A comparison of combustion dynamics for multiple 7-point lean direct injection combustor configurations

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Outline

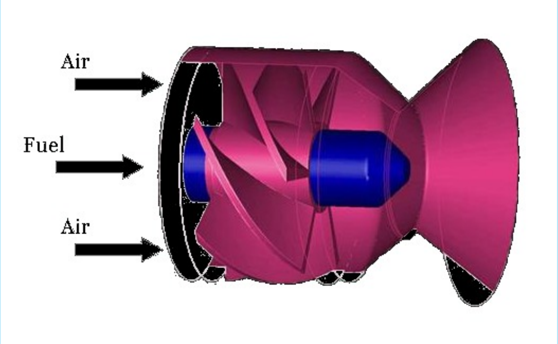
- Background
- Experimental Setup
- Data Analysis Technique
- Results
- Summary and Future Work

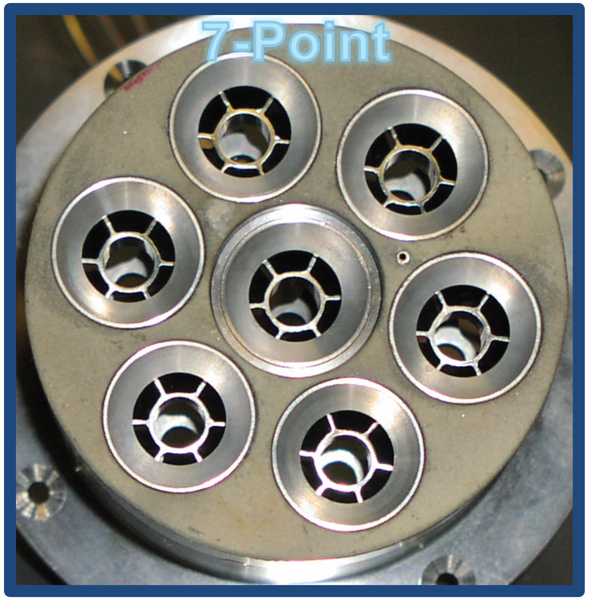
Background: LDI

- Fuel lean: no rich front end
  - All *combustion* air enters through the dome
- Fuel is injected directly into the flame zone
  - Reduces problems with autoignition, flashback, and combustion instabilities
- Requires fine atomization and rapid, uniform fuel/air mixing
- Several small fuel/air mixers replace 1 conventionally-sized fuel/air mixer
- Many fuel/air mixing strategies
  - Size and number of fuel/air mixer
  - Swirler: radial, axial, or discrete jet
  - Venturi: **placed downstream of swirler** or omitted
  - Fuel injector: type (**simplex**, air assist, plain orifice) and flow number

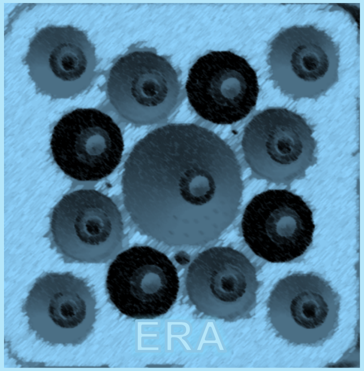
Results are presented here for Swirl-Venturi LDI (SV-LDI)

SV-LDI





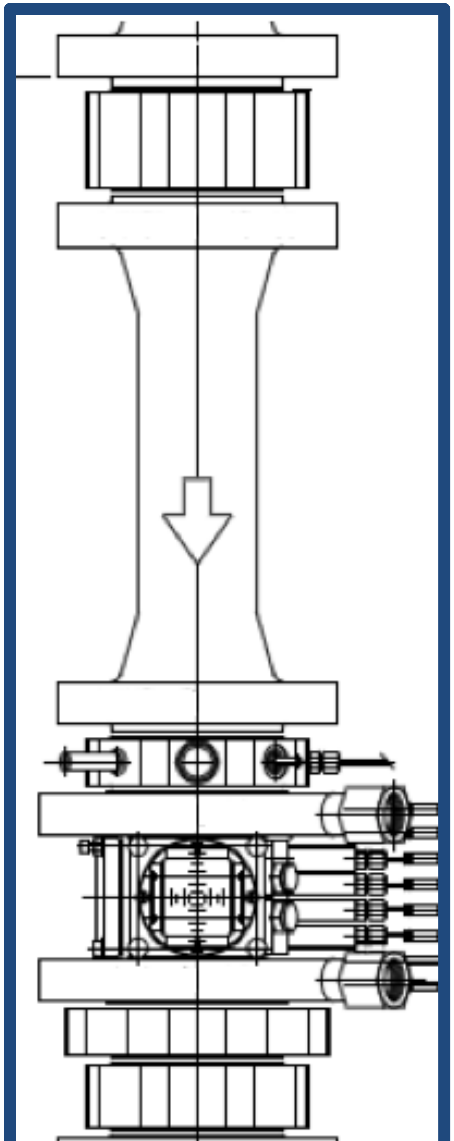
- Each swirl-venturi (SV) LDI fuel/air mixer consists of
  - an helical axial air swirler followed by a venturi.
  - a simplex fuel injector, inserted into the center of the air swirler, with its tip near the venturi throat
- 7 fuel/air mixers, each nominally 1”, are arranged in an array.
- Design is similar to:
  - HSR and UEET SV-LDI designs
  - Woodward ERA N+2 SV-LDI designs

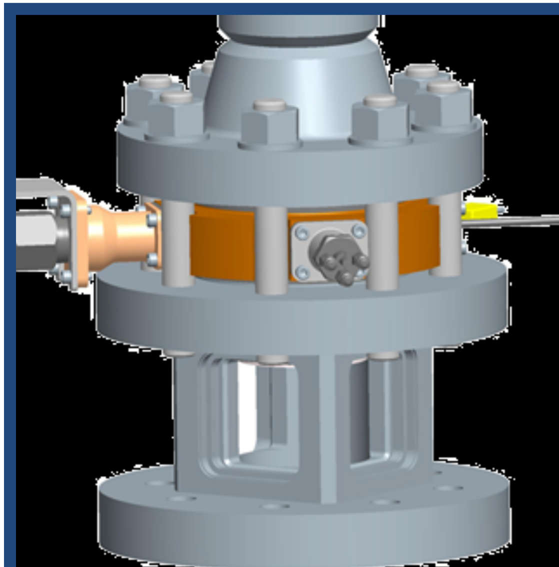


Background: Why do we care about combustion dynamics?

