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

Fuel-Flexible, Low-Emissions Catalytic Combustor for Opportunity Fuels

Enabling Clean Combustion of Low-Btu and Reactive Fuels in Gas Turbines

By enabling ultralow-emission, lean premixed combustion of a wide range of gaseous opportunity fuels, this unique, fuel-flexible catalytic combustor for gas turbines can reduce natural gas consumption in industry.

Introduction

Gas turbines are commonly used in industry for onsite power and heating needs because of their high efficiency and clean environmental performance. Most often, natural gas is the fuel of choice for these turbines because of its availability, historically low cost, and consistent composition.

"Opportunity fuels" offer an alternative to natural gas. These unconventional fuels are often derived from agricultural, industrial, and municipal waste streams or from byproducts of industrial processes. Common examples include synthetic gas (syngas) derived from coal or biomass, anaerobic digester gas, and refinery gas from the petroleum industry.

Typically, industrial gas turbines are unable to operate effectively when powered by these fuels. With some opportunity fuels, a low Btu rating causes difficulty in achieving a stable flame, particularly in low-emissions, lean premixed combustors. Other opportunity fuels are high in reactive components, such as hydrogen, propane, and butane, leading to problems with destructive flashback and autoignition.

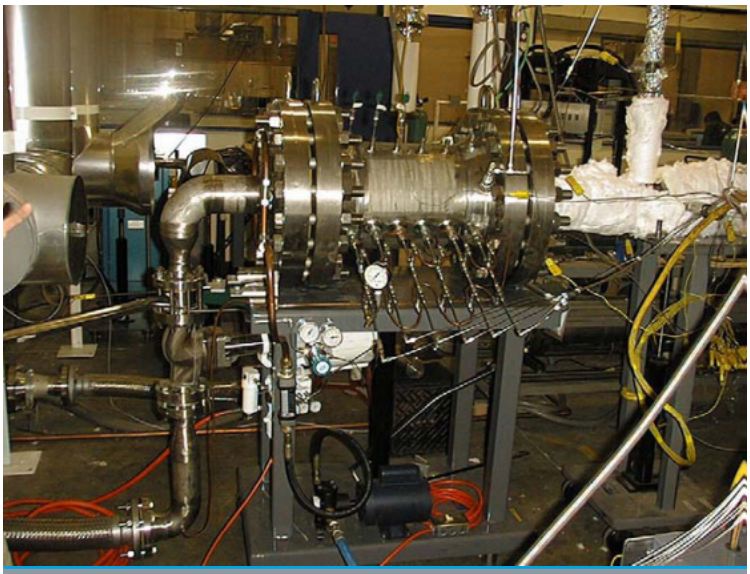
Due to these challenges, opportunity fuels have more commonly been used in boilers than in gas turbines. Boilers have inherent fuel flexibility and a low cost.

However, a gas turbine operating as a combined heat and power system or in a combined cycle with a steam turbine displays high efficiency and produces electricity, which can provide more economic value than steam alone from a boiler.

This project developed an injector with an integrated catalytic reactor to reform opportunity fuels before normal combustion. This reforming raises the fuel temperature, changes its composition, and leads to a stable flame free of flashback and autoignition.

Benefits for Our Industry and Our Nation

The use of opportunity fuels in industrial gas turbines with catalytic combustion systems displaces natural gas consumption, results in ultralow nitrogen oxide (NO_x) emissions, reduces capital costs (compared to use of post-combustion emission controls), and reduces greenhouse gas emissions, particularly when biomass fuels are used.



The catalytic reactor was tested in a high-pressure (10 atmospheres) subscale combustor rig. *Photo courtesy of Precision Combustion, Inc.*

Applications in Our Nation's Industry

Fuel-flexible catalytic combustion technology can benefit industries that utilize industrial gas turbines and have access to an alternative fuel source. Potential fuels and their sources include the following:

- Blast furnace gas from steel producers
- Refinery fuel gas from the petroleum industry
- Wellhead gas from oil and natural gas wells
- Gasification streams from solids such as coal and biomass
- Volatile organic compound streams from chemical manufacturers
- Landfill and digester gases from municipal, industrial, and agricultural waste

Project Description

This project developed a unique, fuel-flexible catalytic combustor capable of enabling ultra-low emission, lean premixed combustion of a wide range of gaseous opportunity fuels. This broadens the range of fuels that can be utilized.

The new combustor design enables use of low and ultra-low Btu gases, such as digester and blast furnace gases, by extending the limits of stable combustion. The new combustor also enables use of fuels containing reactive species, such as refinery, wellhead, and industrial byproduct gases, by reforming the gases (reducing hydrogen content) to a less reactive mixture, thereby preventing early autoignition and flashback.

Barriers

Technical challenges the project aimed to address include the following:

- Achieving adequate catalytic contribution to stabilize the flame downstream
- Addressing space constraints in design of existing turbines to enable the retrofit of combustors for low-Btu fuels

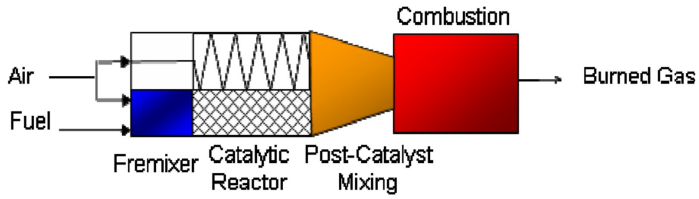
Pathways

The new combustor design is based on the Precision Combustion, Inc. (PCI) Rich-Catalytic Lean-burn (RCL®) combustion system. Initially, the project analyzed the fuel mixtures and expected engine applications to determine the appropriate reactor configuration for each class of fuel.

PCI fabricated a set of subscale test modules and tested them at expected engine inlet conditions. The project investigated and reported reactor performance and mechanisms of downstream flame anchoring. The results of the subscale testing provided reactor designs that can be scaled up to future full-scale single-injector fabrication and tested with gas turbine manufacturers.

Milestones

- Demonstration of high reactor conversion for low Btu fuels to enhance stability
- Demonstration of high preferential reaction for high-reactivity fuels to reduce flashback and autoignition
- Demonstration of low nitrogen oxide (NO_x) combustion of opportunity fuels
- Demonstration of the stable combustion of opportunity fuels with no cofiring and wide turndown capability



The Rich-Catalytic Lean-burn (RCL®) combustion system, designed by Precision Combustion, Inc., was modified for use with opportunity fuels. *Illustration courtesy of Precision Combustion, Inc.*

Accomplishments

- A reactor design capable of achieving 145°F enhanced lean blowout on low Btu fuels was demonstrated, with less than 2 parts per million (ppm) NO_x and less than 5 ppm carbon monoxide (CO)
- Improved subscale reactor design exceeded the goal of greater than 150°F turndown enhancement for low Btu fuels (greater than 250°F enhancement was achieved)
- Reactive fraction fuels showed a wide range of stable, low-emissions operation, with less than 2 ppm NO_x and less than 5 ppm CO

Commercialization

This project developed a fuel-flexible catalytic combustion system for gas turbines. Once the technology is further developed and validated, PCI will license it to gas turbine manufacturers for integration into their gas turbine product lines. In addition, PCI will provide catalytic core manufacturing.

Project Partners

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