Research Efforts at NETL for Supercritical CO_2 Power Cycles

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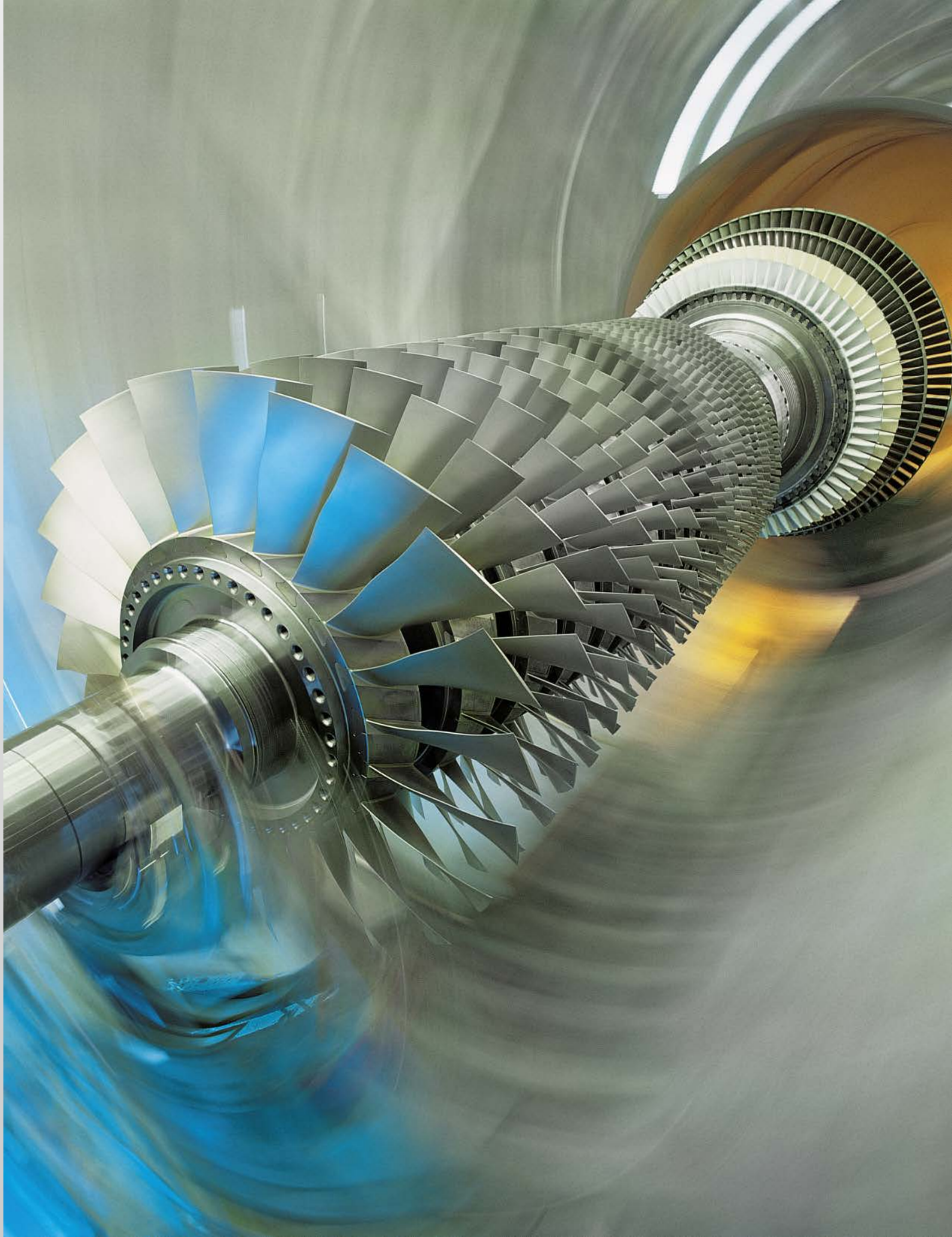
5th International Symposium Supercritical CO2 Power Cycles, Mar. 28-31, 2016, San Antonio, TX.

