coolant purification system

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Central requirements for DEMO are production of net electricity and operation with a closed fuel cycle. Thus, the machine will be equipped with a primary and a secondary coolant loop for heat extraction and energy conversion, and with a breeding blanket and a fuel cycle respectively for tritium production and processing. Such configuration inevitably opens a path to tritium migration because heat removal and tritium production occur both in the blanket region where the presence of high temperatures, large metallic surface areas and high tritium concentrations facilitate tritium permeation from blanket to primary coolant. Once in the primary coolant circuit, tritium permeates either across coolant tubes and into secondary coolant loop from which it easily reaches external environment. Obviously, the entire phenomenon is of safety relevance for DEMO and for the future fusion power plants, therefore a series of activities are ongoing with the intent to identify and implement effective strategies to mitigate tritium permeation. Along the years, simulation tools have been developed to evaluate tritium migration and inventory in blanket, operational coolants, structural materials, steam generator etc., as well as tritium losses into environment under different operating conditions. Results of these simulation analyses have been used to guide the design activities towards the definition and development of possible strategies to mitigate tritium permeation. Particularly tritium migration analyses have identified, as countermeasure to permeation, the chemistry (mainly H2 and H2O addition) in the blanket and coolant side, the use of effective anti-permeation barriers and the appropriate dimensioning of a coolant purification system.

This contribution provides a general description of the problem of tritium transport in two blanket concepts, the Helium Cooled Pebble Bed (HCPB) and the Water Cooled Lithium Lead (WCLL), highlights the impact of most relevant parameters and main results of the sensitivity analysis. In addition, the solutions currently considered for the Coolant Purification System (CPS) are illustrated and the status of their design is presented. For the case of water-CPS, a review of the existing and under development facilities for water detritiation was carried out during the pre-conceptual design phase, posing emphasis on dimension and complexity. Due to the high tritium permeation rate in water blanket concept, both strategies require the adoption of anti-permeation barrier on blanket walls. Although off-line approach presents relevant advantages such as plant simplification and less stringent issues related to the size of CPS technologies, a sensitivity analysis has demonstrated the need of an on-line CPS to reduce tritium inventory in primary coolant. For this reason, the on-line strategy has been considered in the presented design activity. For the case of helium, two processes were identified in the pre-conceptual design phase: one based on conventional technologies, such as CuO and molecular sieve beds, and one on novel getter materials for the direct adsorption of hydrogen isotopes. Recent analysis suggests that a major parameter to be considered in the definition of the helium CPS design is the H2 content in primary coolant.

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