- Expected to be a problem with lean-burn combustor designs
- 7-point tends to be “noisy” compared to other LDI designs
  - Many points with peak-to-peak pressure fluctuations above 1 psi
- 7-point is used as a testbed for trying out active combustion control and passive damping techniques

Combustion and Dynamics Facility





Facility Setup

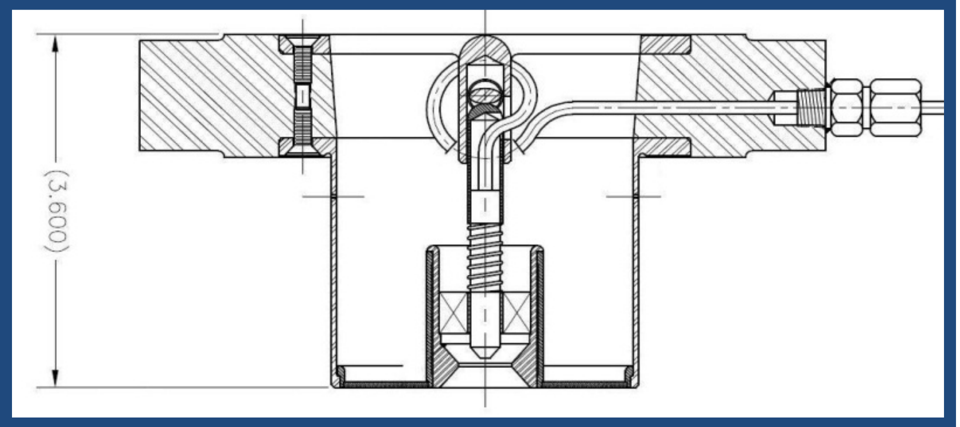
- Circular cross-section
- Diameter of 7.62-cm (3-in)
- Flow is downward
- Combustor section has 3 windows, each 5.8-cm × 6.1-cm (2.3-in × 2.4-in)

Inlet Conditions

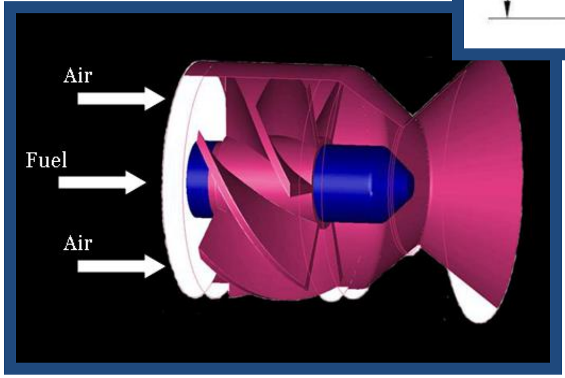
Temperature	300-810 K (70-1000 F)
Pressure	101-517 kPa (15-75 psia, 1-5 atm)
Air Flow	0-0.35 kg/s (0-0.78 lbm/s)
Fuel Flow	0-0.9 kg/min (0-2 lbm/min)

SV-LDI : Fuel/Air Mixer Geometry

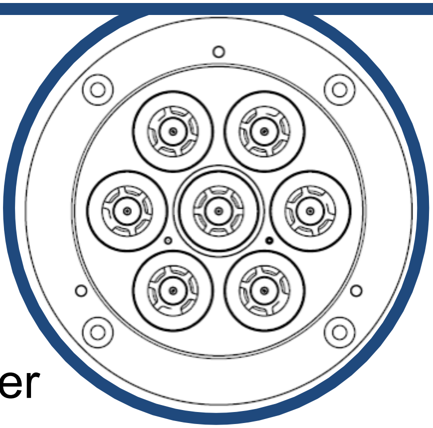
Current Study: Single-Point Configuration



A Fuel/Air Mixer



7-Point Configuration

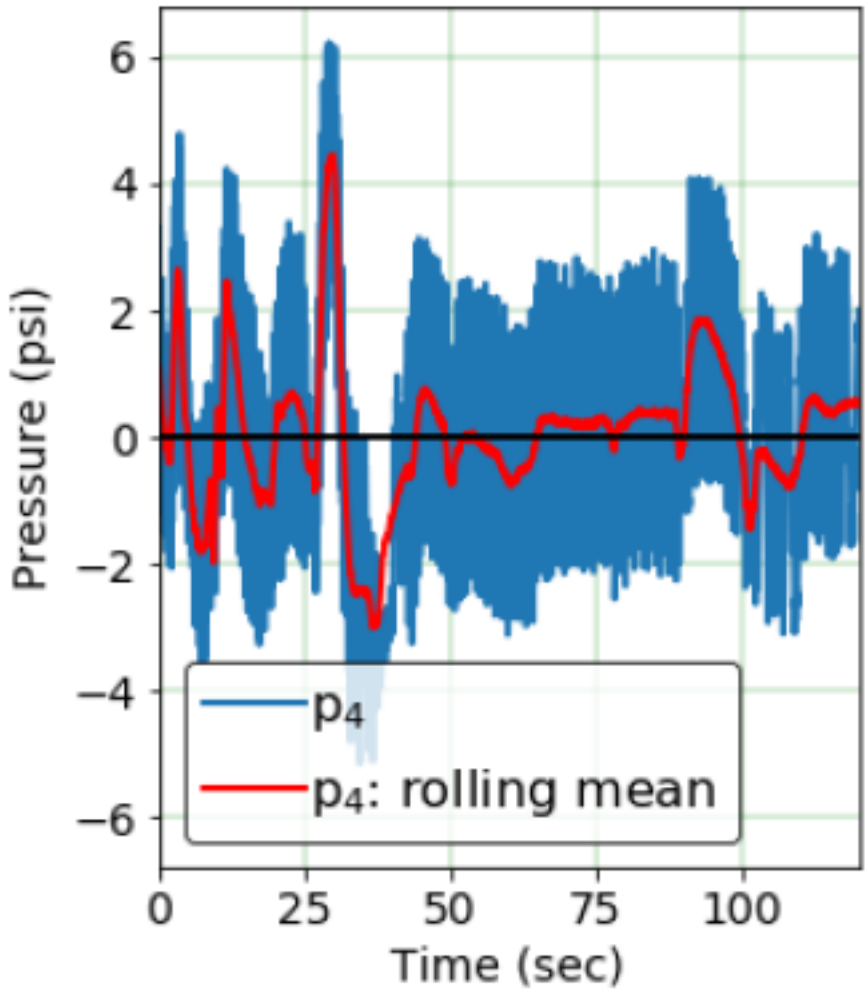


- 6-bladed, 60° helical air swirler
- Swirl number: 1.0
- Converging-diverging venturi
- Fuel/air mixer nominal size: 2.5-cm

- Simplex fuel injectors
- Flow number: 0.7
- Fuel injector tip near the venturi throat

Even this relatively simple LDI geometry produces a complex flowfield!

