Fundamental Studies in Syngas Premixed Combustion Dynamics

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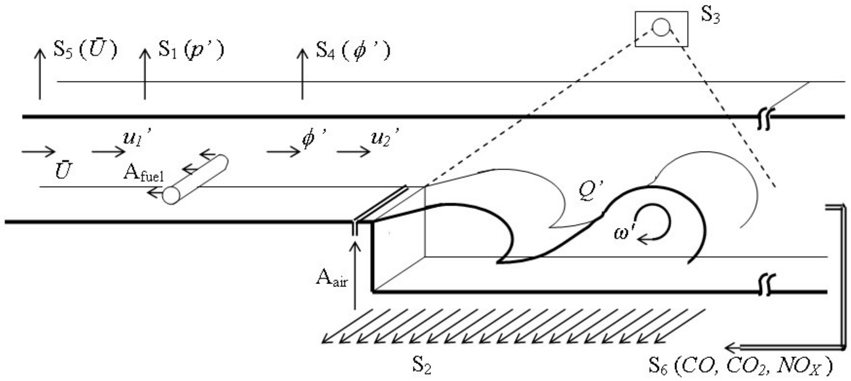
SCIES Project 05-01-SR121
Project Awarded (08/01/2005, 36 Month Duration)

Needs & Objectives

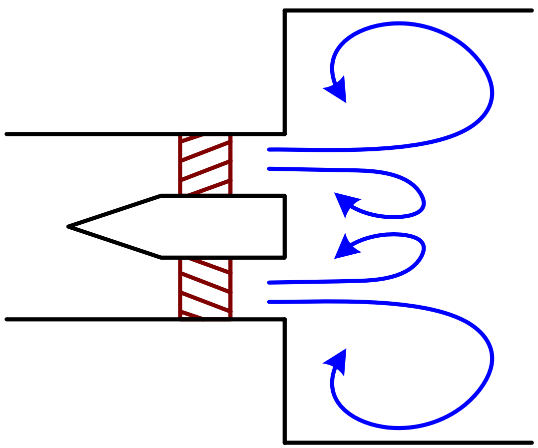
- Gas Turbine Needs
  - Flexibility to operate with variable syngas compositions
  - Ensure stable operation over a wide range of conditions
  - Reduce emissions of CO and NO_x
- Project Objectives
  - Study experimentally lean premixed syngas combustion over a range of gas compositions and thermodynamic and dynamic conditions
  - Quantify syngas combustion lean stability limits over a range of turbulence conditions and flame anchoring configurations
  - Examine combustion dynamics near and around these limits in configurations that are similar to gas turbine combustors
  - Use passive methods to extend syngas lean stability limits

Project Approach: Flame Anchoring Configurations

- Backward-facing step combustor
  - Flame is anchored by recirculation below step
  - Low-intensity, large-scale turbulence

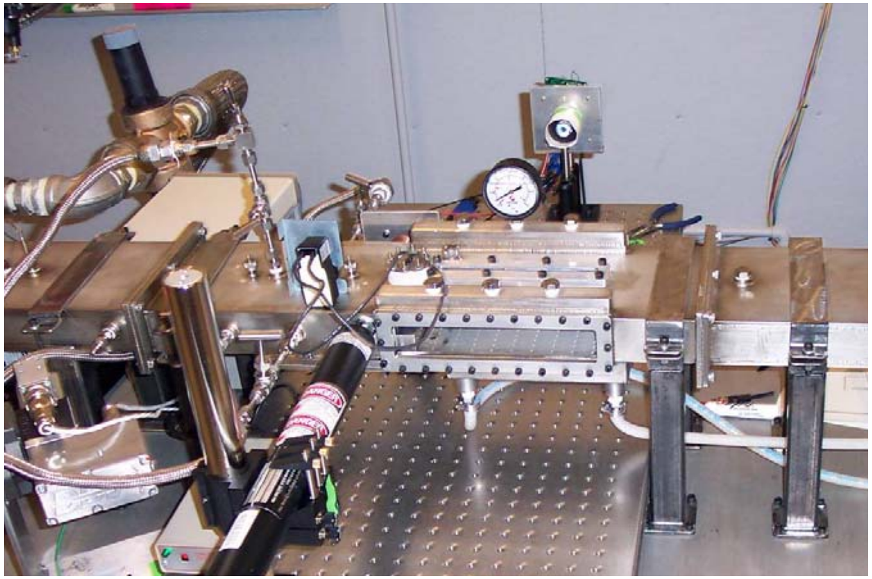


- Swirl stabilized combustor
  - Recirculation established by swirl and sudden expansion
  - High-intensity, small-scale turbulence

