

# Success Stories

## Progress at the National Energy Technology Laboratory

Pittsburgh, PA

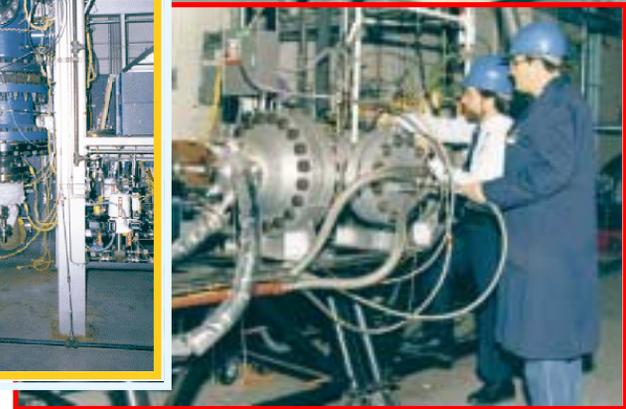
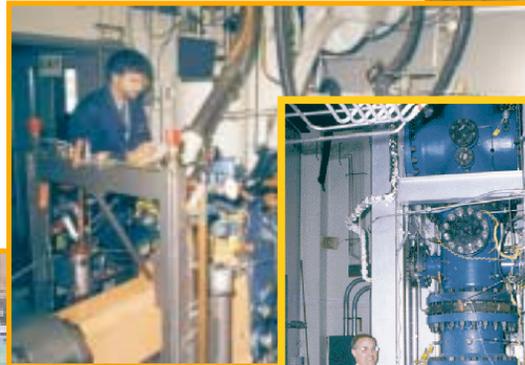
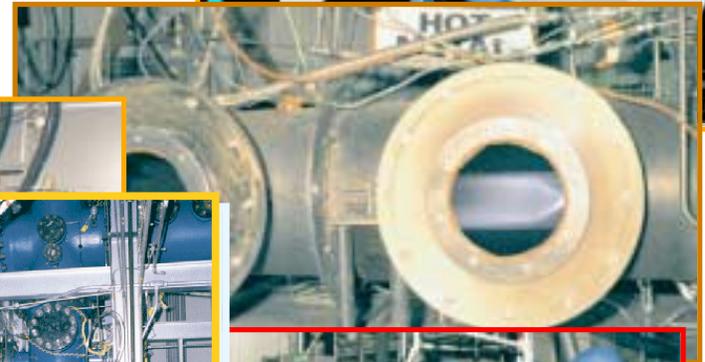
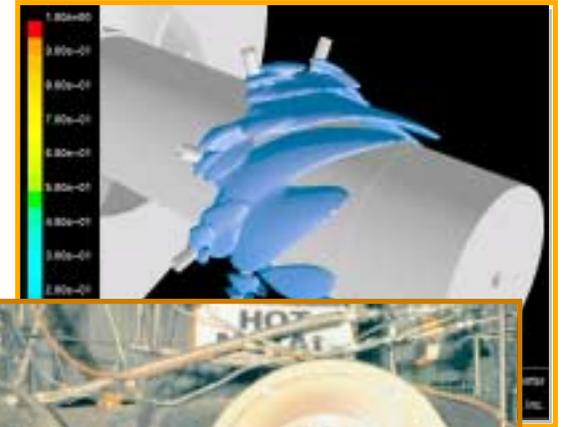


Morgantown, WV



# NETL's Staff and Facilities

- High pressure turbine combustion
- Hybrid turbine fuel cell systems
- Simulation of energy systems
- Reciprocating engines
- Sensors and control
- Fuel cells