Data Analysis Technique



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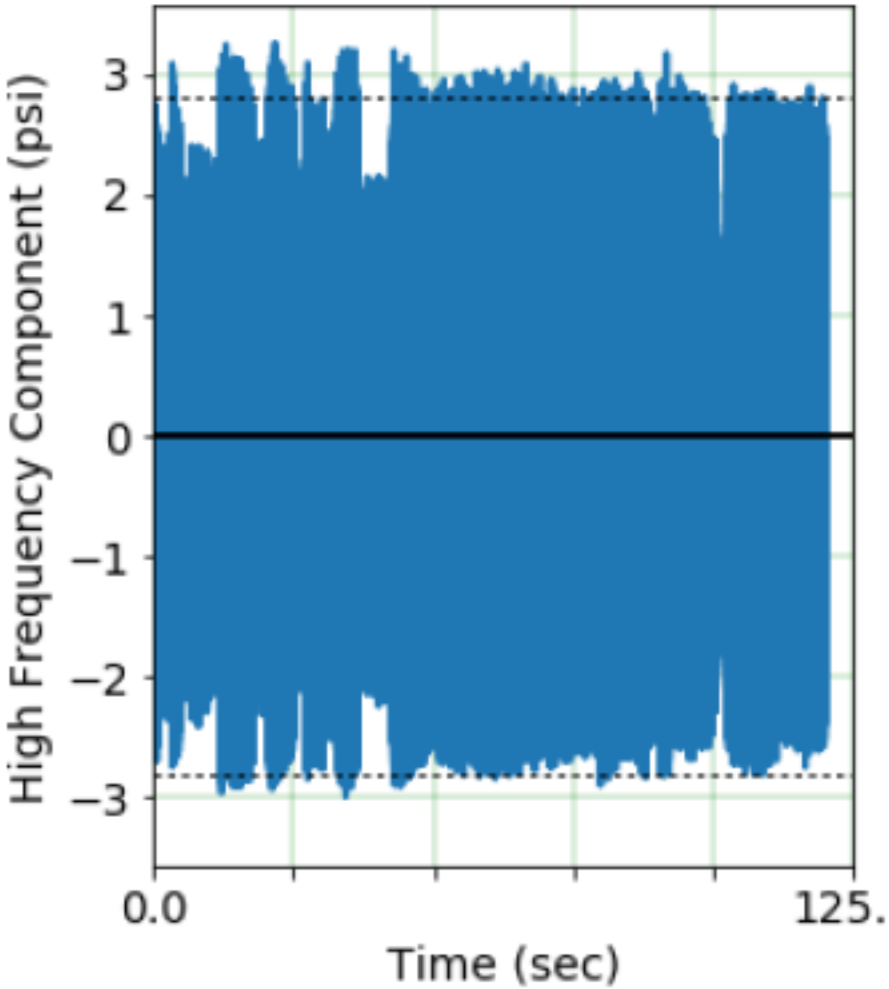

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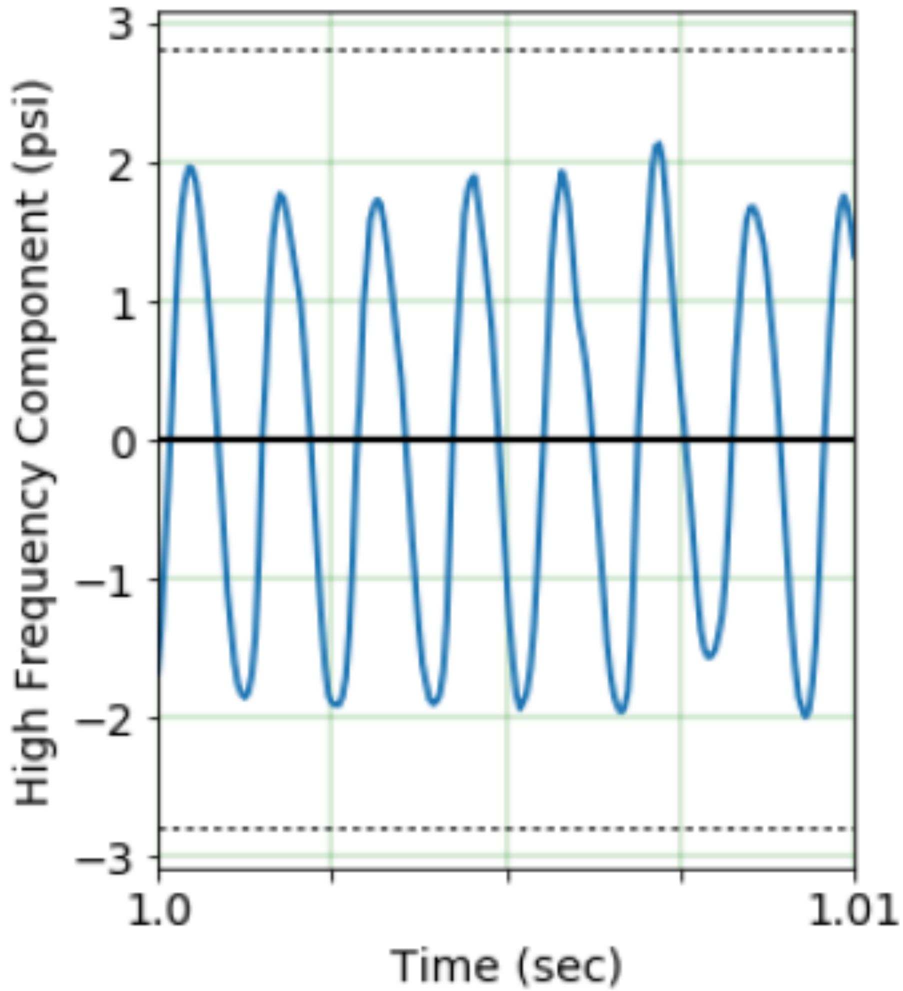