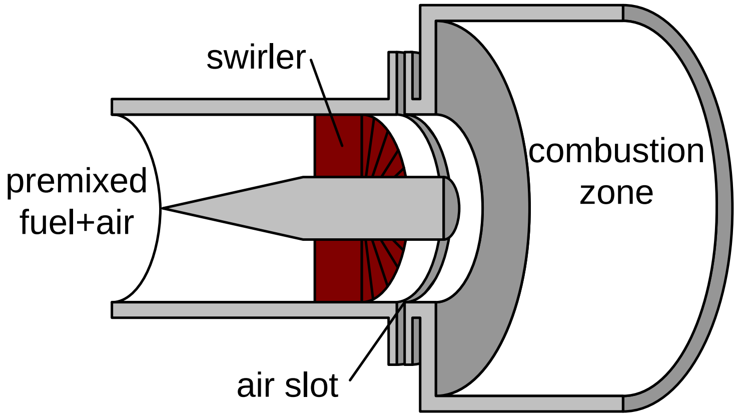


Project Approach:
Step Combustor & Swirl Combustor

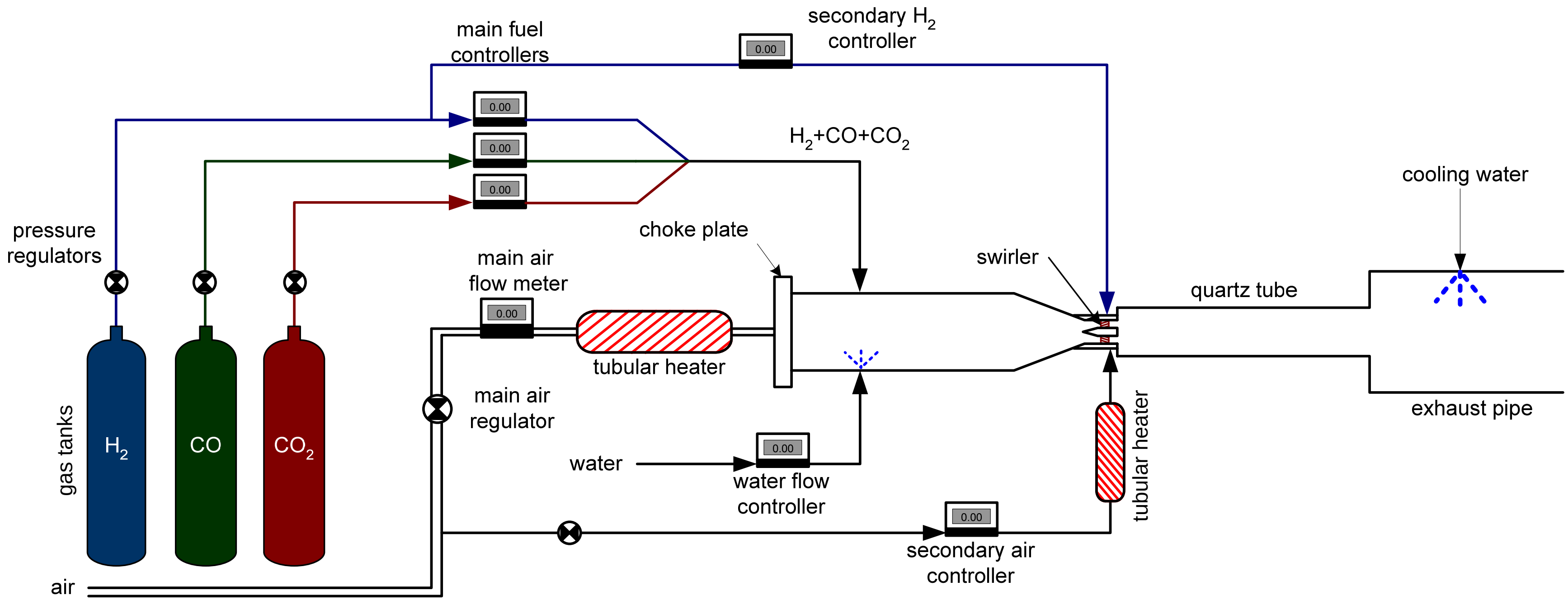
- Conduct initial experiments on backward facing step combustor
  - Simplified setting with easy measurement opportunities
  - Dynamics and instabilities
    - Flame-vortex interaction
    - Equivalence ratio oscillations



