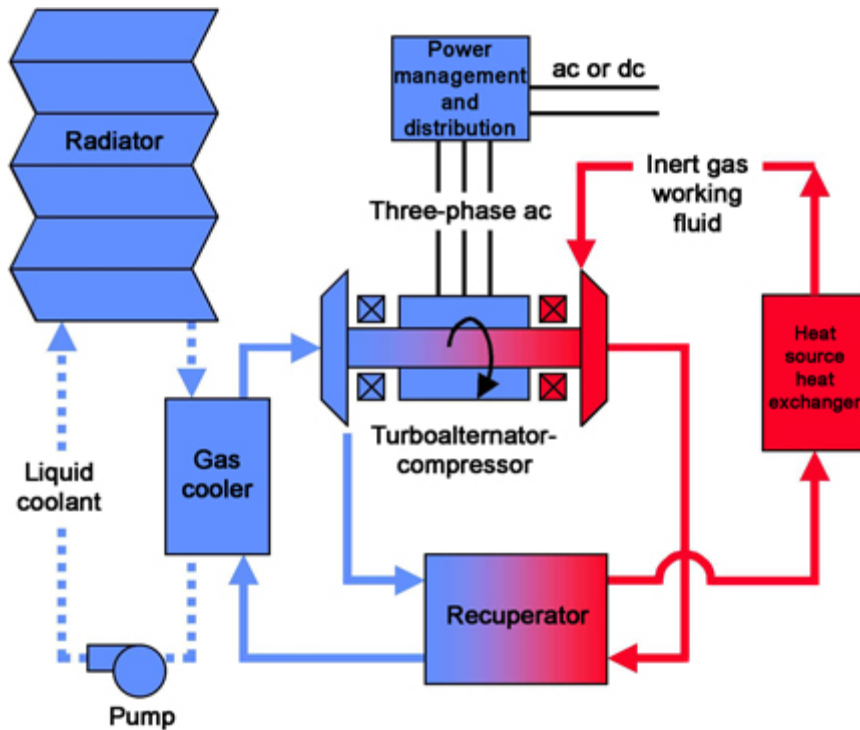


# Closed-Cycle Engine Program Used to Study Brayton Power Conversion

One form of power conversion under consideration in NASA Glenn Research Center's Thermal Energy Conversion Branch is the closed-Brayton-cycle engine. In the tens-of-kilowatts to multimewatt class, the Brayton engine lends itself to potential space nuclear power applications such as electric propulsion or surface power. The Thermal Energy Conversion Branch has most recently concentrated its Brayton studies on electric propulsion for Prometheus. One piece of software used for evaluating such designs over a limited tradeoff space has been the Closed Cycle Engine Program (CCEP).

The CCEP originated in the mid-1980s from a Fortran aircraft engine code known as the Navy/NASA Engine Program (NNEP). Components such as a solar collector, heat exchangers, ducting, a pumped-loop radiator, a nuclear heat source, and radial turbomachinery were added to NNEP, transforming it into a high-fidelity design and performance tool for closed-Brayton-cycle power conversion and heat rejection. CCEP was used in the 1990s in conjunction with the Solar Dynamic Ground Test Demonstration conducted at Glenn.

Over the past year, updates were made to CCEP to adapt it for an electric propulsion application. The pumped-loop radiator coolant can now be n-heptane, water, or sodium-potassium (NaK); liquid-metal pump design tables were added to accommodate the NaK fluid. For the reactor and shield, a user can now elect to calculate a higher fidelity mass estimate. In addition, helium-xenon working-fluid properties were recalculated and updated.



*Recuperated closed-Brayton-cycle power-conversion system with heat rejection.*

Long description of figure. System diagram showing pump, liquid coolant, radiator, gas cooler, turboalternator-compressor, three-phase ac, power management and distribution (ac or dc), recuperator, heat source heat exchanger, and inert gas working fluid.

CCEP allows researchers to design a closed-Brayton-cycle power-conversion system and then evaluate the system's off-design performance. Design trade-off studies conducted with CCEP included varying alternator power output, system peak pressure, turbomachinery shaft speed, helium-xenon molecular weight, and compressor pressure ratio. Design point calculations of interest were the system total mass, radiator area, and heat input required. Steady-state off-design performance studies included reducing the shaft speed, bypassing the recuperator, and reducing the turbine inlet temperature to see how the change in operating conditions affected the heat input required, the alternator power output, and the potential for the radiator fluid to freeze. Transient analysis in CCEP is being used in more extensive off-design performance analysis.

CCEP contains enough flexibility to make it useful for a variety of closed-Brayton-cycle configurations. Whether future CCEP versions are maintained in the Fortran format or the methods and equations are transported to a new platform, CCEP will continue its legacy as a powerful closed-Brayton-cycle design and analysis tool.

## Bibliography

Ensworth, Clint B., III; and McKissock, David B.: Closed Cycle Engine Program Used in Solar Dynamic Power Testing Effort. Research & Technology 1997, NASA/TM--1998-206312, 1998, pp. 139-140.

<http://www.grc.nasa.gov/WWW/RT1997/6000/6920ensworth.htm>

Mason, Lee S.: Power-Conversion Concept Designed for the Jupiter Icy Moons Orbiter. Research & Technology 2003, NASA/TM--2004-212729, 2004, p. 76.  
<http://www.grc.nasa.gov/WWW/RT/2003/5000/5490mason.html>

**Find out more about this research.**

**Glenn contact:** Michael J. Barrett, 216-433-5424, [Michael.J.Barrett@nasa.gov](mailto:Michael.J.Barrett@nasa.gov)

**Analex Corporation contact:** Paul K. Johnson, 216-433-3814,  
[Paul.K.Johnson@grc.nasa.gov](mailto:Paul.K.Johnson@grc.nasa.gov)

**Author:** Paul K. Johnson

**Headquarters program office:** Exploration Systems

**Programs/Projects:** Project Prometheus