U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy
ADVANCED MANUFACTURING OFFICE

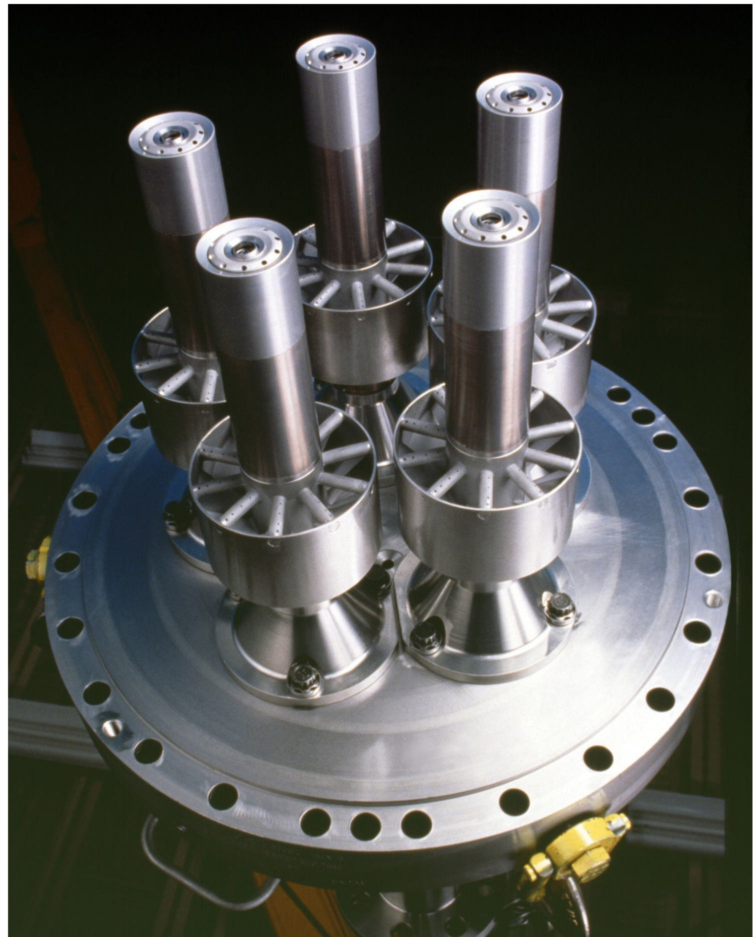
Development of Fuel-Flexible Combustion Systems Utilizing Opportunity Fuels in Gas Turbines

Reduced Energy Consumption through the Development of Fuel-Flexible Gas Turbines

Introduction

Gas turbines—heat engines that use high-temperature and high-pressure gas as the combustible fuel—are used extensively throughout U.S. industry to power industrial processes. The majority of turbines are operated using natural gas because of its availability, low cost, and reliability. However, a combination of recent factors, including volatility in fuel supply and pricing, global concerns about carbon emissions, and excess risk from heavy reliance on a single energy source, have made the utilization of natural gas substitutes such as industrial, municipal, and agricultural opportunity fuel sources very attractive from environmental and economic standpoints. Nevertheless, a major barrier to the utilization of opportunity fuels remains in the inability of industrial gas turbines to operate effectively when powered by such fuels.

This project aimed to address this barrier by developing and testing new fuel-flexible gas turbine nozzle technology concepts that will enable end users to efficiently generate power and heat from industrial off-gases and gasified industrial, agricultural, or municipal waste streams, as well as blends of these opportunity fuels with readily available pipeline gases. The project developed fuel-flexible premixer technologies to maximize the interchangeability of fuels in gas turbine configurations. The team also developed a plasma-assisted fuel nozzle technology that enabled gas turbine operation using fuel streams with ultralow British thermal unit (Btu) values, such as very weak natural gas, highly diluted industrial process gases, or gasified waste streams, beyond the capability range of current product offerings.