- Design and construct an axisymmetric swirl stabilized combustor
  - Interchangeable swirler section
  - Radial air injection slot
  - Optical access for CCD camera, photodiode array

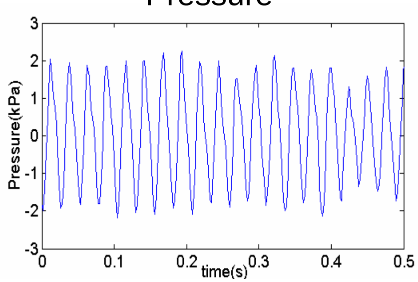


Project Approach: Experimental Setup

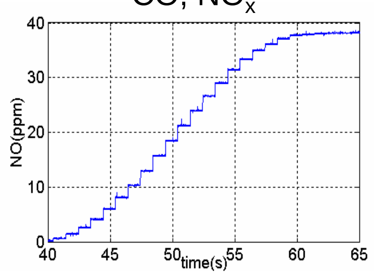


Measurement Capabilities

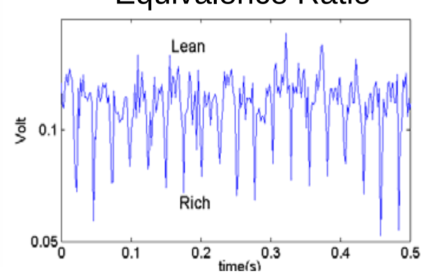
Pressure



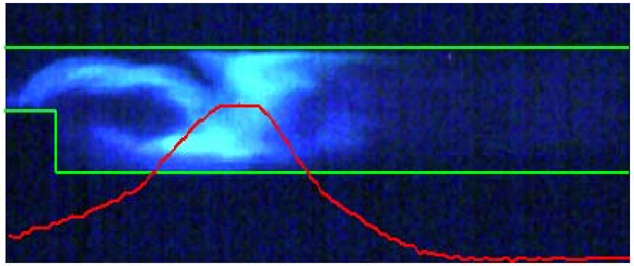
CO, NO_x



Equivalence Ratio

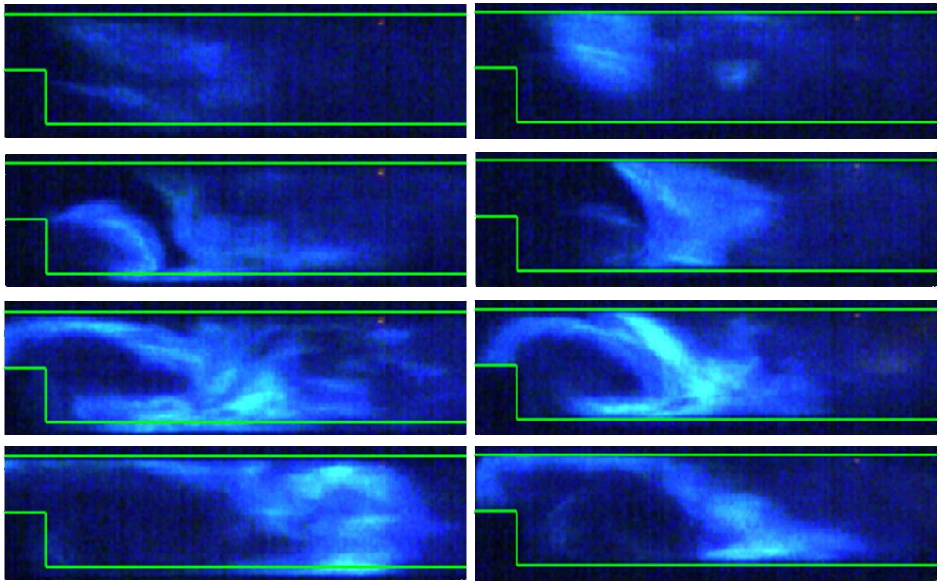


CCD Camera
