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Process Intensification in Water Detritiation System : A Case Study

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Water Detritiation System (WDS) is a critical safety system for ITER to reduce the tritium release to the atmosphere and help in the recovery of tritium for self-sustainability. The tritium released/leaked into plant area from the process systems is sent to Atmosphere Detritiation System (ADS), where it is converted to moisture by catalytic reaction with oxygen in air and then scrubbed with lean water to transfer the tritium into water in order to reduce the releases to the atmosphere. The water collected in ADS is generally of low tritium concentration and it requires a process like Combined Electrolysis and Catalytic Exchange (CECE) which separates concentrated tritium with hydrogen in gas form and is sent to Isotope Separation System (ISS) for enrichment.

Similar to ITER fusion reactor scenario, a typical Pressurized Heavy Water Reactor (PHWR) also handles heavy water with low tritium concentration that can be processed in a detritiation system to reduce the tritium release to the atmosphere. The heavy water used as coolant and moderator undergo radioactive contamination due to neutron absorption of deuterium atoms. The tritiated heavy water liquid that escapes into the reactor building environment due to leakages or spillages is collected as Low Isotopic Purity (IP) heavy water and treated as Low Level radioactive waste. The heavy water leakage in vapor form is collected by adsorption/condensation. This low level radioactive waste is generally discharged through waste management system by Dilute and Disperse method.

This paper evaluates theoretically the feasibility of using CECE as a Process Intensification step to process low level tritiated waste in order to improve the isotopic purity for further upgradation and also reduce the release of tritium to atmosphere. For the current case study, a feed with <100mCi/L of radioactive contaminant activity and <1% IP was considered for CECE based water detritiation system. A process model for CECE consisting of mass balance and equilibrium equations was developed and solved using the Differential Algebraic equation solver package of Scilab. The model was solved for the feed considered and the concentration of top stream of CECE for the current case study was targeted to as low as 100 μCi/m3 and bottom stream with an isotopic purity of >10% as deuterium atom fraction. The experiments were conducted using hydrogen isotopes and results were used to validate the model which was further utilized to evaluate practical feasibility of CECE for detritiation of wastewater. It was estimated that CECE based detritiation system has resulted in reduction of annual fresh water requirement by ~50% of that used for dilution. Thus theoretically CECE has proven to be a potential heavy water and tritium recovery technique for similar atmospheric detritiation applications. Such a process system intensification can be utilized in integrated detritiation safety systems of ITER.

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