A Dry-Low NO_x combustor end cover and premixing fuel nozzles. Evolutionary and revolutionary concepts were evaluated in order to increase the fuel flexibility of gas turbine combustion systems.
Photo courtesy of General Electric

Benefits for Our Industry and Our Nation

The implementation of fuel-flexible gas turbines that provide an efficient, low-emissions source of electricity and process heat has major energy, economic, and environmental benefits, including the following:

- Economic benefits through avoided waste disposal fees
- The release of significantly fewer air pollutants due to advanced combustion technology
- A reduction of solid hazardous waste through the use of gasifier technology
- The utilization of an untapped energy source with significant energy substitution potential from biomass, municipal solid waste, petroleum coke, black liquor, and other opportunity fuels

Applications in Our Nation's Industry

The vast majority of industrial natural gas use in the United States consists of boilers that generate steam, heat water, and cogenerate electrical power. Thus, the potential applications of the project technology are in industries such as the food and beverage, petrochemical, pulp and paper, refining, steel and metals, and cement and glass manufacturing industries. Specifically, the project technology is expected to find an opportunity fuels market using industrial off-gases, digester gases, gasified solid waste, refiner off-gases, and steel mill gases.

Project Description

The goal of this project was to develop a low-emission, efficient, fuel-flexible combustion technology that enables operation of a given gas turbine on a range of opportunity fuels that lie outside of current natural gas-centered fuel specifications.

Barriers

- Fuel-flexible operability using dry-low NO_x emissions technology
- Application of plasma under gas turbine combustor conditions
- Fuel composition variability from gasified waste streams
- Flame stability/robust combustion on fuels with less than 125 Btu per standard cubic foot

Pathways

First, the project team defined and evaluated fuel-flexible combustor nozzle concepts for utilization with a wide range of opportunity fuels. The team also developed and validated analytical tools that were useful in this project and in later applications of fuel-flexible combustion concepts. Experimental evaluation of fuel-flexible nozzle concepts and the validation of model predictions followed. Experimental results were compared against model predictions, and the concepts went through one last round of optimization and retesting. Finally, the team designed, built, and tested the down-selected nozzle configurations at full gas turbine combustion conditions using target opportunity fuel blends.

Milestones

- Definition of target demonstration gas turbine architecture, combustion conditions, opportunity fuel scope of interest, and target combustion performance values and success criteria
- Definition of technology concepts (minimum of three advanced fuel-flexible premixers and three plasma-enhanced fuel nozzles)
- Evaluation and down-selection of new, well-defined nozzle concepts with reasonable promise of success
- Bench-scale experiments and evaluation of fuel nozzle concept hardware; risk retirement for all risks except those requiring high-pressure combustion testing
- Concept reevaluation and redesign for performance improvements; definition and plan of down-selected concepts for high-pressure testing
- Evaluation of concepts at full combustor conditions, including completion of high-pressure testing, data evaluation, and report completion

Accomplishments

GE was able to successfully demonstrate the operability of two fuel-flexible combustion nozzles over a wide range of opportunity fuels at heavy-duty gas turbine conditions while meeting emissions goals.

Commercialization

Technology commercialization is focusing on opportunity fuels that may not currently be served well by high-efficiency gas turbines and on those that would benefit from fuel-flexible low-emissions combustion technology advancement. The final commercial goal of this project is a validated fuel nozzle technology and design tool for a fuel-flexible, retrofittable combustion system for a GE gas turbine. Depending in part on future economic conditions, as well as the general energy-environment, GE may partner with an industrial architect and engineering firm to design plant upgrades and an established gasifier vendor (including GE) for solid-phase opportunity fuels.

In the near term, gaseous fuels that do not require gasification or digestion have the most commercialization potential because they are easier to interchange with natural gas in gas turbine applications. However, fuels such as biomass, black liquor, pet coke, and municipal solid waste have significant long-term potential because they are abundant and can replace large quantities of natural gas.

Project Partners

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DOE/EE-0481 • May 2014
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