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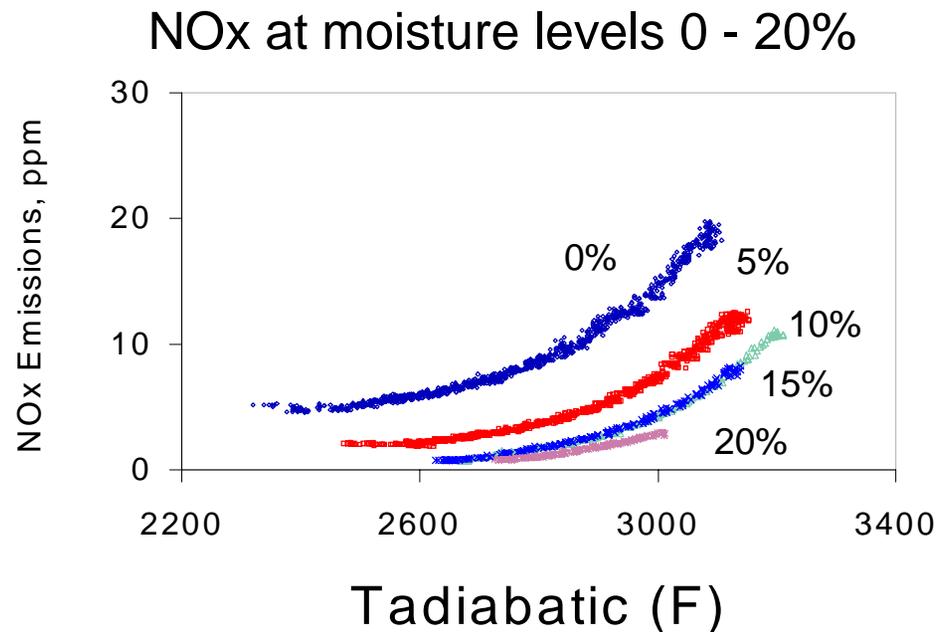
# Outline of talk

- **Successful research during the ATS program**
  - Low-emission combustion studies
- **New research directions supporting**
  - Next Generation Turbines
  - Hybrid Turbine Fuel Cells



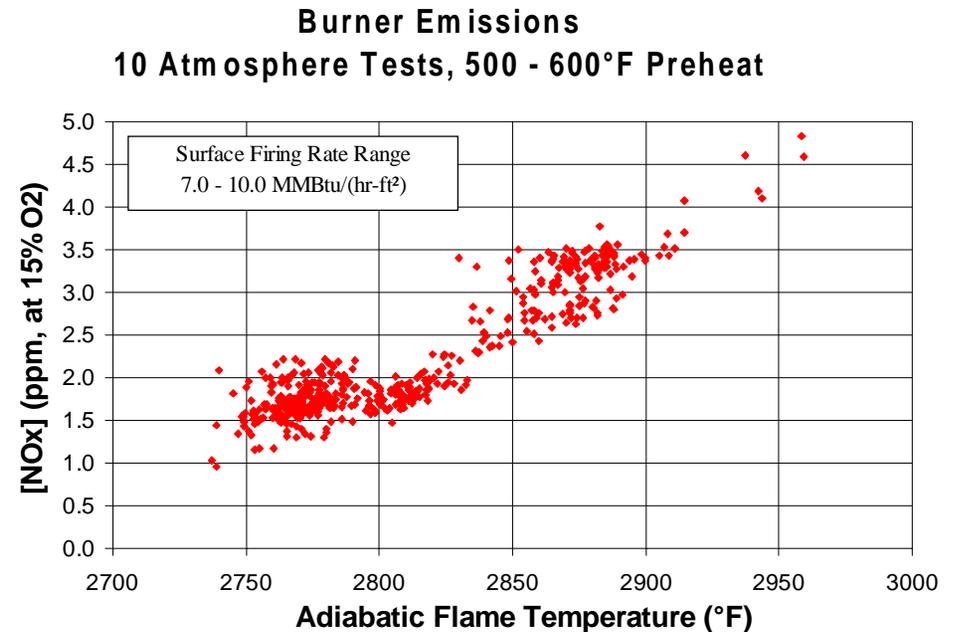
# HAT Cycle Combustion Tests at NETL

- Collaboration with UTRC/P&W
- Evaluate effects of steam loading and  $\Phi$  on dynamics, NO<sub>x</sub>, and CO emissions
- Observed sub-9 ppm NO<sub>x</sub> and CO levels
- NO<sub>x</sub> emissions primarily due to piloting
- Steam addition mitigates NO<sub>x</sub> (chemistry, not temperature)



