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FUEL-FORCED FLAME RESPONSE OF A LEAN-PREMIXED COMBUSTOR

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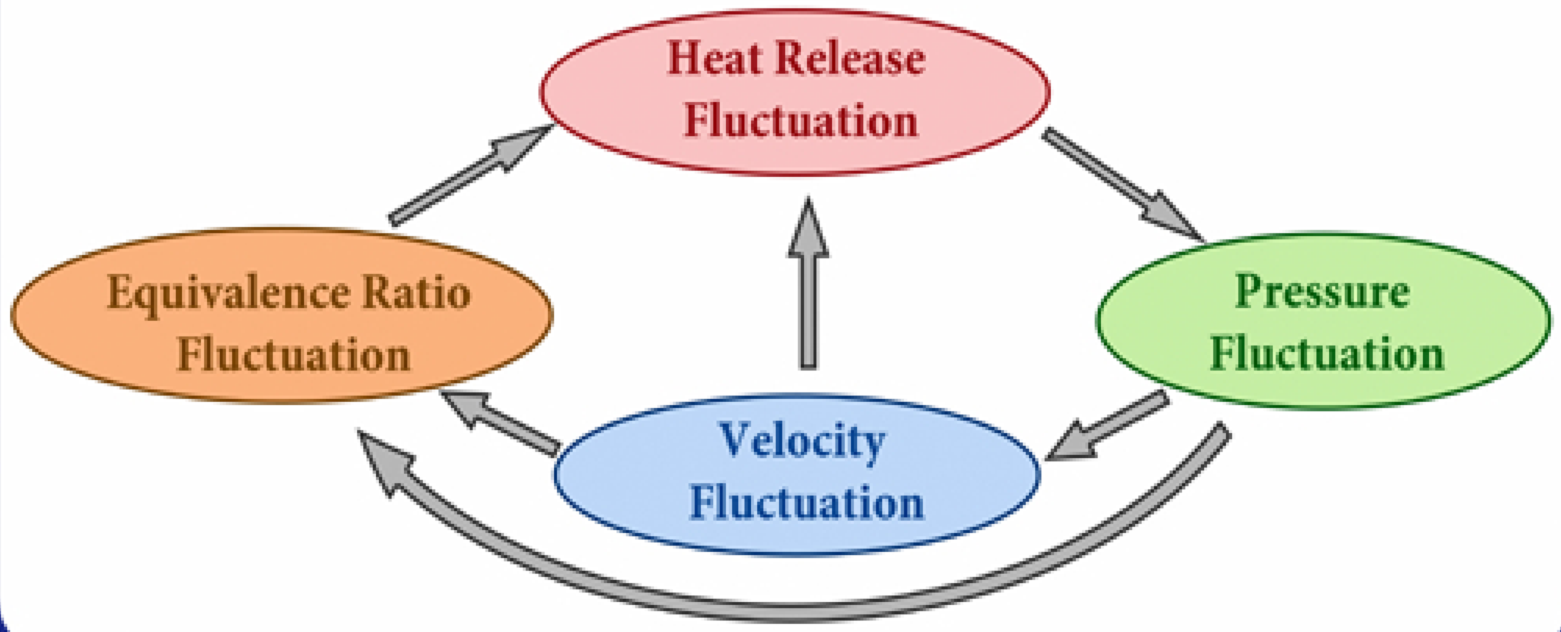
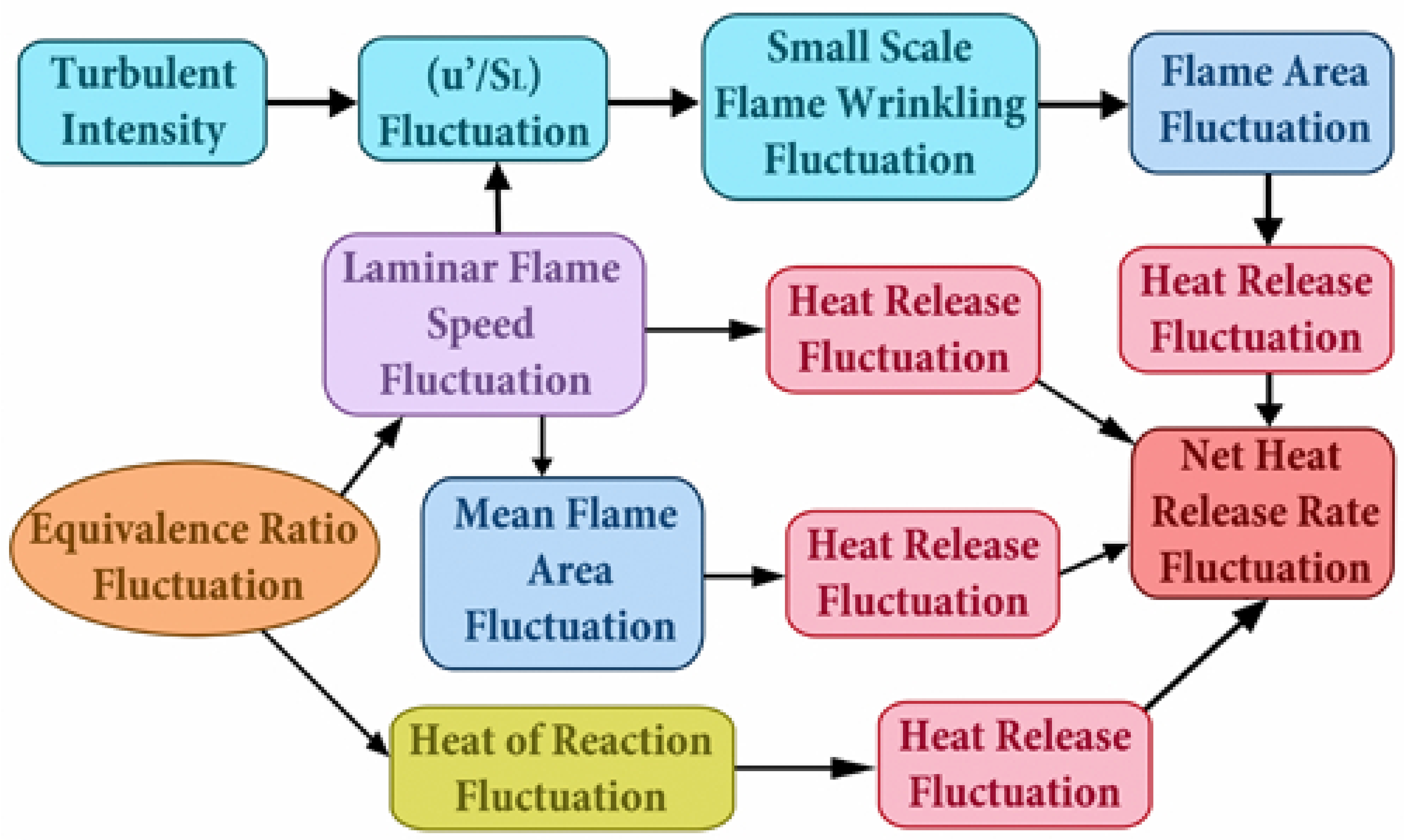
Background

