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Air-Forced Flame Transfer Function Measurements in a High Pressure Combustor

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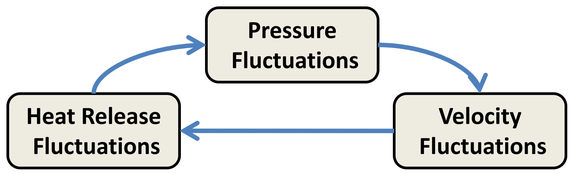
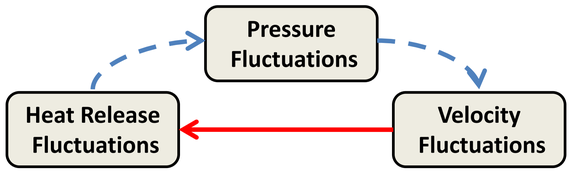
Background

- Lean premixed combustion has been employed to reduce emissions, however it also increases a combustor's susceptibility to self-excited instabilities.
- A thorough understanding of the flames response to periodic flow disturbances is necessary to allow prediction of combustion instabilities in the combustor design stage.



Objectives

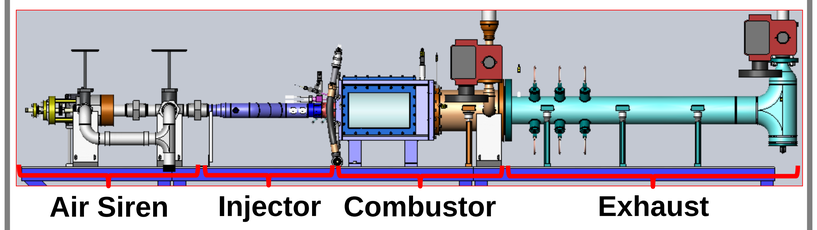
- To experimentally measure the air-forced flame transfer function (FTF) of an industry scale nozzle over a range of combustor pressures, inlet temperatures, mean velocities, and equivalence ratios.
- To determine the mechanisms through which velocity fluctuations cause heat release fluctuations.

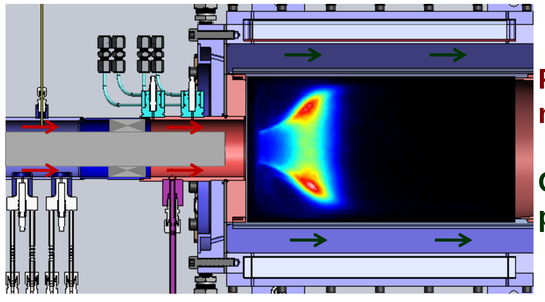


Approach

- A siren device is used to create the input velocity fluctuation over a range of frequencies and the flame's chemiluminescence emission is measured as an indicator of the fluctuation in the flame's overall rate of heat release.
- Phase-synchronized images are taken to identify the mechanisms whereby velocity fluctuations cause fluctuations in the flame's overall rate of heat release.

Experiment





Operating Range
- Combustor pressure: 1-4 atm
- Inlet temperature: 20-300 °C
- Mean velocity: 20-35 m/s
- Equivalence ratio: LBO - 0.80
- Premixed air and natural gas

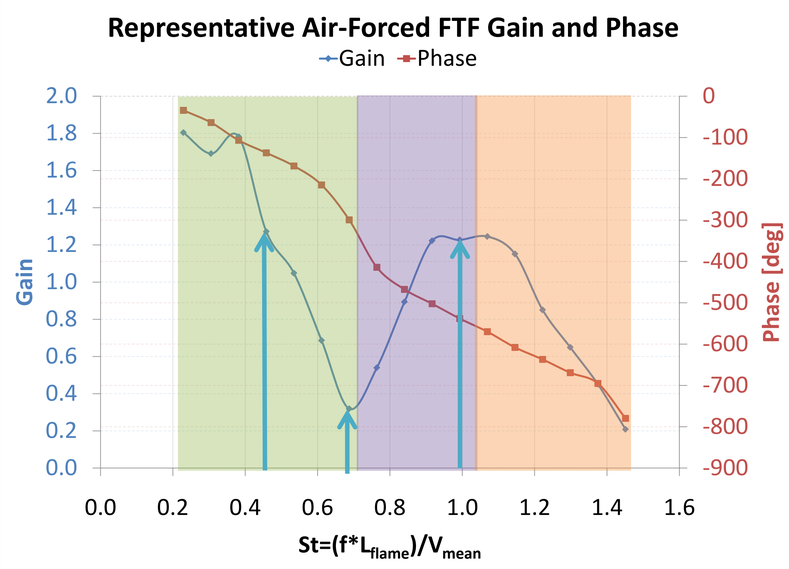
Air Siren
- Velocity fluctuation frequency: 0-500 Hz
- Velocity fluctuation amplitude: 0-45 %