Linear Photodiode Array



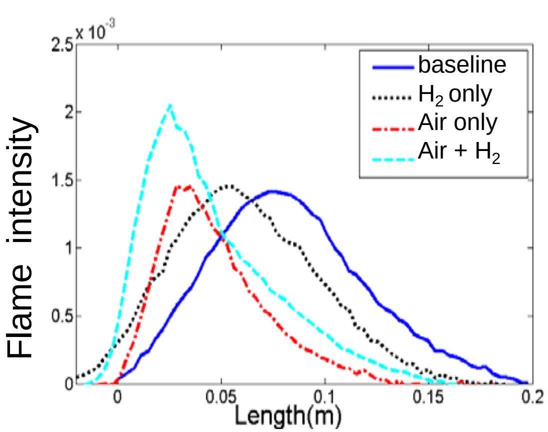
Experimental Approach: Controlling Flame Instability

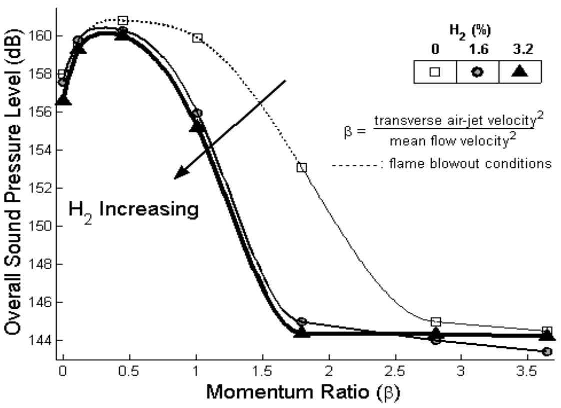
- Flame Instability in step combustor
  - Eliminating equivalence ratio oscillations does not stabilize the flame
  - Basic instability mechanism is flame-vortex interaction
- Passive Control Mechanisms
  - Goals
    - Control combustion instability
    - Reduce emissions
  - Control Mechanisms
    - Changing fuel composition
    - Passive air injection