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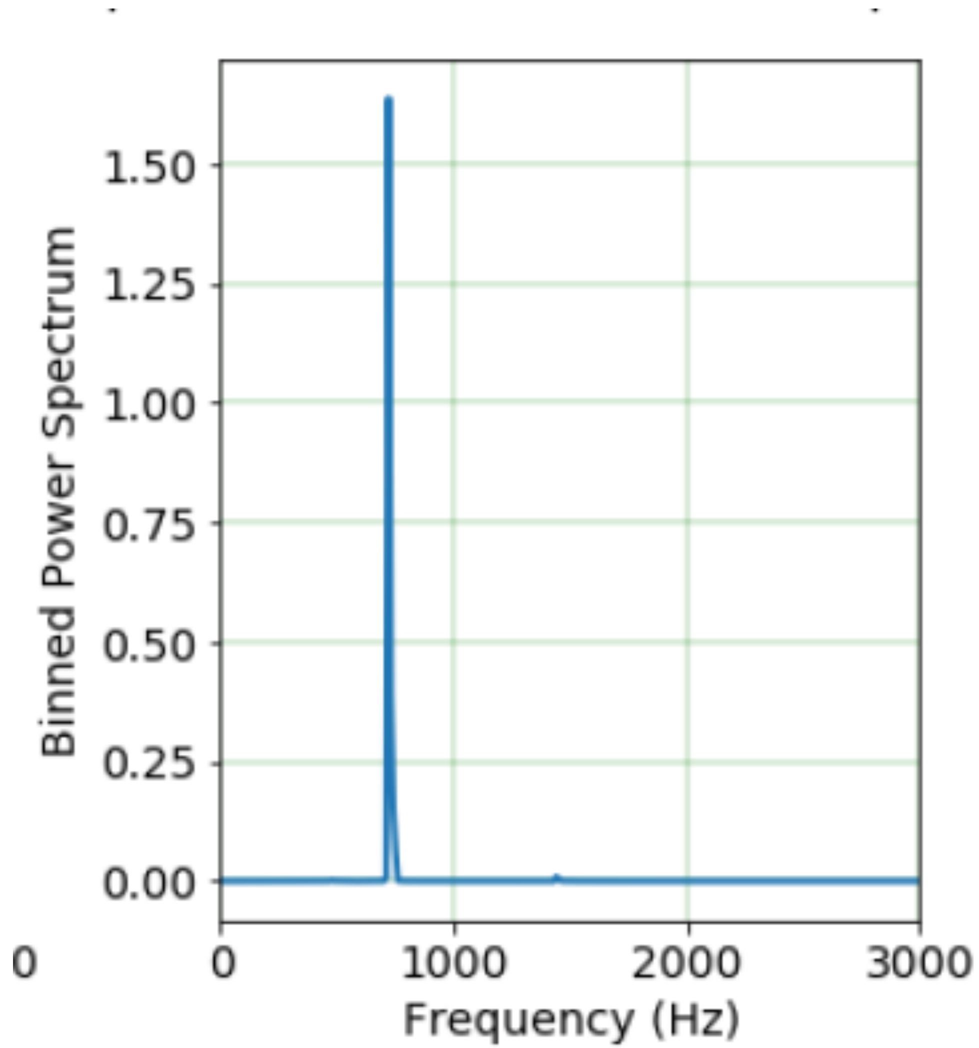

