Optimized Helium-Brayton Power Conversion for Fusion Energy Systems

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This paper will present an overview and a few point designs for multiple-reheat helium Brayton cycle power conversion systems using molten salts (or liquid metals or direct helium cooling). All designs are derived from the General Atomics GT-MHR power conversion unit (PCU). The important role of compact, offset fin heat exchangers for heat transfer to the power cycle helium, and the potential for these to be fabricated from carbon-coated composite materials that would have lower potential for fouling. Specific links will be made to the ITER TBM and laser IFE blanket design, and to Z-Pinch/HIF thick-liquid IFE.

The GT-MHR PCU is currently the only closed helium cycle system that has undergone detailed engineering design analysis, and that has turbomachinery which is sufficiently large to extrapolate to a >1000 MW(e) molten salt coolant gas cycle (MCGC) power conversion system. Analysis shows that, with relatively small engineering modifications, multiple GT-MHR PCU's can be connected together to create a MCGC power conversion system in the >1000 MW(e) class. The resulting power conversion system is quite compact, and results in what is likely the minimum helium duct volume possible for a multiple-reheat system. To realize this, compact offset fin plate type salt-to-helium heat exchangers (power densities from 10 to 120 MW/m^3) are needed. Compact plate heat exchangers are already commonly used for heat transfer at lower temperatures. Of great interest for fusions is the potential to fabricate compact plate type heat exchangers that would provide very high surface area to volume ratios and very small fluid inventories while operating at high temperatures. Both metal and non-metal heat exchangers are being investigated for high-temperature, gas-cooled reactors for temperatures to 1000ºC. Recent high temperature heat exchanger study for nuclear hydrogen production has suggested that carbon-coated composite materials such liquid silicon infiltrated chopped fiber carbon-carbon preformed material potentially could be used to fabricate plate fin heat exchangers that would have lower potential for fouling. Optimization and cost models for the power conversion systems applicable to fusion power plants could be used to select optimum parameters such as system pressure, numbers of reheat and intercooling, and other important parameters. This paper summarizes a few power conversion system point designs for three options of ITER US DEMO blanket designs. Among three blanket design options, self-cooled FLiNaBe salt option potentially can achieve the best thermal efficiency through MCGC. For dual-coolant options, dual cycles, helium direct cycle plus MCGC cycle can combine to achieve a good thermal efficiency.