Self-excited instabilities in lean premixed combustors are the result of feedback mechanisms involving velocity and equivalence ratio fluctuations. The nature of these mechanisms can be characterized in terms of a flame transfer function which relates the amplitude and phase of the velocity or equivalence ratio fluctuation to the amplitude and phase of the resultant fluctuation in the rate of heat release.



Mechanisms Involved in Equivalence Ratio Fluctuation

There are four local mechanisms whereby equivalence ratio fluctuations result in fluctuations in the rate of heat release.



Flame Transfer Function

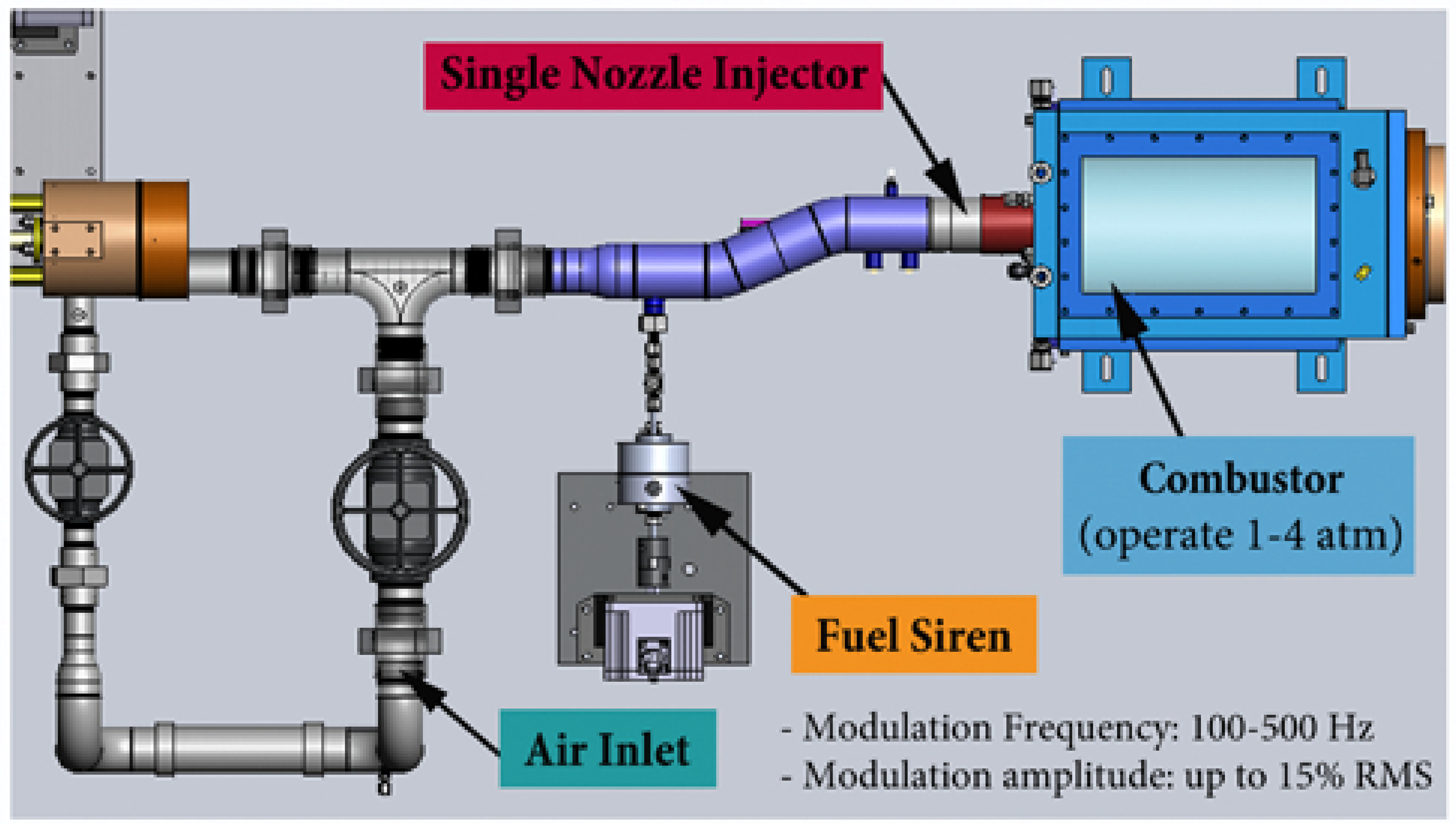
$$FTF(f) = \frac{Q'(f)/Q_{mean}}{\phi'(f)/\phi_{mean}} \quad \begin{cases} Gain(f) = |FTF(f)| \\ Phase(f) = \measuredangle\,[FTF(f)] \end{cases}$$