Injector
- Industry scale injector
- Swirl stabilized

Combustor
- Double walled quartz combustor
- Optically accessible

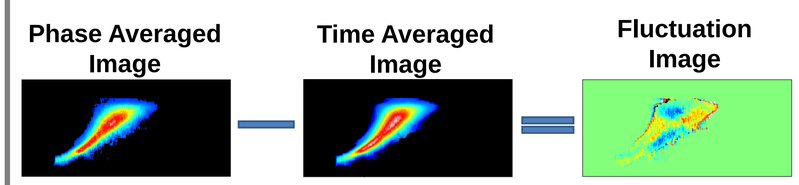
Measurements
- Static and dynamic pressure
- Temperature
- Velocity fluctuation (Two-microphone method)
- CH* chemiluminescence (Photomultiplier tube)
- Flame structure (ICCD camera)

Results

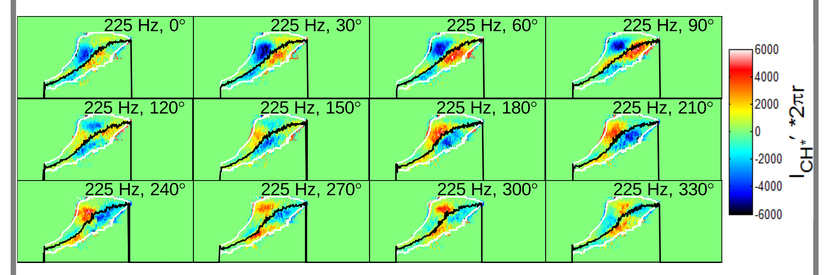


- **All measured FTFs exhibit the same characteristics:**
  - **At low frequencies the gain is larger than 1 and decreases with increasing frequency to a minimum.**
  - **A further increase in frequency causes the gain to increase to a second peak.**
  - **Increasing the frequency beyond the second peak causes the gain to decrease to a second minimum.**
  - **At the frequencies corresponding to minima in gain, the phase curve exhibits inflection points.**
- **Phase-synchronized images were taken at 3 frequencies to identify the mechanisms affecting the flame's response.**

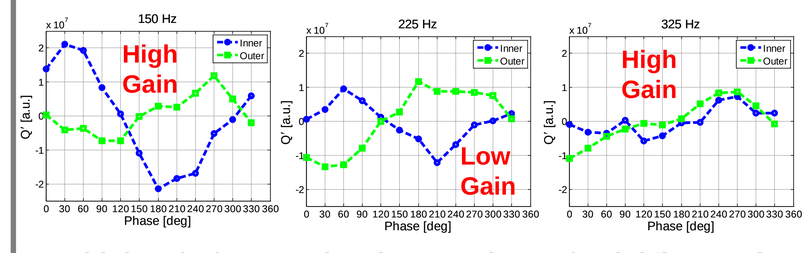
Results



- Phase-synchronized images were analyzed to isolate the fluctuating component of heat release.



- The series of fluctuation images show movement of regions of wrinkling within the flame brush.
- These regions of wrinkling are caused by the vorticity generated in the inner and outer shear layers, between which the flame is stabilized.



- **At high gain frequencies these regions of wrinkling are in phase, and at low gain frequencies they are out of phase.**