R & D facts

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

Turbines

12/2006

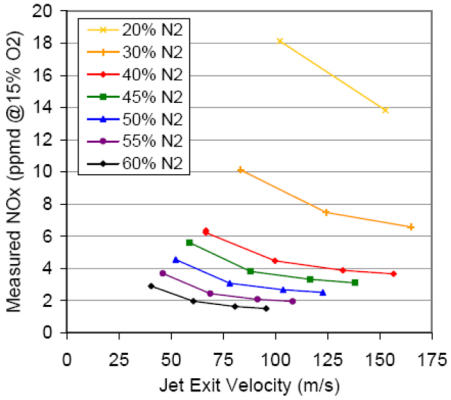
Hydrogen Dilute Diffusion Flame Project

The U.S. Department of Energy's (DOE's) Turbines Program is developing advanced Integrated Gasification Combined Cycle (IGCC) technology to deploy stationary power gas turbines. These turbines can use either coal syngas or other high-hydrogen derived fuels that allow for sequestration of the carbon in the syngas. The nitrous oxide (NO_X) emissions in the program goals are aggressively reduced to 2 ppmv NO_X at 15 percent oxygen, which is substantially lower than conventional natural gas fired turbines (i.e., 9ppmv). These reductions must also be achieved at comparable firing temperatures. To accomplish these goals, new approaches to fuel-flexible combustion must be explored.

Existing lean premixed gas turbines operating on natural gas are susceptible to a number of problems including flame flashback and combustion instabilities when operating on fuels containing large amounts of hydrogen. Combustion strategies for syngas and hydrogen utilize diffusion flames where the fuel and air are not premixed prior to combustion. The challenge is to design a diffusion flame combustor that meets DOE's aggressive NO_X goals.

The National Energy Technology Laboratory's (NETL's) Fundamental Combustion Laboratory (FCL) approach to this challenge involves highly strained dilute hydrogen diffusion flames. Nitrogen—an available byproduct in an IGCC power plant—is used to dilute the hydrogen fuel. The diluted fuel combined with very high injection velocities and small fuel injectors generates cooler flames, and NO_X production is significantly reduced.

At FCL, studies are underway to investigate the effects of nitrogen dilution, injection velocity, and injector diameter on peak flame temperature and NO_X formation rates in an atmospheric pressure laboratory-scale combustor. Results show significant reductions in NO_X levels over more conventional diffusion flame combustors.



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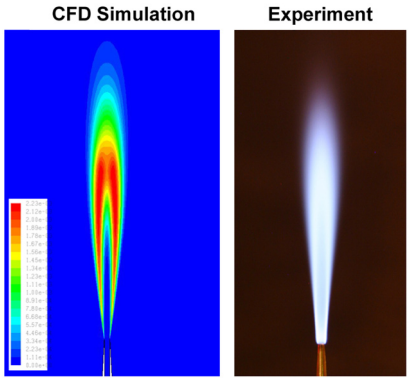
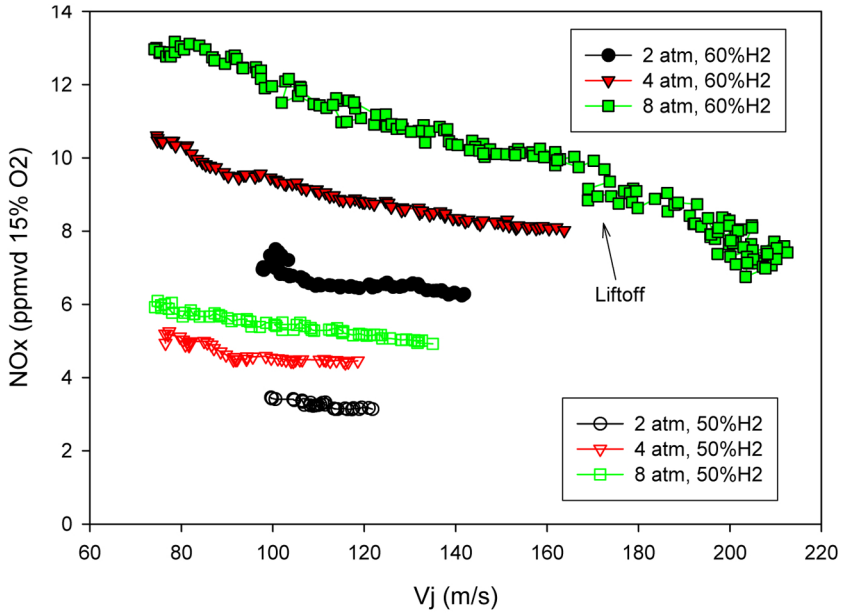
To provide insight into the complex fluid mechanics and chemistry occurring in these flames, a parallel effort is also being conducted using Computational Fluid Dynamics (CFD) to model the flames. The CFD results, which are validated using the experimental data, are also being used to improve upon current injector designs in an effort to design a "next generation" combustor which will meet the program's emission goals.



A companion study also being performed at NETL's Low Emission Combustion Test and Research Facility (LECTR) is capable of conducting experiments at pressures up to 20 atmospheres and at a size scale more typical of industrial gas turbine combustors. The fundamental knowledge generated in the FCL experiments and CFD modeling studies will be applied to a high-pressure, larger scale combustor that better simulates the operating conditions of an industrial gas turbine combustor.



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