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Key Considerations in the Power Extraction from Fusion Reactors

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As the demand for energy grows, futuristic energy sources like the D-T thermonuclear fusion using the magnetic confinement scheme called tokamak are being researched upon. It is generally presumed that a fusion blanket surrounds the tokamak plasma which absorbs the fusion neutrons, using their energy to convert into heat energy and nuclear transmutation with lithium to re-generate the lost tritium. Since the focus of the fusion community is largely on design, construction, operation and research of fusion devices and plasma performance, the engineering study (in-depth) of how is one going to take the power out from the blankets, through the complex geometry, all the way up to the Steam Generator (SG) has hardly received any attention. It is almost assumed without any reason that 'if we have the heat source, the rest is well known'. To some extent, this state of affairs could also be due a belief that such reactors would be realized only in the far future. This paper presents an in-depth look at the key considerations for transporting the power from the blankets to the SG. The main purpose of the study is to develop and compare conceptual designs for the above, based on engineering considerations. The problem involves three main steps: (a) transport of heat from the blanket-outlet up to the SG, (b) heat-exchange within SG and (c) return of the blanket coolant to the blanket-inlet. Three different coolants seem to have been considered currently by the fusion blanket community: Water, Helium and Lead-Lithium eutectic (PbLi). However, it appears that an additional heat-exchanger (HX) will be needed for PbLi (which is most likely to be with Helium) before the heat is transferred to SG. From this point of view, both the concepts (PbLi and He cooled) end up in requiring a design of SG based on He-water HX. Using the current available designs of fusion power plants; to some extent the layout of ITER and the consideration of SG for fission power reactors, we have developed some conceptual designs for extraction of power. A computational tool has been developed to efficiently determine the thermo-hydraulic parameters to be verified by detailed ANSYS calculations.
Keywords: Fusion power plant design, heat exchanger design, efficiency of thermal cycle

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