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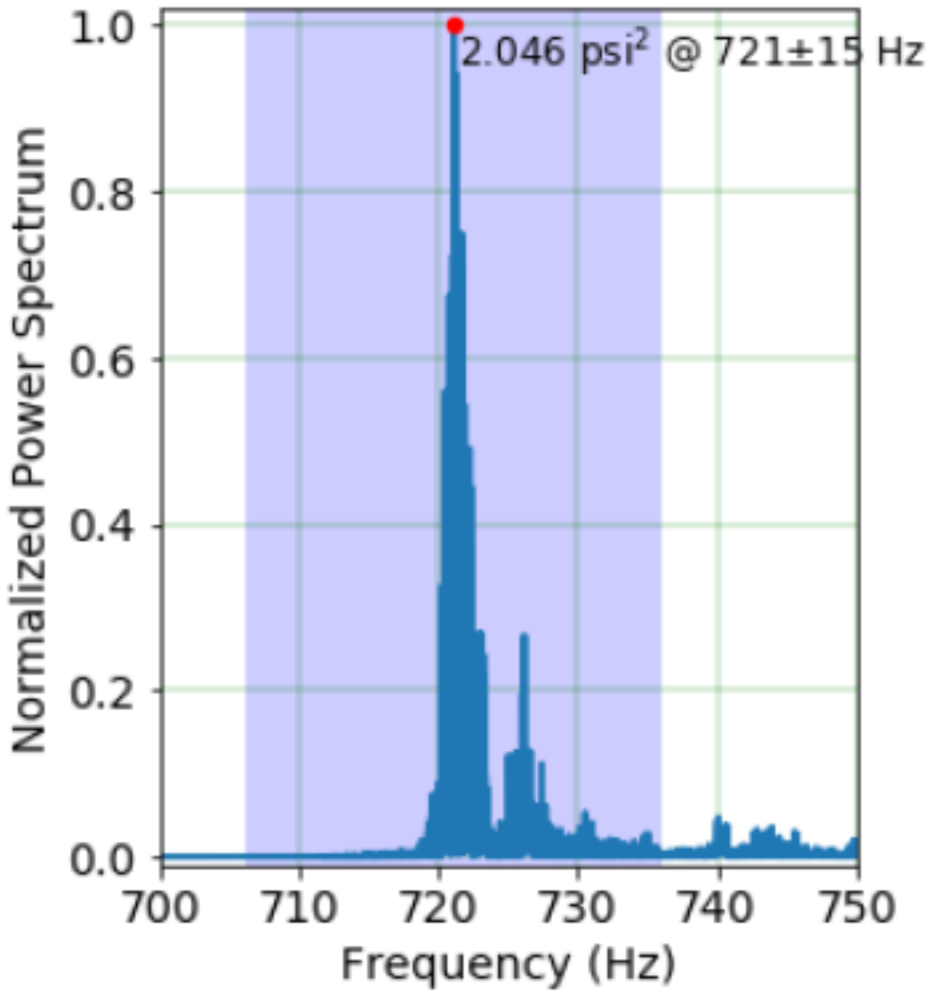
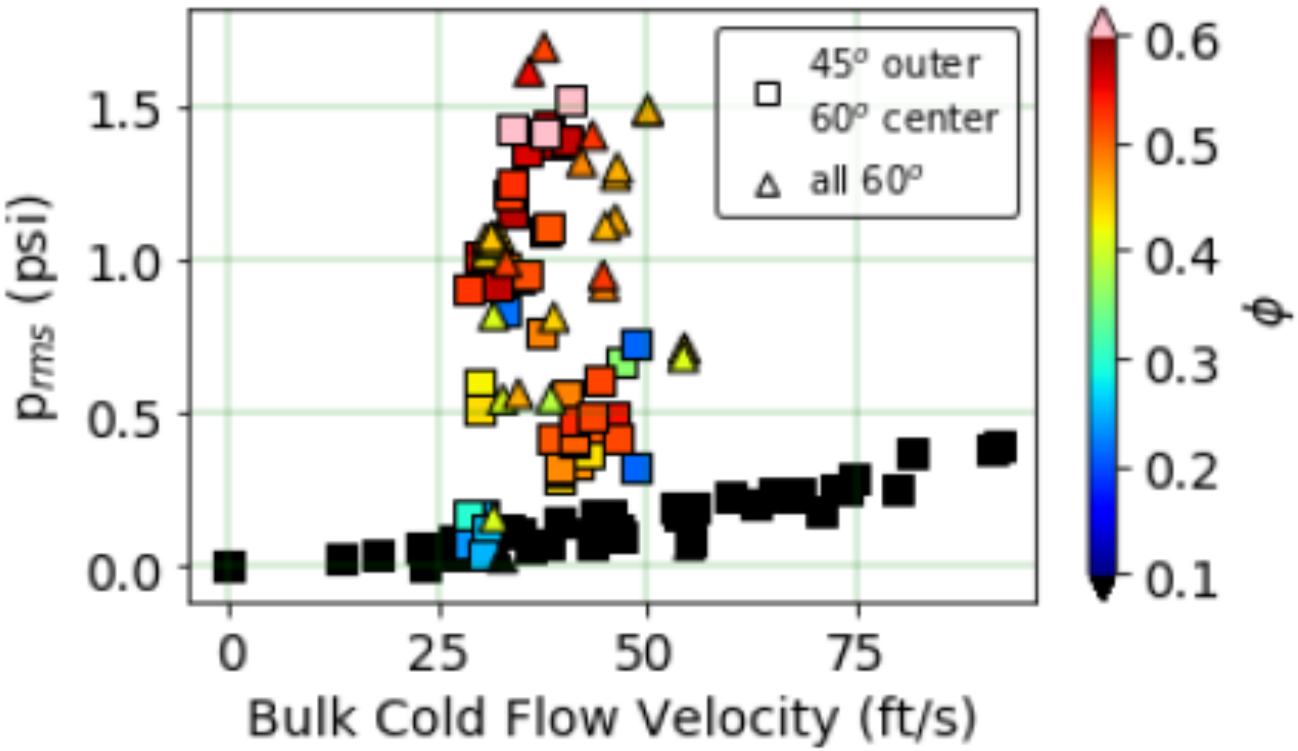