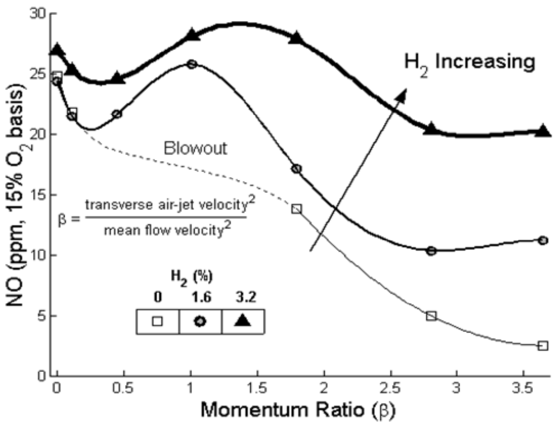


Fuel bar 175 mm upstream

Fuel bar 350 mm upstream

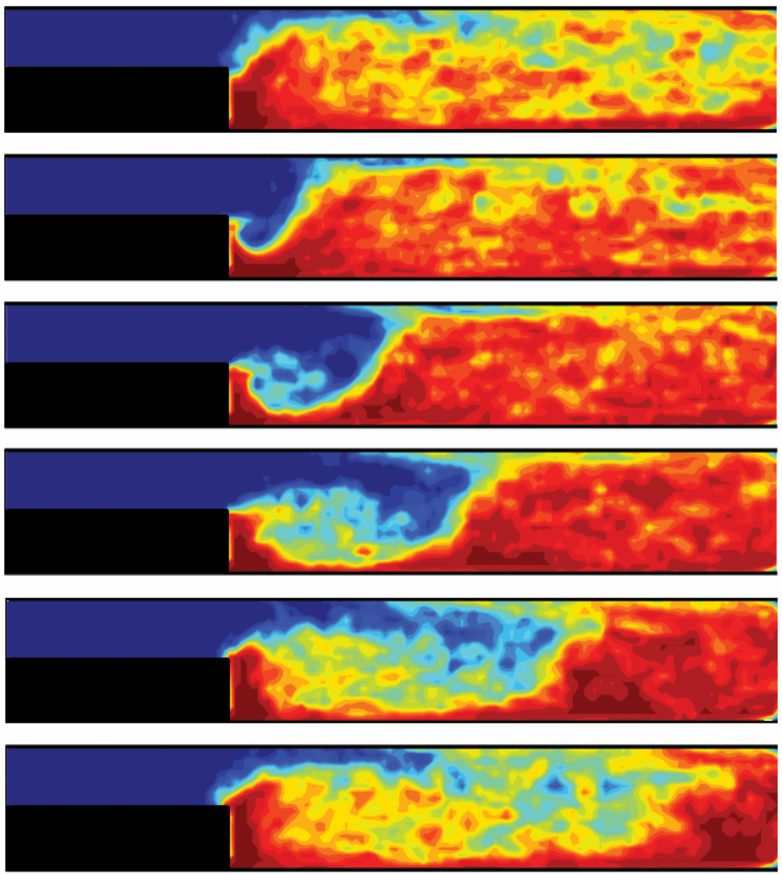




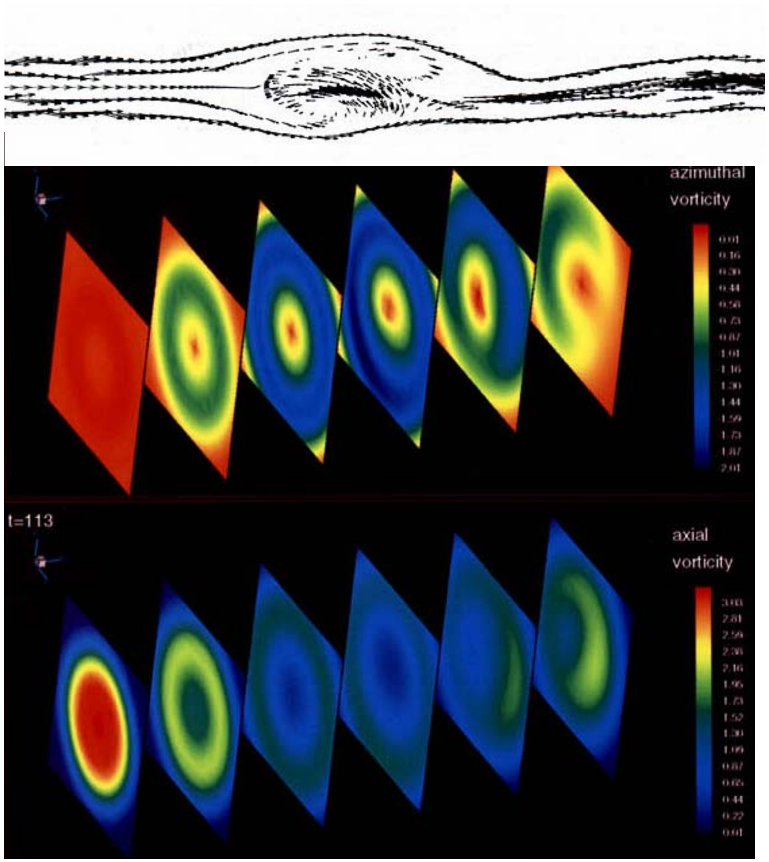


Numerical Approach: Flame-Vortex Interaction

- Use numerical tools to understand the interaction between flame dynamics and combustor dynamics