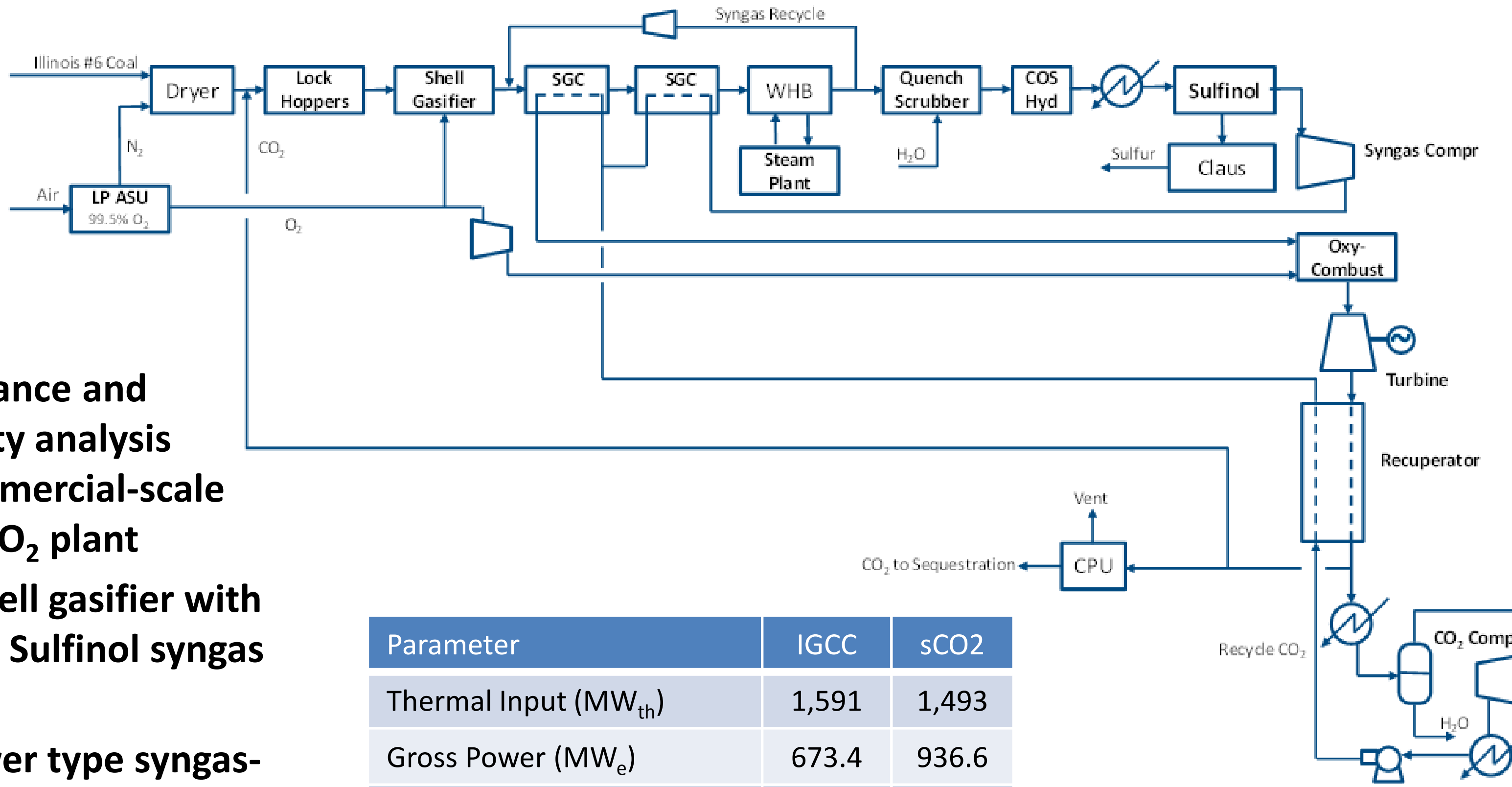
U.S. DEPARTMENT OF ENERGY | National Energy Technology Laboratory



Current Research Efforts at NETL

- ***Systems analysis***
  - Thermodynamic modeling of high temperature direct and indirect fired cycles for natural gas and coal. Steady state and dynamic models for performance, cost and transient analysis.
- ***Materials***
  - High pressure autoclave (800°C, 275 bar) for exposure of coupons and welded/bonded specimens.
  - Low cycle fatigue and compact-tension of exposed specimens.
- ***Combustion***
  - CFD modeling of injection, combustion and wall cooling.
  - High-pressure oxy-fuel combustor development: Designing a 300 bar, 1MW combustor.
- ***CO_2 turbine blade cooling.***
  - Internal cooling designs (forced convection, thermosyphon, etc.)
  - Plans for initial testing of concepts in FY17.