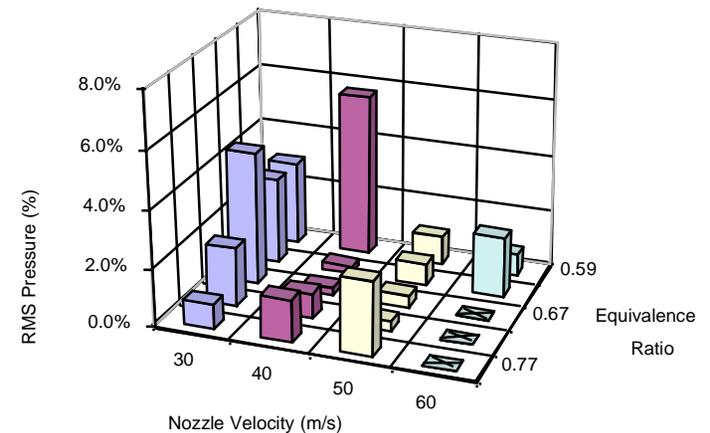
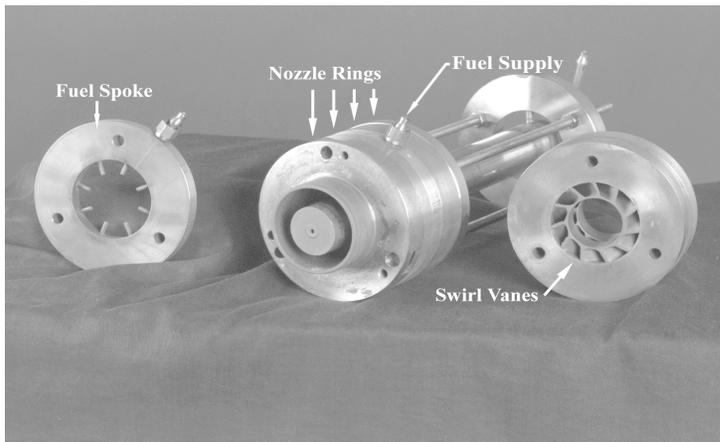
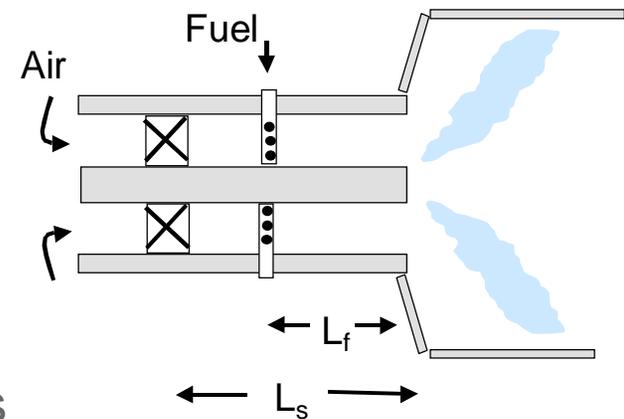
# Surface Stabilized Combustor Tests at NETL

- Collaboration with Alzeta Corp.
- Outward fired cylinder within slotted, air cooled can
- Simultaneous ultra-low emissions of NO<sub>x</sub>, CO, and UHCs observed
- Based on these results, Alzeta now collaborating with CEC, Solar, and DOE/EE to advance the technology