RMS: Cold Flow vs Reacting



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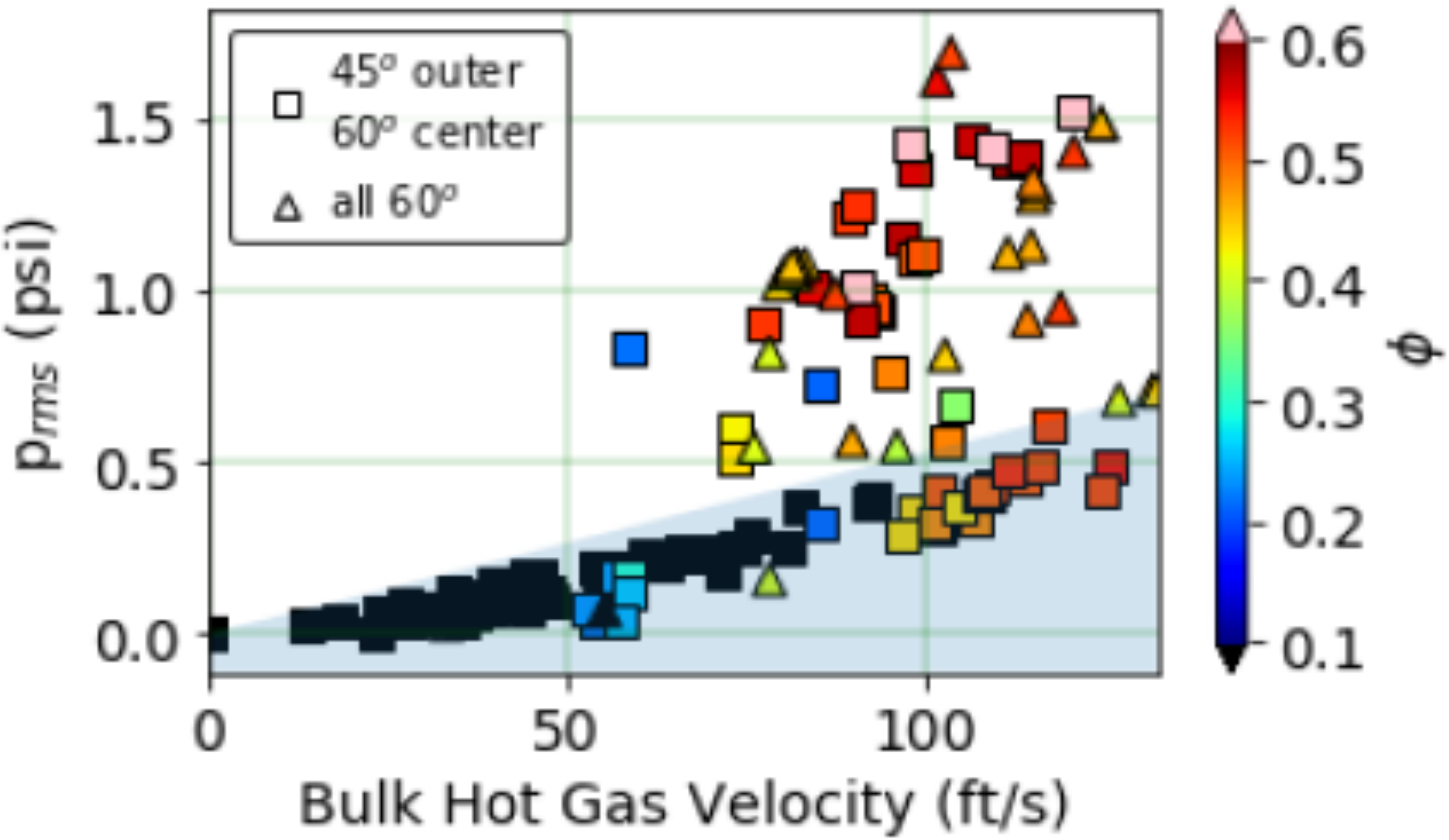
