ANALYSIS OF REQUIRED SUPPORTING SYSTEMS FOR THE SUPERCRITICAL CO_2 POWER CONVERSION SYSTEM

By

Rosemary M. Freas

Submitted to the Department of Nuclear Science and Engineering on August 10, 2007 in partial fulfillment of the requirements for the degree of Master of Science in Nuclear Science and Engineering and the Nuclear Engineer's Degree

Abstract

Recently, attention has been drawn to the viability of using S-CO_2 as a working fluid in modern reactor designs. Near the critical point, CO_2 has a rapid rise in density allowing a significant reduction in the compressor work of a closed Brayton Cycle. Therefore > 45% efficiency can be achieved at much more moderate temperatures than is optimal for the helium Brayton cycles. An additional benefit of the S-CO_2 system is its universal applicability as an indirect secondary Power Conversion System (PCS) coupled to most GEN-IV concept reactors, as well as fusion reactors. The United States DOE's GNEP is now focusing on the liquid Na cooled primary as an alternative to conventional Rankine steam cycles. This primary would also benefit from being coupled to an S-CO_2 PCS.

Despite current progress on designing the S-CO_2 PCS, little work has focused on the principal supporting systems required. Many of the required auxiliary systems are similar to those used in other nuclear or fossil-fired units; others have specialized requirements when CO_2 is used as the working fluid, and are therefore given attention in this thesis.

Auxiliary systems analyzed within this thesis are restricted to those specific to using CO_2 as the working fluid. Particular systems discussed include Coolant Make-up and Storage, Coolant Purification, and Coolant Leak Detection. Concepts discussed include: potential forms of coolant storage, including cryogenic and high pressure gas, with some "back of the envelope" methods which can be used for estimating the coolant transferred; possible coolant contaminants and their sources; options for the procurement of the CO_2 from potential distributors, including available purities and estimated cost; the purity of CO_2 for the S-CO_2 system and purification methods; various methods of coolant leak detection using both in-situ analyzers and portable devices for maintenance personnel, and instrumentation for the monitoring of compartmental CO_2 and CO concentrations to meet OSHA standards. A conceptual design is presented for coolant storage. Systems are discussed in terms of basic functionality, system requirements, desired features, basic safety and design concerns, and identification of issues to be resolved by future research.

Thesis Supervisor: Michael J. Driscoll
Title: Professor Emeritus of Nuclear Science and Engineering

Thesis Reader: Pavel Hejzlar
Title: Principal Research Scientist; Director, Advanced Reactor Technology Program, Center for Advanced Nuclear Energy Systems (CANES)