# Improving Stability of Low Emission Combustion

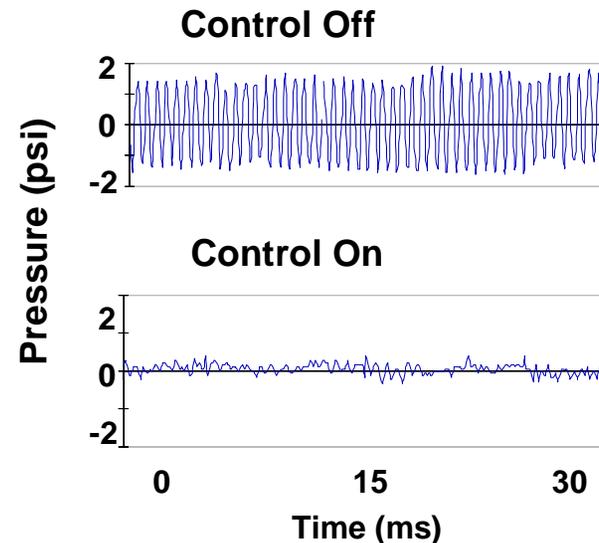
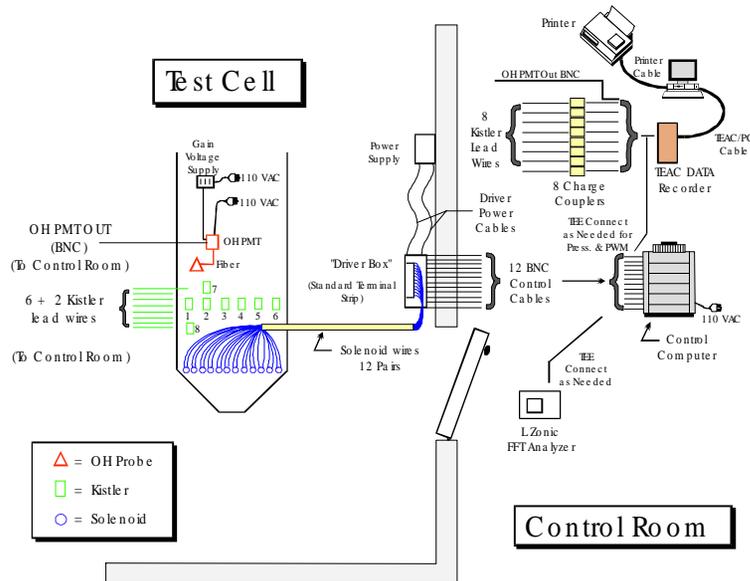
- Low-emission combustion is complicated by dynamic pressure oscillations (*flame driven vibration*).
- *Dynamics* limits operating flexibility, fuel choices, emission performance.
- NETL and AGTSR research has identified design features and analysis to enhance stability.



# Active Control of Combustion Dynamics

CRADA with Solar Turbines, Inc.

- Active control may be a flexible approach to achieve stability.
- NETL/Solar Concept has proceeded from lab to engine using 12 injectors in annular combustor.
- Fuel modulation using commercial NG solenoids.
- No changes to engine control or throttle system.



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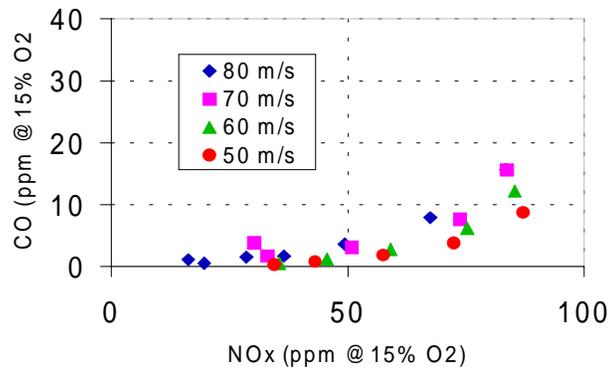


# Dual Fuel Applications

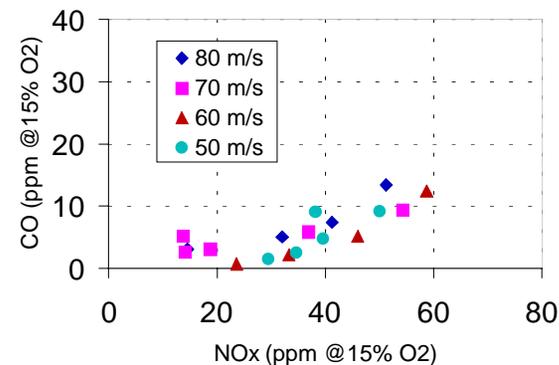
- Low-emission operation on both natural gas and standby liquid fuel is desirable
  - NETL/Parker investigation of “macrolaminate” dual-fuel premixer demonstrates DF-2 and natural gas emissions.