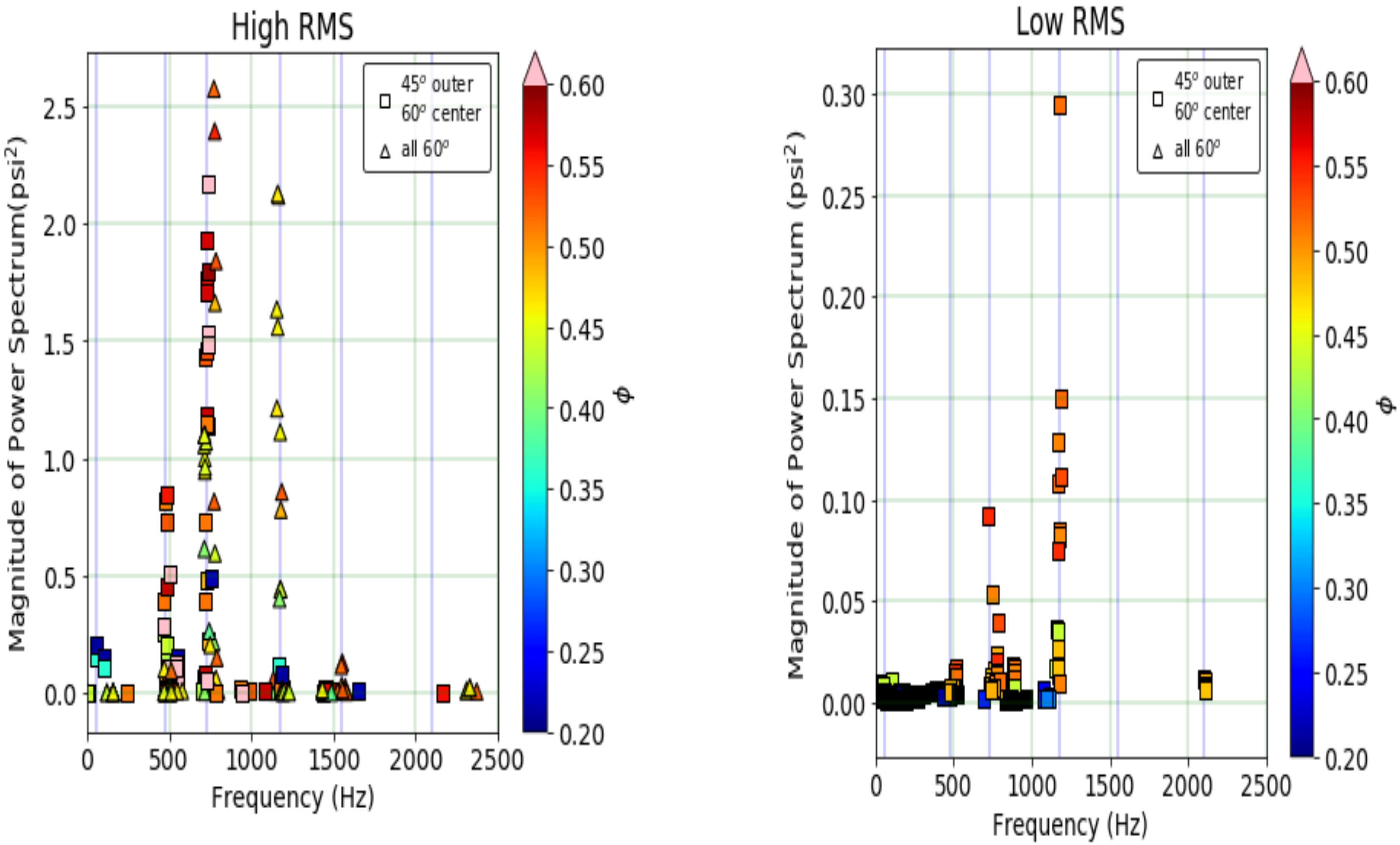
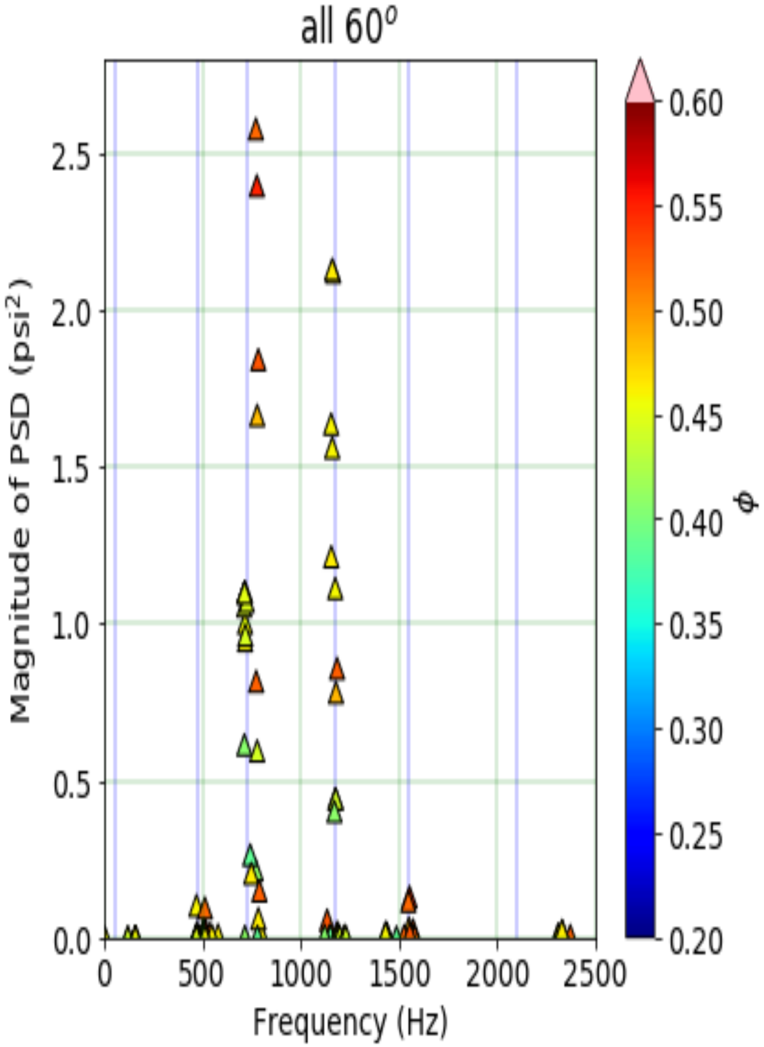
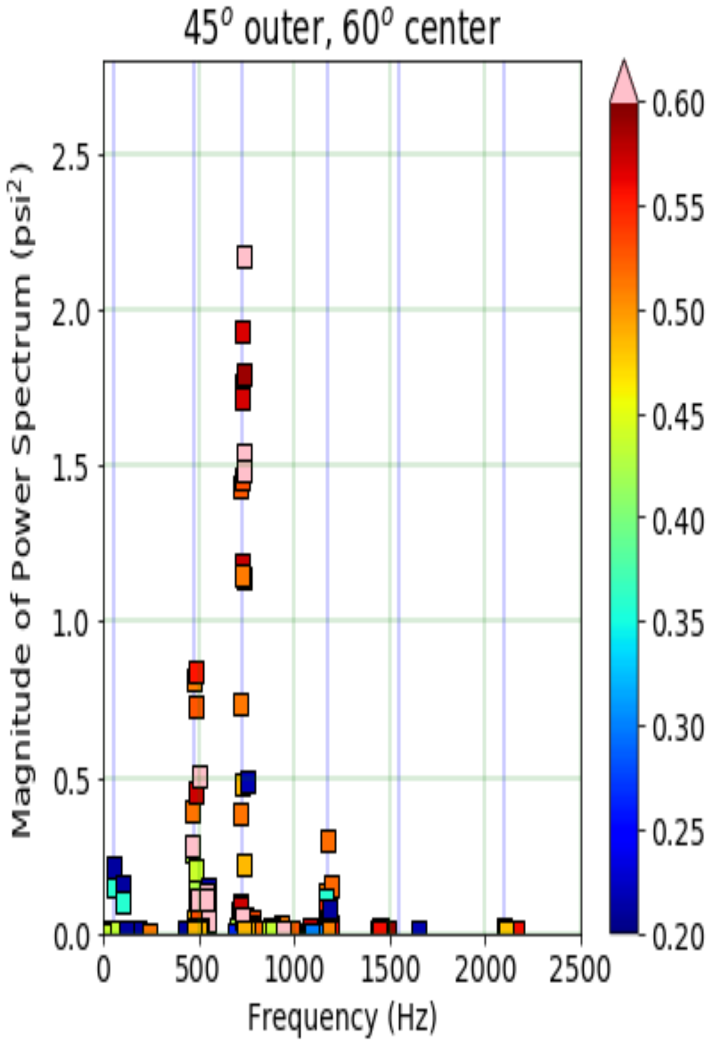