Vortex shedding in a step combustor

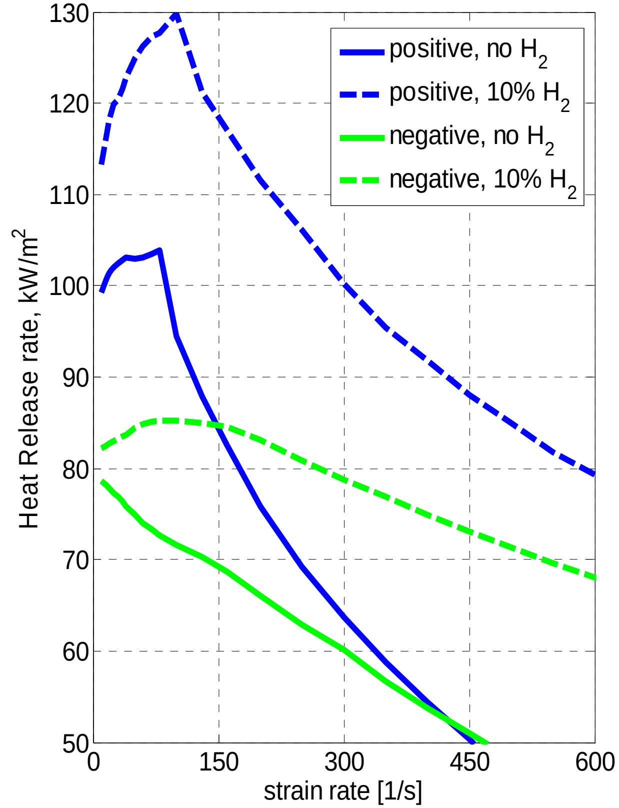


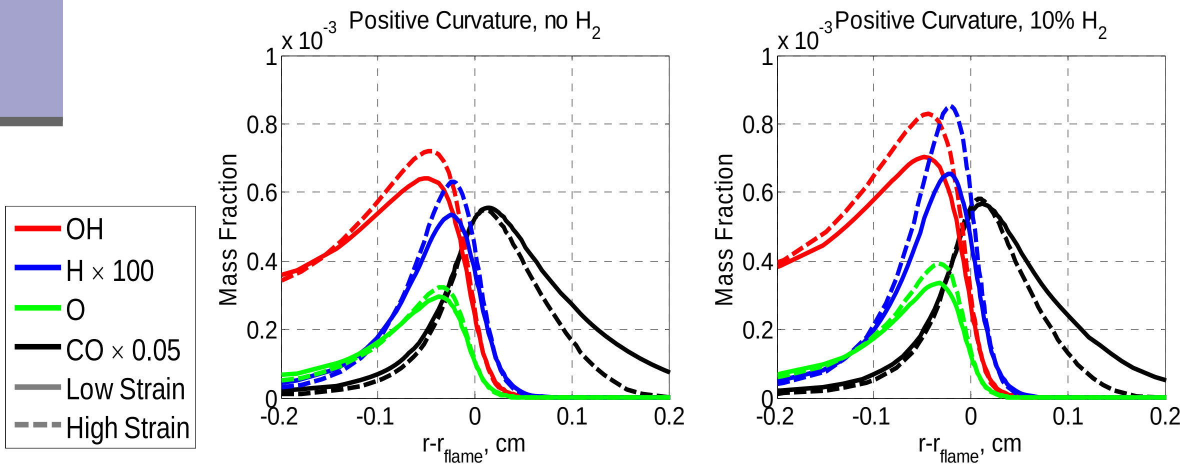
Vortex breakdown in a swirling flow establishes the recirculation zone downstream from the swirl vanes.

Numerical Approach: Unsteady Curved Strained Flame

- Fully unsteady model of curved, strained flames with detailed chemistry and transport
- Obtain results for CO/H_2 flames
- Examine effects of changing fuel composition, equivalence ratio
- Find mechanisms and determine parameters to achieve desired operating goals

flame response to stretch and curvature





Effect of curvature and strain on radical concentrations

Summary

- Study syngas combustion dynamics in a step-stabilized combustor over a range of operating conditions
- Design and construct a swirl-stabilized combustor
- Use existing diagnostic techniques and numerical modeling to understand combustor dynamics
- Apply passive control techniques to extend stability limits and reduce emissions