DF-2 Fuel



Natural Gas



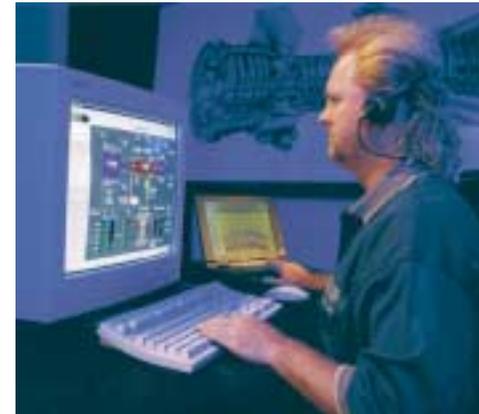
- Dynamic behavior on natural gas and liquid fuel obeys “convective-lag” description.



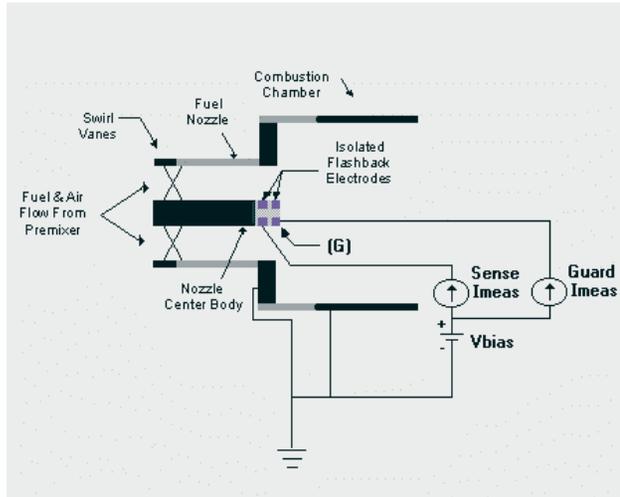
# New Research Directions

**Next Generation Turbines,  
Hybrid Fuel Cell/Turbine Systems, and  
Distributed Generation.**

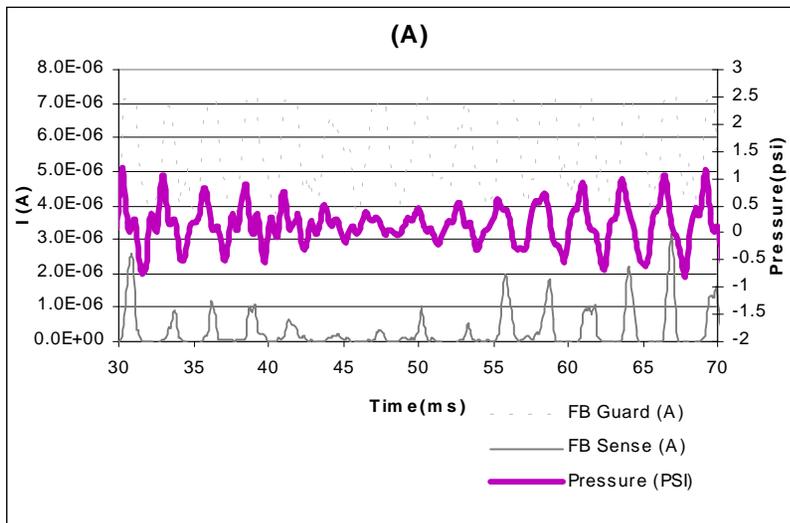
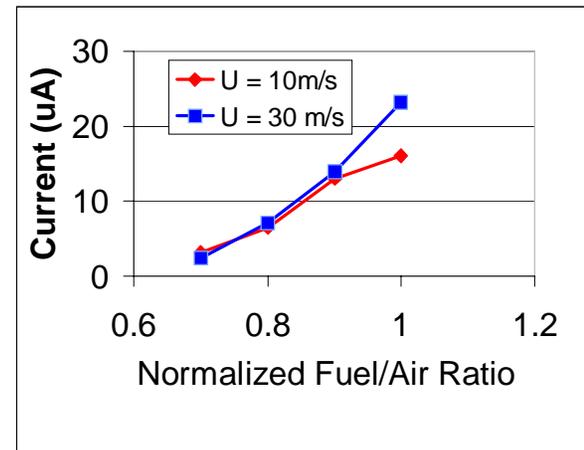
Please visit the NETL poster:  
“Gas Energy Systems Dynamics”



# Combustion Sensors



- Evaluation of local combustion conditions could enhance engine operation:
  - Avoid upset conditions, extend life.
  - Maintain emissions performance.
- NETL Flashback Detection Sensor shows potential for *both* flashback detection and monitoring of combustion parameters.