High RMS vs Low RMS

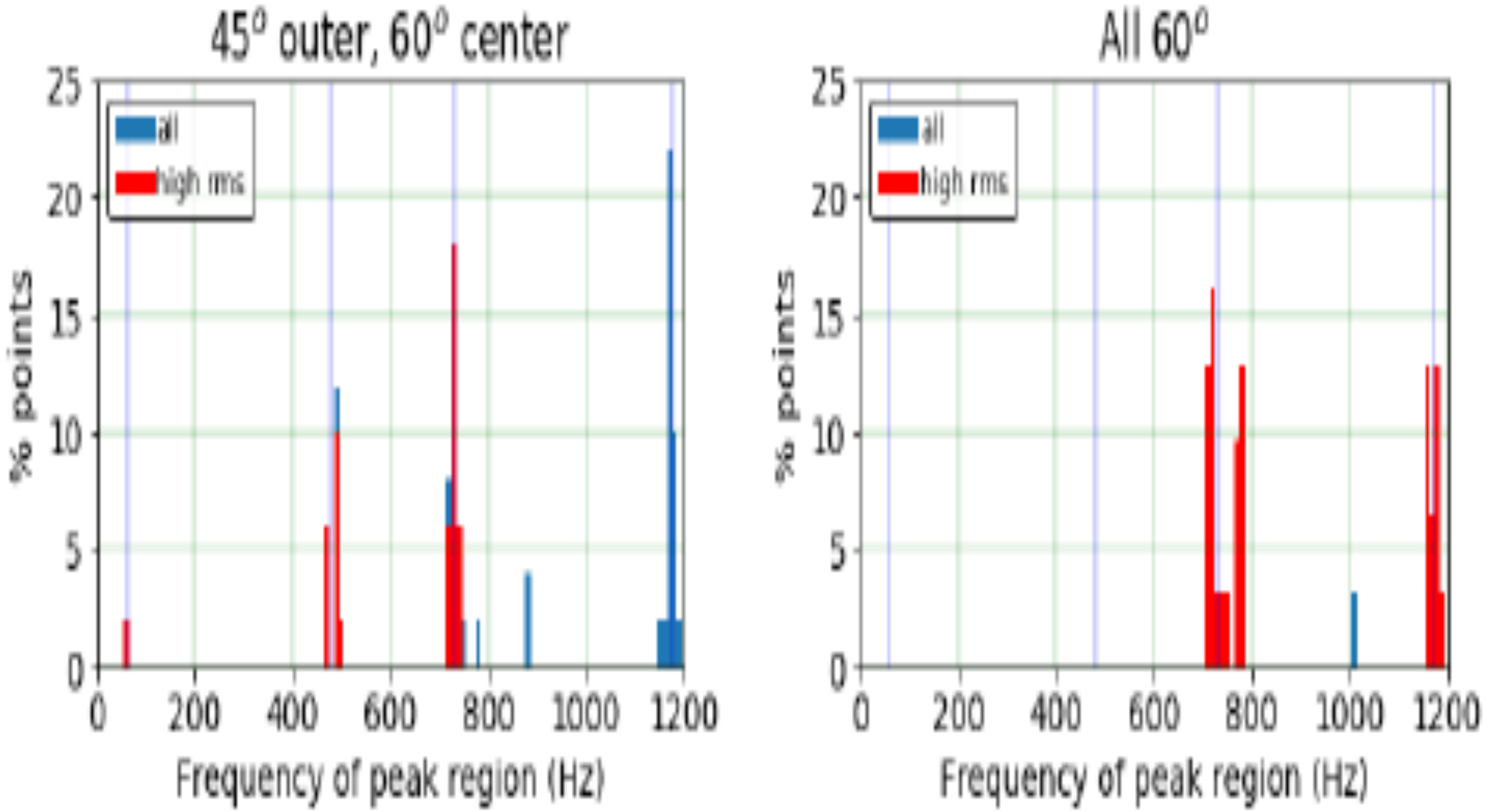


All 60 vs 60 center, 45 outer

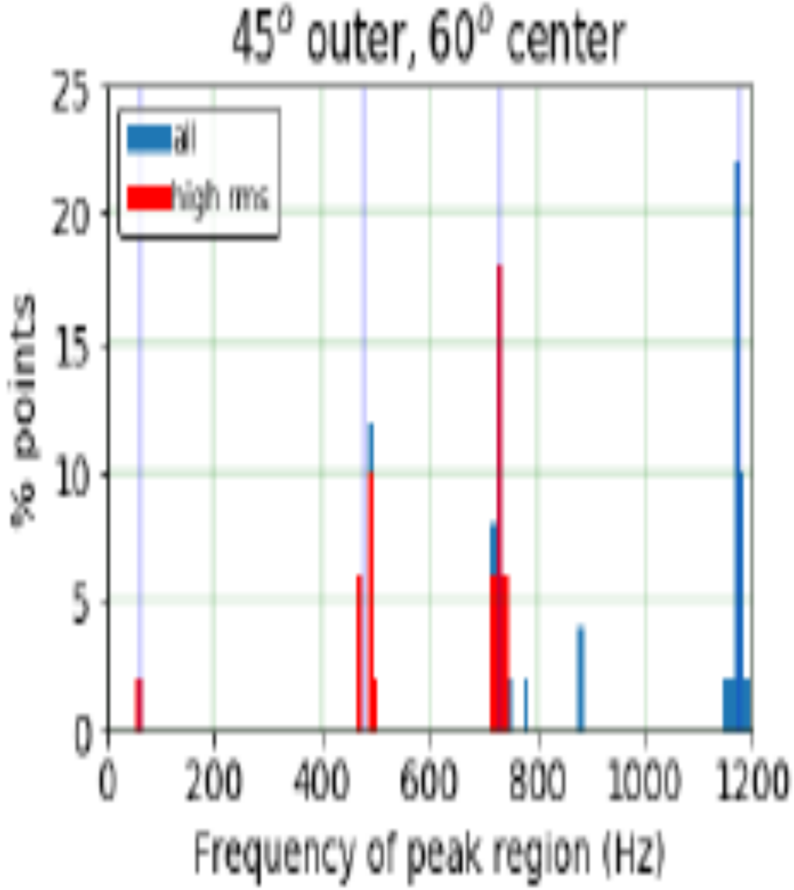


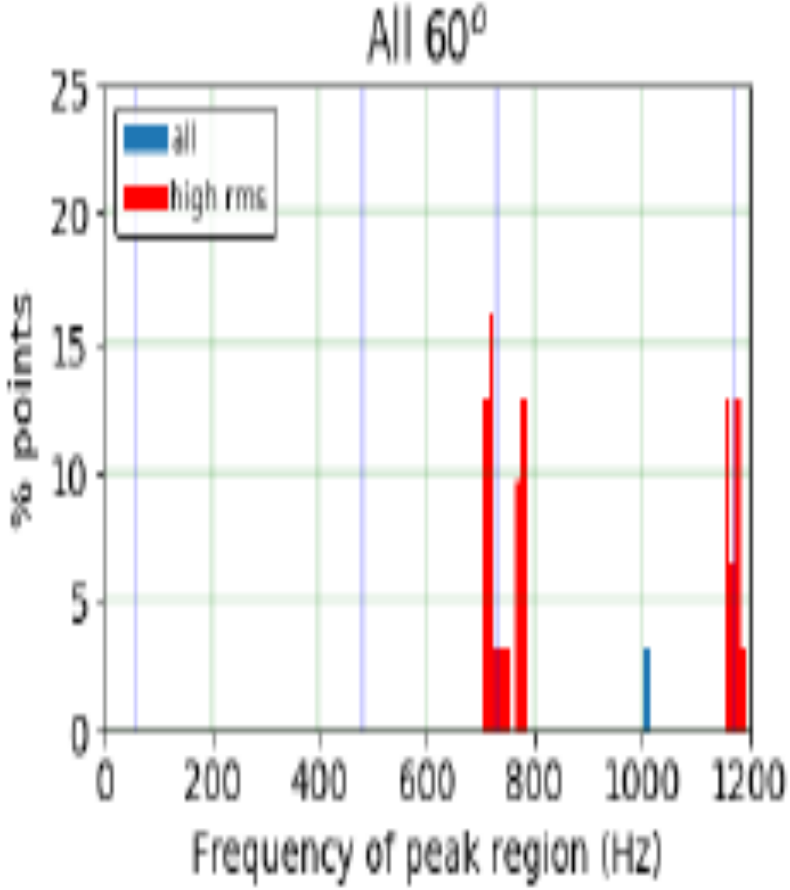


Peak Frequencies



Explanation of Frequencies





Summary and Future Work

- Combustion dynamics at frequencies near 500 Hz, 700 Hz, and 1200 Hz
- These frequencies not depend strongly on the configuration
- The combustion dynamics near 700 Hz are likely a quarter-wave mode
- The source of the dynamics at 500 and 1200 Hz is undetermined
  - Note that 1200 – 700 = 500
- Future work:
  - Examine the frequency content of high speed flame luminosity measurements and compare with combustion dynamics from the pressure measurements
  - Implement closed-loop active combustion control using fuel modulation
  - Examine the effects of passive damping

Acknowledgements

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Spectrum: Nonreacting 7-Point 60° Swirler