Coal-Fired Direct sCO2 Power Plant Performance Analysis



- Performance and sensitivity analysis of a commercial-scale direct sCO_2 plant
- Using Shell gasifier with AGR and Sulfinol syngas cleanup
- NET Power type syngas-fired direct sCO2 cycle with heat integration
- Favorable efficiency vs. IGCC plant, with better CO_2 capture

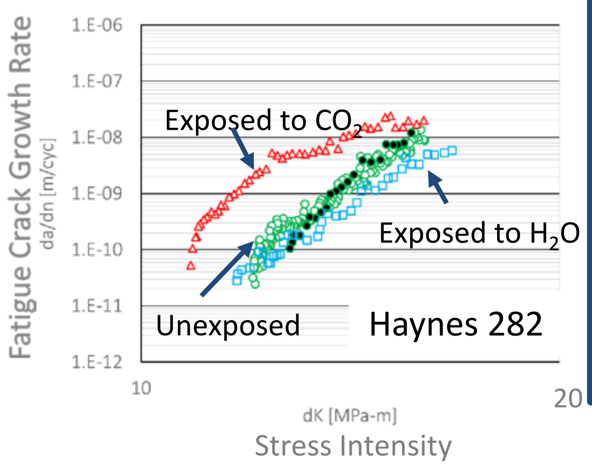
Parameter	IGCC	sCO2
Thermal Input (MW_{th})	1,591	1,493
Gross Power (MW_e)	673.4	936.6
Auxiliary Power (MW_e)	176.5	374
Net Power (MW_e)	496.9	562.6
Net plant efficiency (HHV %)	31.2	37.7
CO_2 Capture Rate	90.1	98.1

Weiland, N., Shelton, W., White, C., and Gray, D., "Performance Baseline for Direct-Fired SCO_2 Cycles," The 5th Int'l Symp. SCO_2 Power Cycles, March 29-31, 2016, San Antonio, Texas.

Materials Research at NETL for Supercritical CO_2 Power Cycles

To enable the development of sCO_2 power cycles, NETL is

- Identifying and evaluating power plant materials for sCO_2 power cycles
- Evaluating fabrication methods for components of sCO_2 power cycles
- Investigating degradation of materials in sCO_2 power cycle environments

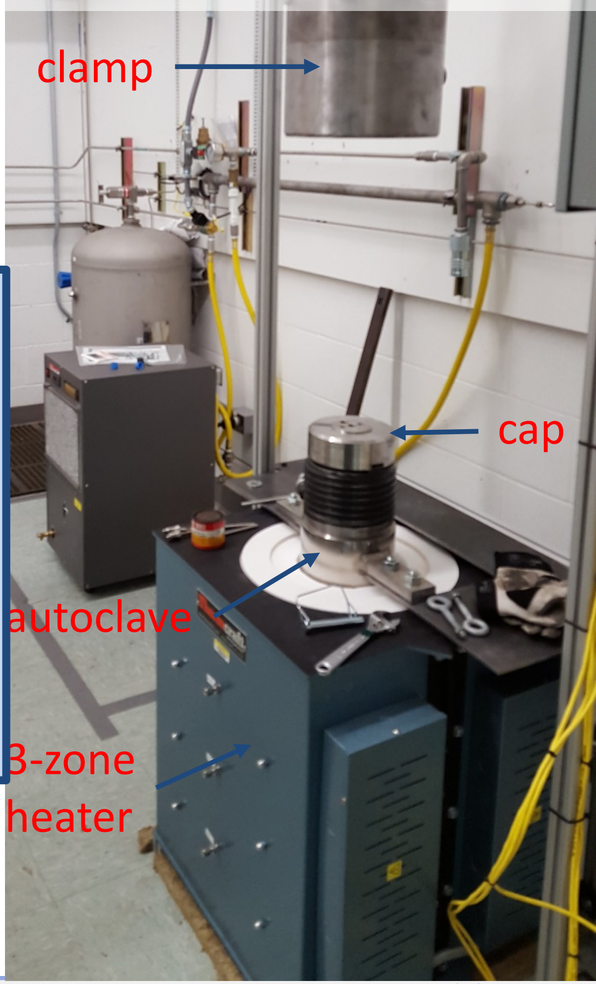


We are able to recreate sCO_2 power cycle environments to perform

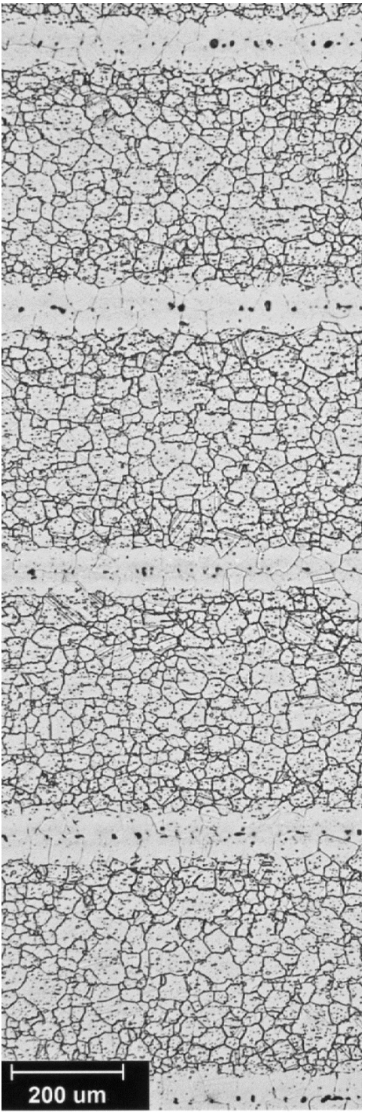
- Corrosion tests of alloy samples
- Corrosion tests of joints (welded, diffusion bonded, brazed)
- Pre-exposure of mechanical test specimens to evaluate the effect of environment on the mechanical properties of power plant materials

