Update

Rita D'Aquino

Zero-Emission Power Generation — Pure Rocket Science

Clean Energy Systems, Inc. (CES; Sacramento CA, www.cleanenergysystems.com) is a step away from commercializing what will be the world's first zero-emissions power plant — one that generates electricity without atmospheric release of sulfur or nitrogen oxides, mercury and other pollutants typically associated with fossil fuel combustion. Central to CES' technology is the replacement of steam boilers and flue-gas cleaning systems on conventional steam power plants (or substitution of normal combustors in gas turbine power plants) with gas generators derived from rocket engines.

"The retrofitted gas generators use the advanced mixing and thermal-management techniques that are characteristic of rocket engine injectors, as well as combustion-chamber cooling, to yield a robust source of high-enthalpy gases to drive turbogenerators," says Keith Pronske, CEO of CES. Final testing on a 20-MW gas generator — the last component of CES' power generation system to be verified — was completed earlier this year, and was considered a success by the U.S. Dept. of Energy's (DOE; Washington, DC; www.doe.gov) National Energy Technology Laboratory, which co-funded the project with CES.

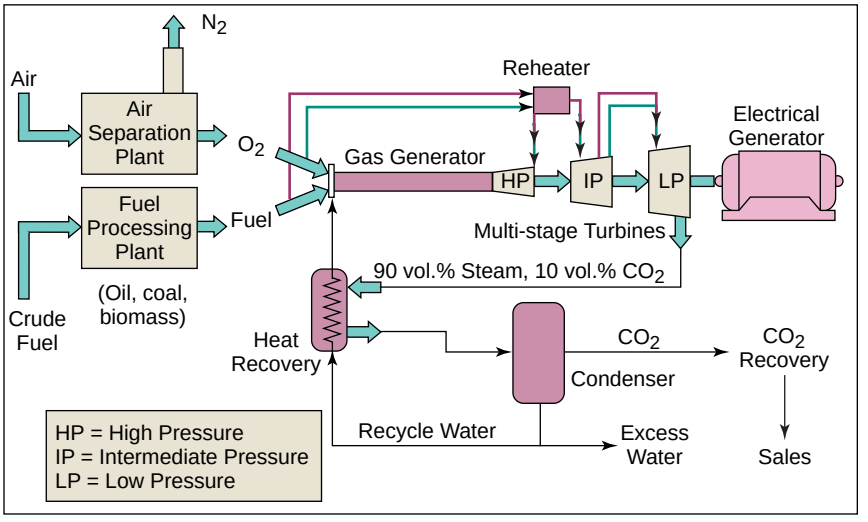
The CES' process design (Figure) features the near-stoichiometric combustion of a clean, gaseous fuel from virtually any organic source (e.g., coal, fossil fuel, biomass and refinery residues) with oxygen (obtained from air via membrane or cryogenic separation) in the presence of recycled water to produce high-temperature, high-pressure steam and carbon dioxide. Water is injected stagewise to decrease the temperature of the turbine-drive gas to a value that is acceptable to the downstream, high-pressure turbine.

Once fed through the high-pressure turbine, the clean gases are reheated by direct firing (with oxygen and fuel), and are sent to intermediate- and low-pressure turbines, respectively. The exhaust is cooled in a heat exchanger using high-quality water that is recycled from the condenser that subsequently separates the exhaust into CO_2 and water (which is recycled). The pure CO_2 is dried and compressed for use in enhanced oil or coal-bed methane recovery, sequestration or for direct sales. CO_2 sequestration costs with CES' technology are about $9/metric ton, compared to $32/metric ton for conventional power plants, including the transportation costs, according to Pronske.

Burning methane in oxygen, the 20 MW generator produced about 50,000 lb/h of mixed steam and CO_2 at a discharge pressure and temperature of 1,500 psia and 1,500°F, respectively. "Such drive gases can re-power existing power plants and convert them to near-zero emissions facilities, or be used to power advanced turbines in near-zero emission power plants," says Roger Anderson, CES' principal investigator for the program. "At these temperatures, efficiencies of 50% are possible with zero emissions and nearly 100% CO_2 capture, which is comparable to the efficiency of a combined cycle plant without any carbon capture," he says. In contrast, a conventional steam boiler typically operates at 1,000–1,100°F, which caps efficiencies at 45%.

Economics are favorable, too. "Natural gas plants using existing steam-turbine systems retrofitted with rocket technology can produce electricity at $0.05–$0.06/kWh, which competes favorably with other green energy technologies, such as fuel cells, microturbines and wind and solar energy," explains Pronske. "Improvements in turbine technology will decrease these costs to $0.04/kWh, and ultimately to $0.03/kWh."

Zero-emission plants that use existing components and burn gasified coal can be built for the same cost as integrated gasification combined-cycle plants with partial carbon capture (85%), says CES. The firm is building a 500-kW power plant in Antioch, CA, with the California Energy Commission (Sacramento; www.energy.ca.gov), Air Liquide (Houston, TX; www.airliquide.com) and Mirant Corp. (Atlanta, GA; www.mirant.com). Scheduled to go online in 2004, the plant will provide 10 metric ton/d of CO_2 to Air Liquide in exchange for oxygen.



A 20-MW gas generator retrofitted with rocket technology.