- Current investigations at NETL
  - Identify techniques to insert electrodes on existing fuel injectors, combustors.
  - Testing at turbine operating conditions in NETL high pressure combustion rig.



# Fuel Flexible Combustion

- Hydrogen fuels (coal gas, biogas, refinery...) may not be amenable to premix combustion.

Rich-Quench-Lean may be an advantage for fuel flexibility?

DoD work on “trapped-vortex” shows promise as a low-emission RQL system.

NETL investigation of trapped vortex concept is in progress.

- Improved *simulation* of combustion (especially w/fuel variability) requires high-pressure combustion data

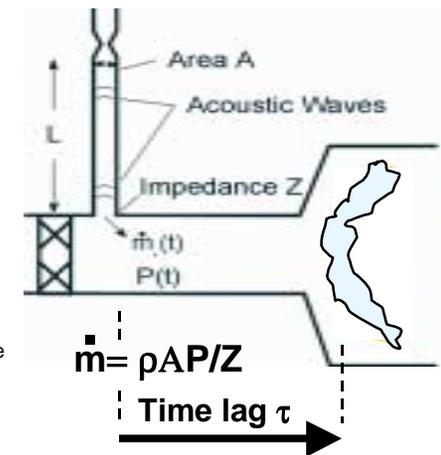
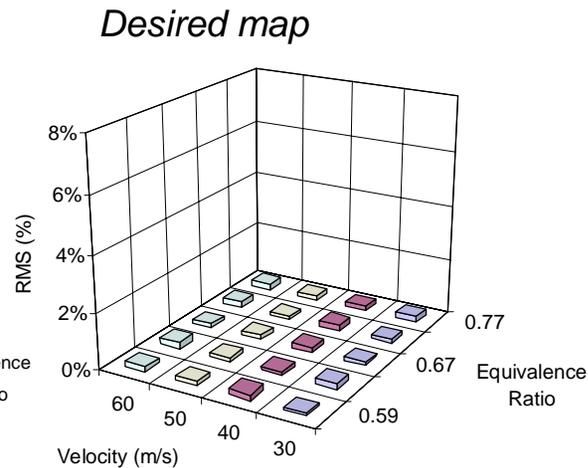
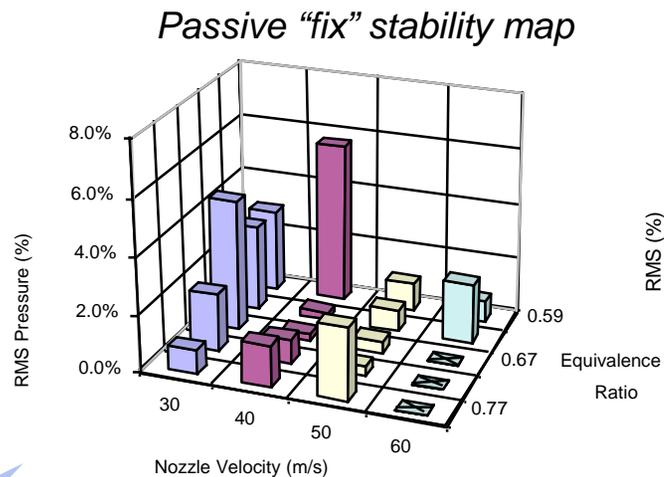
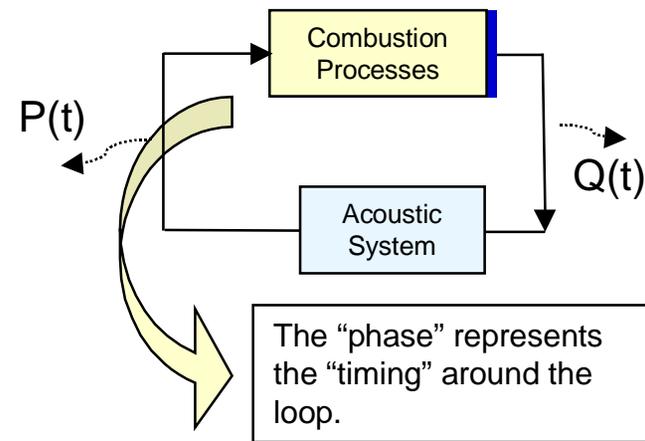
NETL/Sandia investigation of high-pressure turbine combustion.

