# Flashback and Turbulent Flame Speed Measurements in a Low-Swirl Burner at Elevated Pressures and Temperatures

## OVERVIEW

Recently, alternative fuels to that of domestic natural gas have gained interest for use in the stationary gas turbine industry. This is a result of the increasing costs and limited supplies of natural gas, along with increasing regulations on pollutant emissions. One examples of one such alternative fuel is synthesis gas (syngas) which is derived from gasification of coal. Syngas contains high concentrations of $H_2$ along with CO and $CH_4$. Before developing engines to operate with syngas, the combustion characteristics of hydrogen-rich fuels at gas turbine relevant conditions must be well understood before these fuels can be utilized in gas turbines.

A high-pressure lean premixed gas fired combustor rig has been developed in order to study these fuels at gas turbine representative conditions as shown in Fig. 1 and 2. The burner utilizes a Low-Swirl Injector (LSI) for flame stabilization, developed by the Lawrence Berkeley National Laboratory as shown in Fig. 3, along with a quartz liner for complete optical access.

## GOALS

The present research effort aims to quantify flashback and turbulent flame speeds of methane and high-hydrogen flames at elevated pressures and temperatures

## RESULTS

The velocity flow field was mapped out using a Laser Doppler Anemometer (LDA). By measuring the local velocity at the leading edge of flame (Fig. 4) the turbulent displacement flame speed, $S_{T,LD}$ could be deduced. This measurement was performed with methane and high-hydrogen fuels at varying inlet pressures, temperatures, flow rates and equivalence ratios.

Flashback limits were found as a function of the same parameters by steadily increasing the firing temperature until the flame propagated back into the nozzle. Fig. 5 shows an image of a 90%/10% (by volume) hydrogen/methane flame right before and after flashback. Increasing pressure was found to decrease the operating window while increasing inlet temperature and flow rate increased the window as shown in Fig 6.

The turbulent flame speed measurements, as shown in Fig. 7, show that $S_{T,LD}$ is linearly proportional to the turbulence intensity, u'. High-hydrogen $S_{T,LD}$ are roughly twice that of methane. Surprisingly $S_{T,LD}$ was found to be independent of the inlet conditions for pressures between 1 and 7 bar, inlet temperatures from 300 to 450K and adiabatic firing temperatures from 1350 to 1750K.

Fig. 1: Photo of the High Pressure Facility

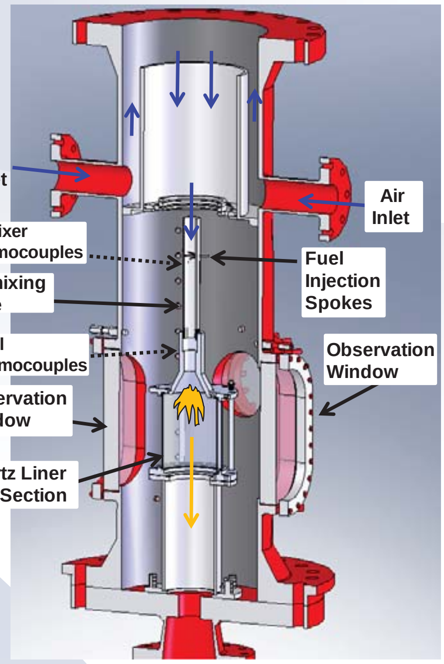
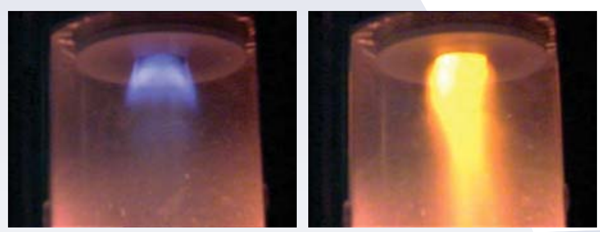



Fig. 2: Pressure Vessel Cut-Away

Upstream Face Downstream Face

Fig. 3: Low-Swirl Injector

Fig. 4: LDA



Stable Flashback

Fig 5: 90%/10% (by mole) Hydrogen/Methane Flame

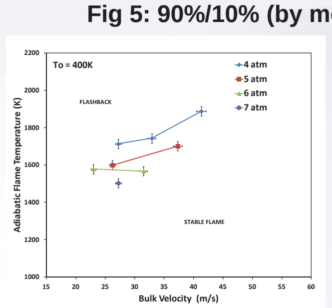



Fig. 6: Flashback Limits

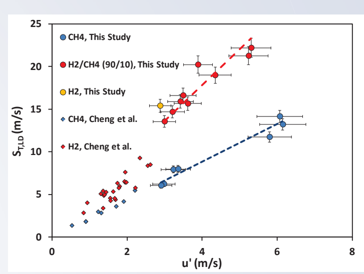



Fig. 7: Turbulent Displacement Flame Speed Measurements

## PUBLICATIONS:

D. Beerer, V. McDonell, Peter Therkelsen, Robert K. Cheng (2012) “Flashback, Blow out, Emissions, and Turbulent Displacement Flame Speed Measurements in a Hydrogen and Methane Fired Low-Swirl Injector at Elevated Pressures and Temperature” Paper GT2012-68216, Turbo Expo 2012, Glasgow, UK.

D. Beerer, V. McDonell, Peter Therkelsen, Robert K. Cheng (2014) “Flashback and Turbulent Flame Speed Measurements In Hydrogen/Methane Reactions Stabilized by a Low-swirl Injector at Elevated Pressures and Temperatures (2014). ASME J. Engr. Gas Turbines and Power, Vol 136, No. 3, pg 031502-1 -- 031502-9.

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Project Sponsor: California Energy Commission and Lawrence Berkeley Lab