R & D facts

U.S. Department of Energy
Office of Fossil Energy
National Energy Technology Laboratory

Energy Systems Dynamics

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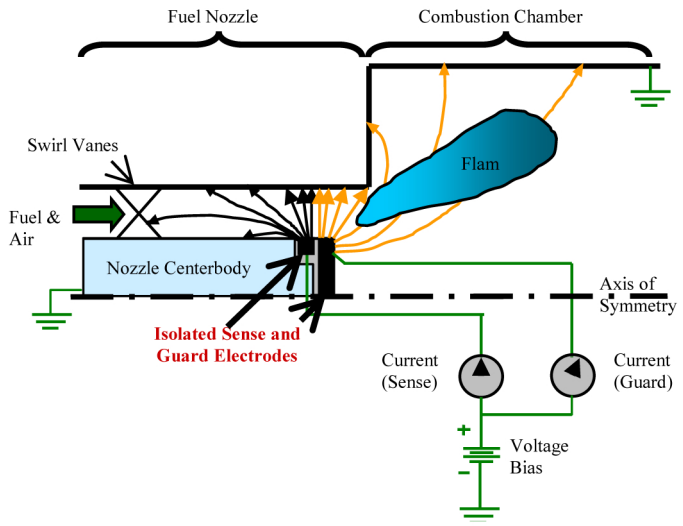
Combustion Control and Diagnostics Sensor (CCADS) Development

Objective(s)

Develop the combustion control and diagnostics sensor (CCADS) for gas turbines to provide key in-situ combustion monitoring for current and future low emissions gas turbines operating on natural gas, coal derived syngas, and hydrogen.

Relevancy

In order to meet the goals of the Department of Energy's (DOE's) Advanced Power Systems Program, gas turbines are being developed to operate on syngas and, eventually, pure hydrogen. Like natural gas fired turbines, syngas turbines will require precise fuel delivery to achieve fuel-lean homogenous mixing of the fuel and air in each local combustion zone, which is necessary for operation at the required ultra-low emission levels. Even with elaborate control schemes, state-of-the-art gas turbines must maintain a wide operating margin away from the lean blowout limit. Turbine manufacturers are reluctant to minimize this stability margin because of a lack of durable in-situ combustion monitoring and the many factors that can change the lean blowout limit during operations including component wear, daily environmental changes, and variations in fuel quality. Component size variations due to manufacturing tolerances further complicate this issue. These variations can result in each local combustor having a different apparent lean blowout limit. As a result, finely tuned control of local combustion is required to maintain flame stability without compromising performance in advanced turbines. Responsive fuel quality monitoring, local fuel control hardware, and in-situ monitoring of local combustion can be employed to achieve local combustion control and improve gas turbine performance.



CONTACTS

Jimmy Thornton
Research Group Leader
National Energy Technology Laboratory
3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26507
304-285-4427
jthorn@netl.doe.gov

Benjamin Chorpening
Principal Investigator
National Energy Technology Laboratory
3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26507
304-285-4673
benjamin.chorpening@netl.doe.gov

ADDRESS

National Energy Technology Laboratory
1450 Queen Avenue SW
Albany, OR 97321-2198
541-967-5892

2175 University Avenue South
Suite 201
Fairbanks, AK 99709
907-452-2559

3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26507-0880
304-285-4764

626 Cochrans Mill Road
P.O. Box 10940
Pittsburgh, PA 15236-0940
412-386-4687

One West Third Street,
Suite 1400
Tulsa, OK 74103-3519
918-699-2000

CUSTOMER SERVICE

1-800-553-7681

WEBSITE

www.netl.doe.gov

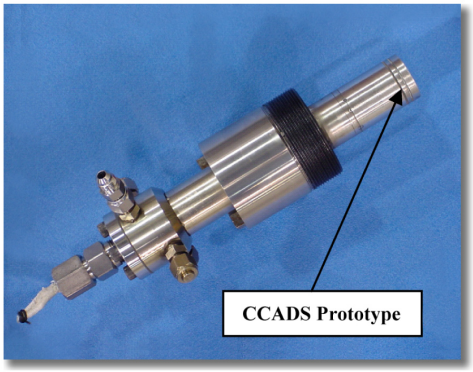
Project Summary

This project focuses on the development of a CCADS for in-situ monitoring in gas turbine combustors. The CCADS flame ionization sensor technique is based on two electrically isolated electrodes installed on the downstream end of the fuel injector centerbody, where the flame is aerodynamically anchored. The multi-sensing capability of CCADS provides a simple, yet robust, in-situ monitoring sensor for combustion diagnostics. Tests conducted at turbine conditions in laboratory combustors have demonstrated the following CCADS capabilities for natural gas fired combustors:

- Detection of flashback in the fuel nozzle
- Detection of precursor events that correlate with local flame extinction
- Detection of combustion-driven pressure oscillations, and
- A qualitative measure of local fuel-air ratio in the combustor

Although useful CCADS capabilities have been demonstrated, improving CCADS to provide quantifiable equivalence ratio measurements is necessary for fine-tuned combustion control applications. Flame instabilities and/or flame location changes at turbine conditions complicate the CCADS equivalence ratio measurements. To provide more information related to the flame location, development has shifted to time varying voltage techniques. When the flame moves away from the CCADS electrode, the weakly ionized region between the flame front and the electrode acts as a capacitance, which can be measured using a time varying measurement technique (e.g. sine wave, triangle wave, and square wave). These advanced measurement techniques and the additional information they can extract from the flame are expected to improve the CCADS performance in advanced power turbine applications.

Assessing CCADS performance with hydrogen blend fuels is necessary for syngas turbine applications. Preliminary test results from laboratory burner experiments indicate that CCADS can be applied in syngas turbine applications. Testing at representative turbine combustion conditions in laboratory combustors has demonstrated CCADS flashback detection with 80 percent hydrogen fuel (by volume). Additional evaluations are ongoing to fully assess sensing potential with hydrogen blends and pure hydrogen.

Fundamental laboratory and computational fluid dynamics model development supports the CCADS project by providing physical insight into the fundamental flame ionization and ion transport processes. The model development is also expected to facilitate the development of tools to aid in the design of CCADS for use in commercial combustor applications.

Assessing CCADS performance in full engine testing, for natural gas and syngas applications is essential for eventual implementation in fielded turbines. This is ongoing through a CRADA partnership with Woodward Industrial Controls.