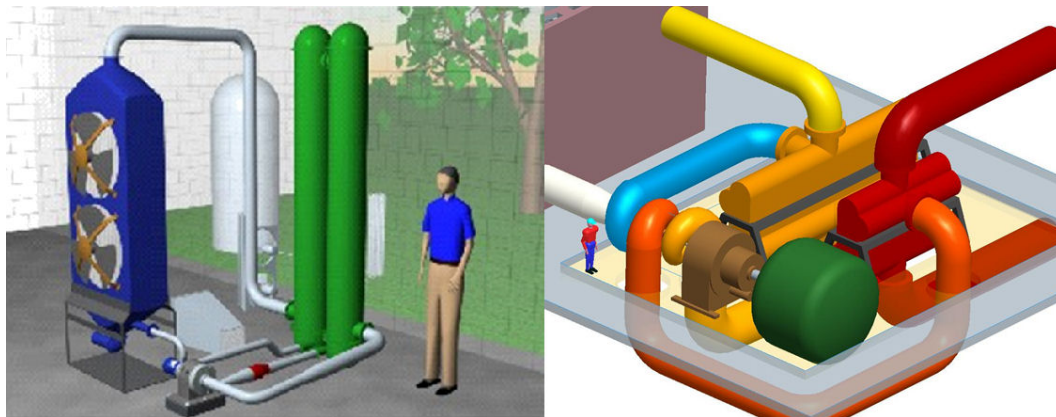


2009/2010 academic year design project offered by the Department of Mechanical and Aerospace Engineering for final year students.

*Project 4: Supercritical Carbon Dioxide Advanced Brayton Cycle Design
Project Manager: Professor H. Saari*

Approximately 25% of Canada's electricity generation comes from the combustion of fossil fuels, which results in the emission of greenhouse gases. Environmental considerations dictate the reduction of these emissions, as well as other air pollutants such as SO₂, NO_x, particulates, and toxic substances. Several methods of reducing greenhouse gas emissions are available, including carbon capture and storage, increasing the energy efficiency of existing power cycles used to generate electricity, and developing new, advanced, high-efficiency power cycles.

For a number of years, the focus of the Gas Turbine Project was the design of a novel gas turbine engine for power generation that would result in near-zero emissions of carbon dioxide and other pollutants. The work was conducted under a contract from Natural Resources Canada. The cycle was semi-closed, used carbon dioxide as the working fluid, and had an electrical output of 50 kW. Starting in 2006, the focus was expanded to include the design of an advanced, high-efficiency Brayton closed-cycle, indirectly-fired 100 MWe gas turbine power plant using supercritical carbon dioxide (S-CO₂) as the working fluid. This work is now the subject of a new four-year contract with Natural Resources Canada.



50 kW zero emission (left) and 100 MWe S-CO₂ (right) power plants

S-CO₂ is an attractive working fluid because of its low critical pressure and temperature, availability, and heat transfer and thermodynamic characteristics. Supercritical fluids are at or above both critical temperature and pressure, and exhibit uncommon properties midway between those of a gas and of a liquid. For example, they expand to fill their container like a gas, but have densities approaching that of a liquid. The main advantage is the high density of the S-CO₂ entering the compressor, allowing the compressor work to be only a fraction of the total turbine output (approximately 20% versus 50% in typical gas turbine cycles), resulting in a higher overall efficiency. Another advantage is the much smaller turbomachinery size required for a given output power, as compared to traditional gas turbines used in power generation. The S-CO₂ cycle is also attracting attention as the power conversion system for the next generation of nuclear reactors. The S-CO₂ cycle is also quite efficient at relatively low turbine inlet temperatures, allowing it to exploit the low-grade waste heat that is produced as a byproduct of a variety of industrial processes to generate electricity.

In 2009/2010, the team will focus on the turbine, compressor and heat exchanger design and performance analysis and optimization. This will build on the preliminary design work that has been carried out over the last several years, which has revealed a number of intriguing technical challenges that will keep the team busy. The work is multidisciplinary, and would appeal to students in aerospace, mechanical, electrical, and computer systems engineering. Some of the tasks include:

- thermodynamic cycle analysis
 - development of the final, optimized cycle including steady-state and transient system models
 - determination of performance data for both design and off-design conditions
- turbomachinery design
 - preliminary design of the compressor and turbine including aerodynamic, structural, and materials considerations
 - preliminary design of a compressor test rig to generate data for model validation
- heat exchanger design
 - main heat exchanger, recuperator, and precooler
- control system design
 - development of a preliminary control system for start-up, shut-down, part load, and steady state operation
 - investigation of monitoring and control challenges
- system integration
 - integration of turbomachinery system components and of the turbomachinery into the overall power plant design

Third year students who are interested in participating in this project are encouraged to attend the final design review for the 2008/2009 team. This will be held on Tuesday, March 24, 2009 in the Senate Chamber, Robertson Hall. If you have any questions, please contact the Project Manager, or you may contact the departmental office at (613) 520-5684.