Experimental work supporting NETL award on advanced combustion simulation development (CFDRC Inc.).



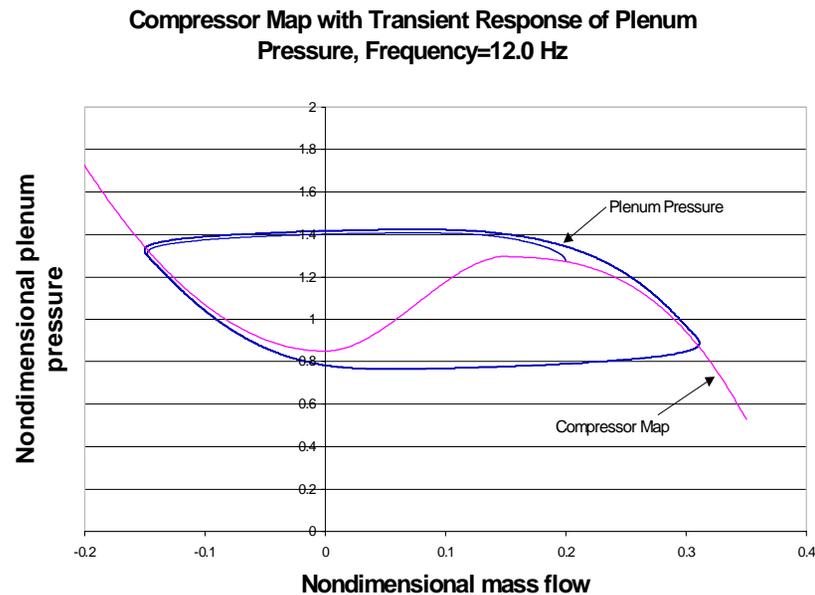
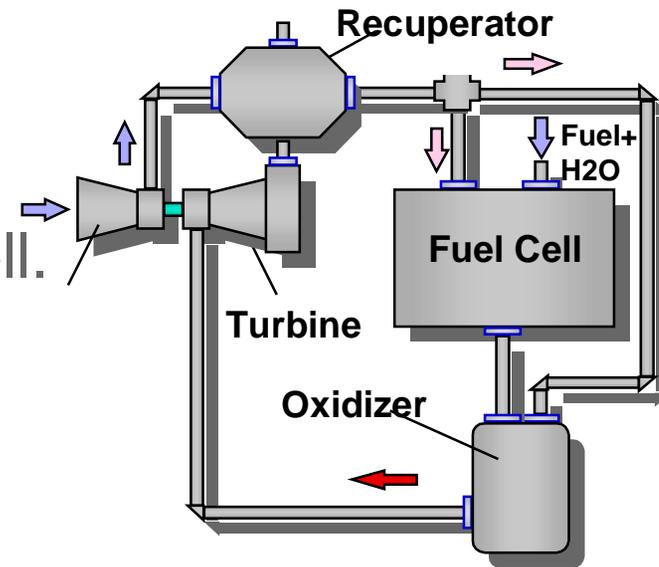
# Enhanced Combustion Stability

- Past progress in enhancing combustion stability has not addressed rig-to-engine development issues.
  - Combustion gain and phase, rig-to-engine
  - Acoustic gain and phase (VT collaboration)
- New ideas, combining passive/active concepts, appear promising.



# Integration of Fuel Cell and Turbine

- Operation of hybrid system should avoid unexpected transients to protect fuel cell.



- Dynamic model allows consideration of transient behavior during upset conditions

Prediction of surge history and conventional compressor map.

# Summary

- NETL's research has identified new technology options for low-emission combustion.
- Partnerships with university and industrial researchers have moved ideas from the lab to applications
- **New research aimed at:**
  - Improved operability and reliability while producing clean power.
  - Reduced development time and cost for *flexible* energy generation.

