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FORCED FLAME RESPONSE OF A LEAN PREMIXED MULTI-NOZZLE CAN COMBUSTOR

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Background

- Combustion dynamics in gas turbines occur when there is closed loop coupling between combustor pressure and heat release fluctuations.
- The mechanisms responsible for the closed loop coupling can be associated with velocity fluctuations and/or equivalence ratio fluctuations.
- The forced response of the flame's rate of heat release to velocity fluctuations and equivalence ratio fluctuations is expressed in terms of the gain and phase of the corresponding flame transfer function.
- To date there have been no forced flame response measurements in multi-nozzle can or annular combustors reported in the literature.

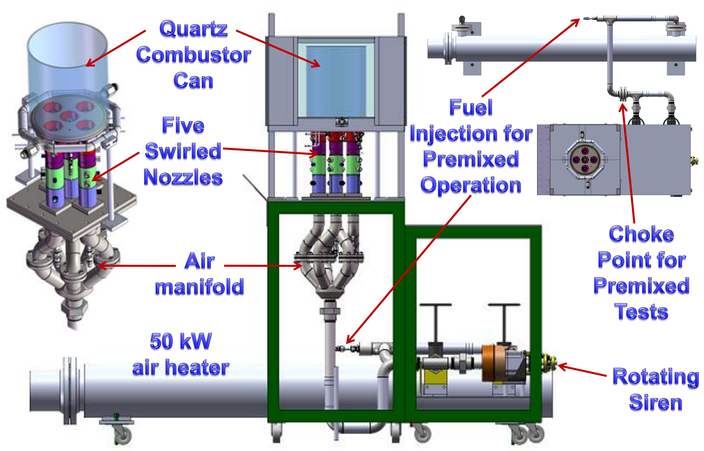
Objectives

- To characterize the air-forced flame response of a lean premixed natural gas multi-nozzle can combustor over a range of operating conditions.
- To compare the multi-nozzle flame response to that of an identical single-nozzle combustor at equivalent operating conditions.
- To characterize the effect of flame-to-flame interactions in the air-forced flame response of a multi-nozzle can combustor.
- Develop a methodology for applying single nozzle results to multi-nozzle combustors.

Approach

- Air-forced flame response tests are performed in a new optically-accessible multi-nozzle can combustor.
- A siren-device is used to produce the air velocity fluctuations over a range of frequencies and amplitudes.
- The total flame chemiluminescence emission is used as a measure of the time varying rate of heat release.
- Phase-locked chemiluminescence imaging is used to characterize the phenomenology of the flame's response to inlet velocity fluctuations.

Experiment

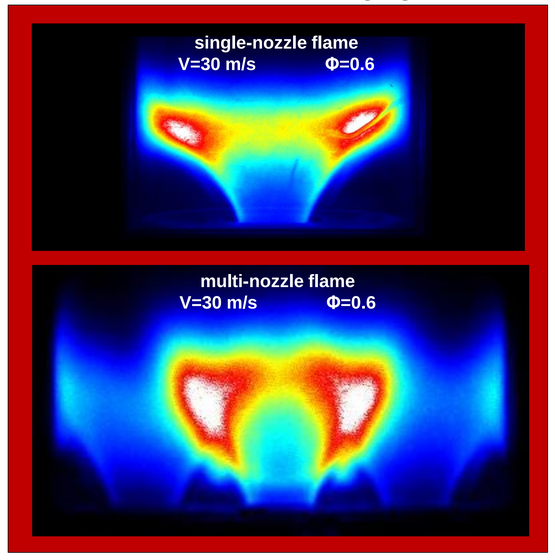


Measurements & Data Processing

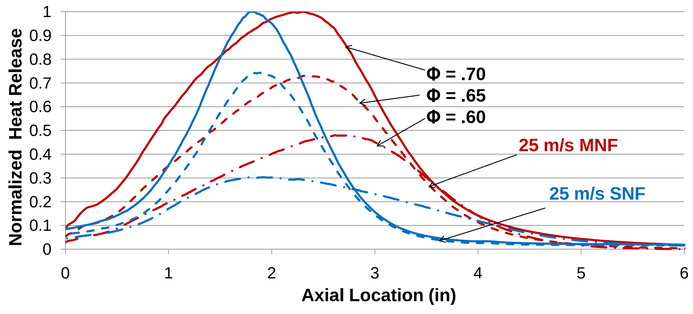
Instrument	Measurement	Data Processing	Calculated Quantity
Piezoelectric pressure sensors	Dynamic pressure in nozzles & combustor	Fast Fourier Transform, Two Microphone Method	Pressure fluctuation amplitude and frequency, Velocity fluctuation amplitude and frequency
Analog differential pressure gauges	Static pressure drop across swirlers	Apply calibration relating pressure drop to mean velocity	Mean velocity in each nozzle
PMT with 430 nm filter	Time domain CH* chemiluminescence from flame	Fast Fourier Transform	Overall heat release rate fluctuation amplitude and frequency
ICCD Camera with 430 nm filter	Phase-synchronized spatially resolved CH* chemiluminescence	Axial heat release	Axial heat release distribution, flame length

Results

Stable Flame Imaging



Comparison of Axial Heat Release Distribution in Stable Single Nozzle Flame and Multi-Nozzle Flame



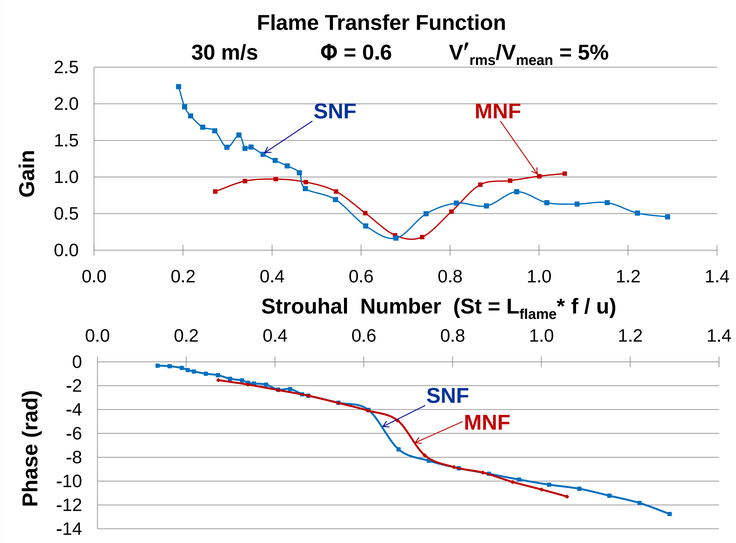
- The difference in the axial heat release distribution can be attributed to the difference between the dump area ratio in the single nozzle combustor (11), and in the multi-nozzle combustor it is 6.5.

Results

Flame Transfer Function

- The gain of the ftf is a ratio of the fluctuating components of the output to the input functions
- The phase describes how long it takes a perturbation to convect to the flame

$$FTF\,(f) = \frac{\frac{Q'(f)}{Q_{mean}}}{\frac{u'(f)}{u_{mean}}}$$



- The gain in both the SNF and the MNF demonstrate a dip that corresponds to two feedback mechanisms interfering most destructively at a similar Strouhal number
- The phase is linearly related to the Strouhal number except around St_{DIP}, where a discrete jump occurs in the phase
- At the lowest Strouhal numbers, the MNF dampens the fluctuation, whereas the SNF amplifies it

Funding for this research was provided by the Department of Energy's University Turbine Systems Research Program and GE Energy.