Objectives

1. To characterize the flame transfer function over a range of temperature, velocities and equivalence ratio

2. To identify and characterize the underlying physics of the flame's response to equivalence ratio fluctuations

Experimental Setup & Capability

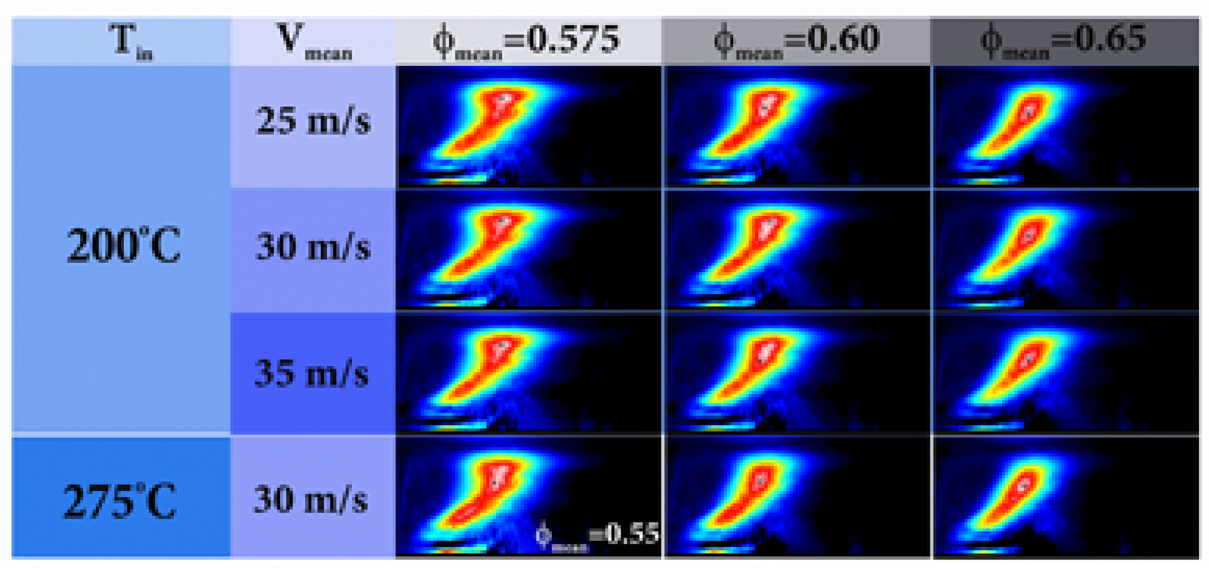


- Modulation Frequency: 100-500 Hz
- Modulation amplitude: up to 15% RMS

Measurement Techniques

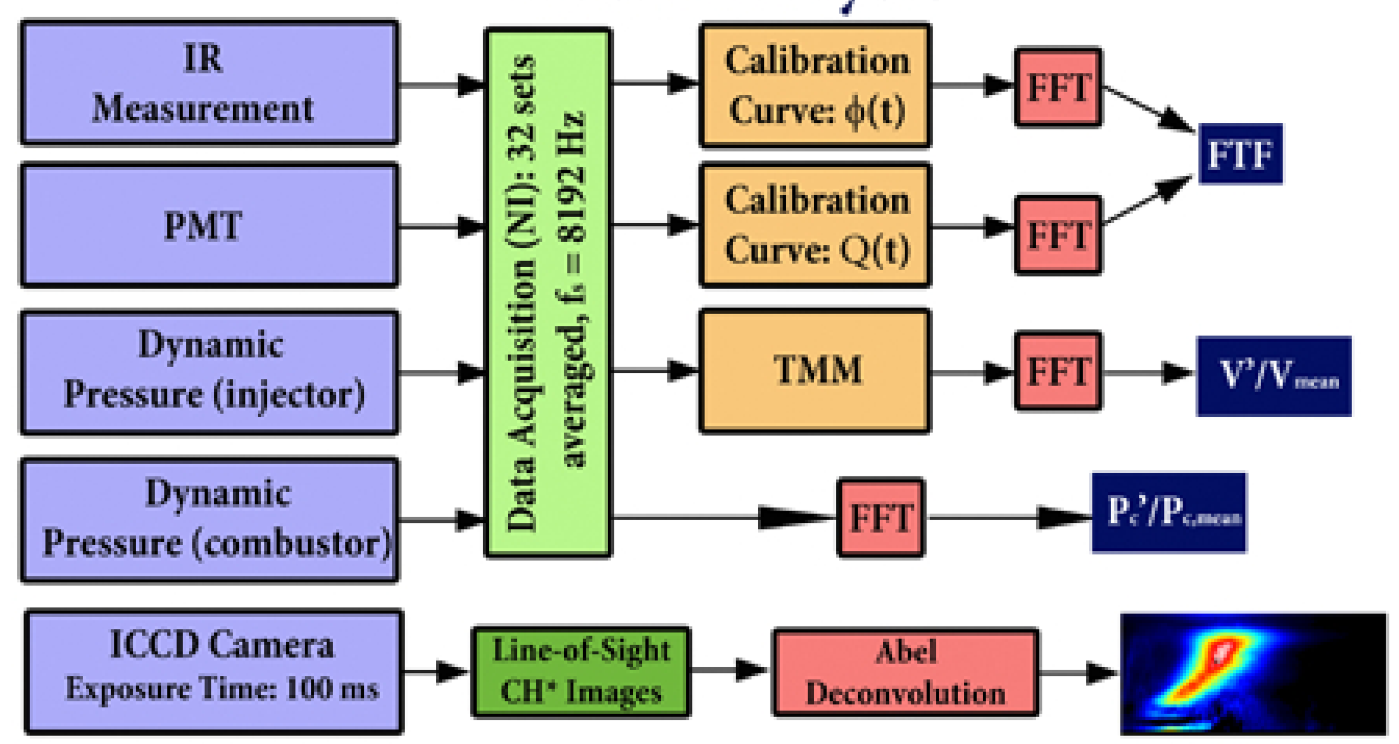
Parameter	Measurement Technique
Equivalence Ratio Fluctuation	IR absorption measurement (He-Ne laser, 3.39 μm & InAs Detector)
Heat Release Fluctuation	3 PMT (CH^*: 432 nm, CO_2^*: 365 nm, OH^*: 307 nm)
Velocity Fluctuation	Two-microphone method
Pressure Fluctuation at combustor	Dynamic pressure transducer
Flame imaging	ICCD camera with CH^* filter

