The Fuel Cycle of Fusion Power Plants and Experimental Fusion Reactors

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Fusion power plans and their experimental precursors will necessarily employ mixtures of the hydrogen isotopes deuterium and tritium as plasma fuel. While deuterium is abundantly on hand from natural sources, the radioactive tritium is so far only available in limited amounts from the operation of heavy water moderated fission power plans. Hence, for economical and ecological incentives, the technology for the complete fuel cycle of fusion plants must be perfected, even for experimental reactors like ITER. This includes the demonstration of removal and recovery of tritium bred in blankets, even though according to current ITER operational scenarios the total amount of tritium available from world civil resources is considered to be sufficient for this experimental machine.

The major guidelines for the design of the fuel cycle are the safe recycling, handling and confinement of tritium with a minimal and controlled inventory and very low effluents and releases. Important operational aspects are high availability and reliability of the fuel cycle subsystems with low quantities of solid wastes produced and low costs.

Results from R&D work in all relevant areas of the fuel cycle, particularly from EURATOM associations, have been used for the preliminary design of the ITER fuel cycle. However, further experimental work and mathematical modeling on processes for certain subsystems and prototype testing of specific components are required to support the final design work for ITER and hence to the eventual development of the technology for commercial fusion power reactors.

The paper will describe the status of the development of fuel cycle technologies, covering storage and fuel supply, torus vacuum pumping, plasma exhaust gas processing, isotope separation and water detritiation, tritium recovery from breeding blankets and auxiliary systems. Emphasis will be given to tritium inventory control issues, effluents and releases, and to extrapolation aspects from the ITER experimental reactor to fusion power plants.