

An Assessment of the Brayton Cycle for High Performance Power Plant

R.W. Schleicher, C.P.C. Wong

General Atomics, P.O. Box 85608, San Diego, CA 92186

A.R. Raffray

University of California, San Diego, CA

The potential for economically competitive fusion power is, in part, dependent on achieving a high net thermal efficiency. This means that heat must be removed at the highest possible temperature and converted to electric power in the most efficient cycle. For fusion systems, practical design choices are limited by material, compatibility, high heat fluxes, electromagnetics and nuclear radiation. Given these limitations, the He Brayton cycle appears to be the best near-term power conversion method for maximizing the economic potential of fusion. Helium is an excellent working fluid, its high specific heat and thermal conductivity leading to low pump work and heat transfer surface requirements (for a gas). It is chemically and neutronically inert and compatible with any fusion material. As a gas, its pressure can be selected independently of temperature. Its main disadvantage is its low density. For source temperatures more than 500C, a highly recuperated Brayton cycle is the most efficient power cycle available. Its range of applicable working temperatures is limited only by structural materials for heat exchange and pressure retaining structures. For advanced fusion concepts, an upper temperature of 1100C appears achievable. Currently, blade/disk cooling is required for higher temperatures with a high corresponding efficiency penalty. Other key factors affecting the Brayton cycle efficiency are compressor and turbine adiabatic efficiencies, recuperator effectiveness and cycle fractional pressure loss. The compressor pressure ratio is also important because for fusion conditions, structural and turbomachinery limitations often prevent use of an optimum value.

This paper examines these parameters and proposes achievable values for fusion power plant studies based on existing products, test results, current knowledge, and, if justified, reasonable extrapolation. The economic impact of achieving high-performance Brayton cycle parameters is also assessed. Preliminary results indicate that gross plant efficiencies of up to 60 percent are possible for a turbine efficiency approximately 93 percent, compressor efficiency more than 90 percent (achievable in split-shaft arrangements), recuperator effectiveness of 96 percent (consistent with latest compact prime surface and plate-fin designs), and minimization of pressure losses through high pressure operation (approximately 12-20 MPa). The challenge for fusion then becomes to limit recirculating power and house loads and the demonstration of advanced blanket designs.