Result: Unforced Chemiluminescence Flame Images



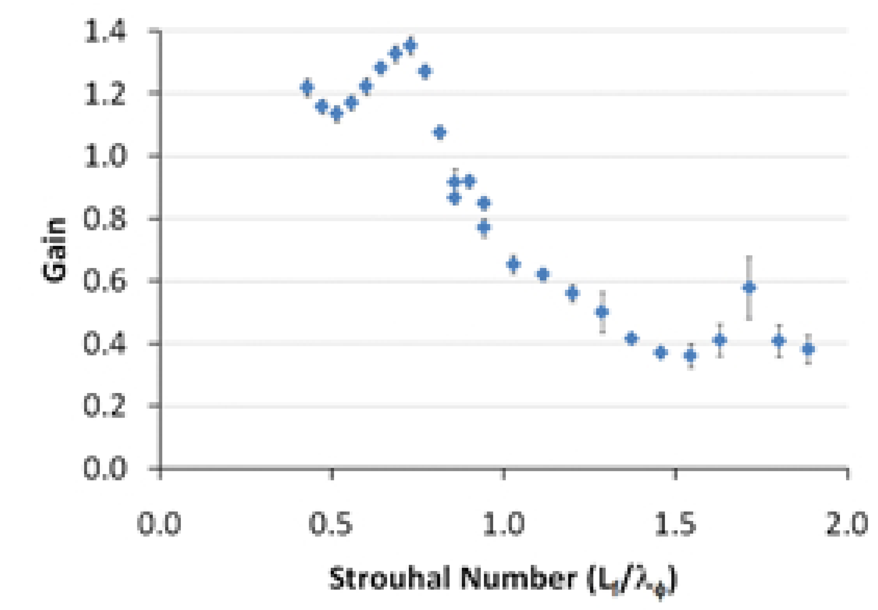
- Time averaged forced flames over periods of oscillations are not different in both shape and length from unforced flames

Data Analysis

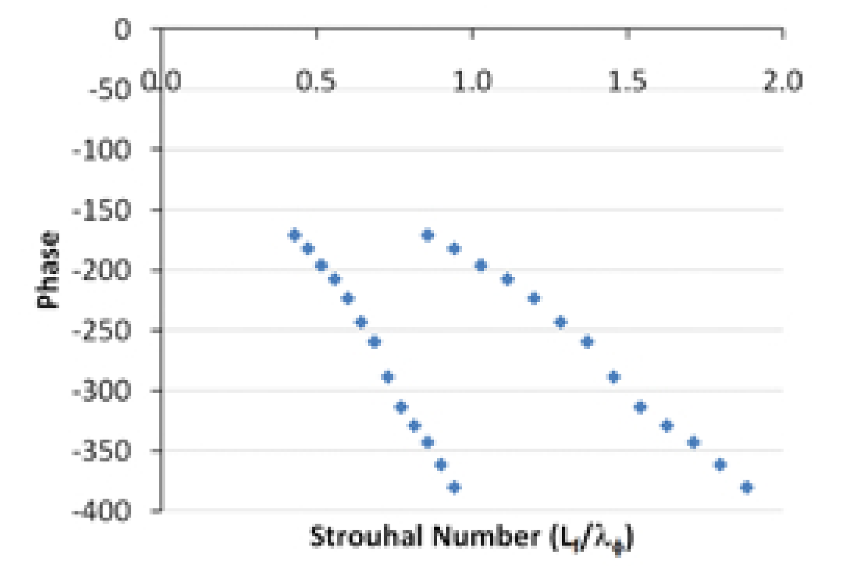


Result: Flame Transfer Functions

Flame transfer functions were taken at T_{in}=200°C and 275°C, V_{mean}=25,30, 35 m/s and ϕ_{mean}=0.55,0.60,0.65, modulation frequency=200-440 Hz (20 Hz increments) and fixed modulation amplitude at 3.5-4% RMS.



- All of transfer functions can be scaled with St which indicates driving mechanisms in this case is purely convective transport
- Gain behaves like a low-pass filter and exhibits local maxima
- 1st maxima occur at different modulation frequencies in varied mean velocities but the same frequency at different mean equivalence ratio and inlet temperature
- Gain is greater than one implies flame response's influenced by more than one mechanism
- Gain may be characterized by attenuation of flame speed and flame area fluctuations with increasing frequency and their relative phase



- Phase is linearly proportional with St and the slope represents convective time
- Convective time decreases when T_{in} and V_{mean} increase