TITLE: PREDICTION OF COMBUSTION STABILITY AND FLASHBACK IN TURBINES WITH HIGH-HYDROGEN FUEL

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1. ABSTRACT

Program Introduction: Rationale and Objective

The objective of this research is to develop tools that can predict flashback and combustion instability in lean premixed combustors operating on high-hydrogen fuels. It utilizes state-of-the-art numerical simulations, experimental techniques, and reduced order modeling, and is based on a collaborative effort involving two universities. Such a design tool is essential for the successful development of gas turbine power systems that can operate on coal-derived high-hydrogen fuels in an environmentally acceptable manner. In addition, the proposed research is structured to provide significant student involvement and therefore will make a significant contribution to the education of students who can provide the engineering expertise required for meeting our nations future energy needs in an environmentally friendly manner.

Accomplishments Achieved During the Current Period of Performance

Significant accomplishments were made in this reporting period in analytic, computational, and experimental analysis of combustion instability. First, substantial improvements in physics-based models of the flame response to fuel/air ratio oscillations were made. These analyses incorporated non quasi-steady and nonlinear effects into existing models, two key features that are needed for amplitude prediction in practical combustors. Second, progress was made in the development of a technique for measuring heat release fluctuations in unsteady flames with equivalence ratio fluctuations. This is a very challenging problem due to the inherent sensitivity of chemiluminescence to heat release, strain, and fuel/air ratio. Work focused on correctly subtracting background, including unsteady corrections, and measuring ratio's of emissions at different wavelengths. In addition, experiments were performed to study the influence of harmonic excitation on background turbulence. Finally, development of tools for large eddy simulation of combustion dynamics were initiated.

Plans for the Remaining Period of Performance

Future work will continue toward developing predictive models and validating measurements of the flame response to fuel/air ratio oscillations over a range of amplitudes. In addition, measurements and computations will be performed to

improve understanding of the interactions between narrowband acoustic fluctuations and broadband turbulent fluctuations.

2. LIST OF PUBLISHED JOURNAL ARTICLES, COMPLETED PRESENTATIONS AND STUDENTS RECEIVING SUPPORT FROM THE GRANT

Conference Presentations

- Sai Kumar Thumuluru, Karthik Periagaram, and Tim Lieuwen, "Flame Brush Dynamics in a Harmonically Oscillating, Turbulent Jet Flame," Proceedings of the 2008 Technical Meeting of the Central States Section of the Combustion Institute.
- Shreekrishna, Santosh H. and Tim Lieuwen, "Non-linear Flame Response to Equivalence Ratio Perturbations," accepted for Poster Presentation at The International Symposium on Combustion, Montreal August 3-8 2008.
- Sai Kumar Thumuluru and Tim Lieuwen, "Characterization of acoustically forced swirl flame dynamics," Accepted for Oral presentation at the 2008 *Combustion Symposium*, Montreal, Canada 2008.

Students Supported Under this Grant

- Sai Kumar Thurmuluru, PhD graduate student in the Department of Aerospace Engineering, Ben T. Zinn Combustion Laboratory, Georgia Institute of Technology.
- Vishal Acharya, PhD graduate student in the Department of Aerospace Engineering, Ben T. Zinn Combustion Laboratory, Georgia Institute of Technology.
- Hsin-Hsiao Ma, undergraduate student in the Department of Aerospace Engineering, Ben T. Zinn Combustion Laboratory, Georgia Institute of Technology.
- Liwei Zhang, PhD graduate student in the Department of Mechanical and Nuclear Engineering, the Pennsylvania State University.