Mechanical properties of materials pre-exposed to sCO_2 { Fatigue, Creep, Creep-Fatigue }

Supercritical CO_2 autoclave system capable of 275 bar up to 800°C



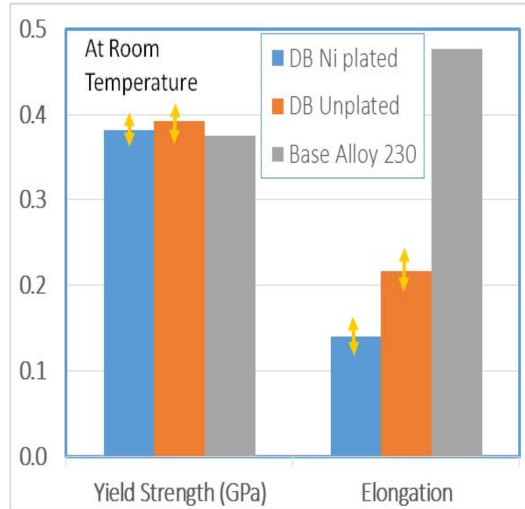
Fabrication and Durability of Compact Heat Exchangers for sCO_2 Power Cycles



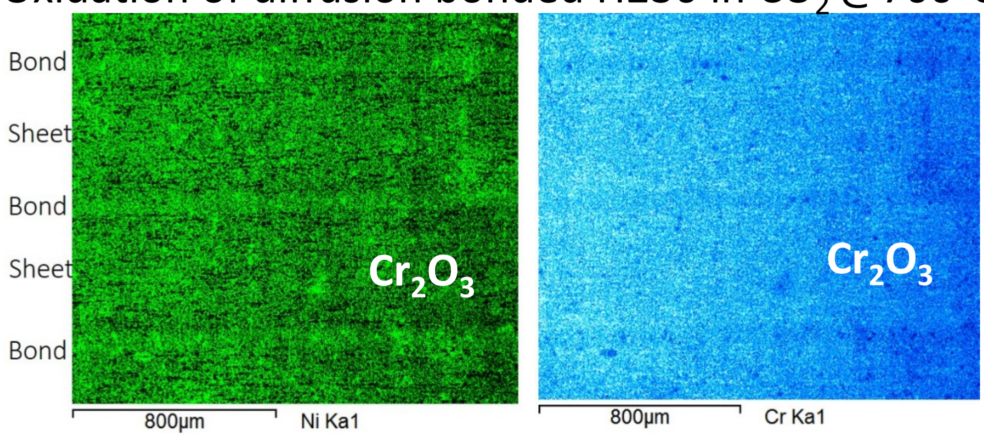
DIFFUSION BONDING

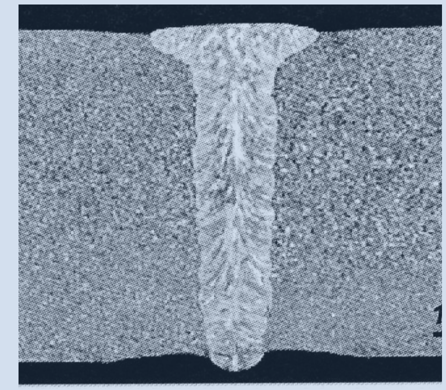
Diffusion bonding was demonstrated as a viable process to fabricate high-temperature, high-pressure microchannel heat exchangers

Sufficient mechanical strength of diffusion bonded stacks of alloy 230 sheet material was obtained through process modeling and experimental verification.



Oxidation of diffusion bonded H230 in CO_2 @700°C





- **Similar and dissimilar metal welds**
  - P22 – P91
  - P91 – 347H
  - P22 – Alloy 263
  - Alloy 625 – Alloy 263
  - 347H – Alloy 263
  - P22 – P22
  - P91 – P91
  - 347H – 347H
  - Alloy 625 – Alloy 625
  - Alloy 263 – Alloy 263
- **Corrosion tests of welds**
- **Mechanical testing of welds**

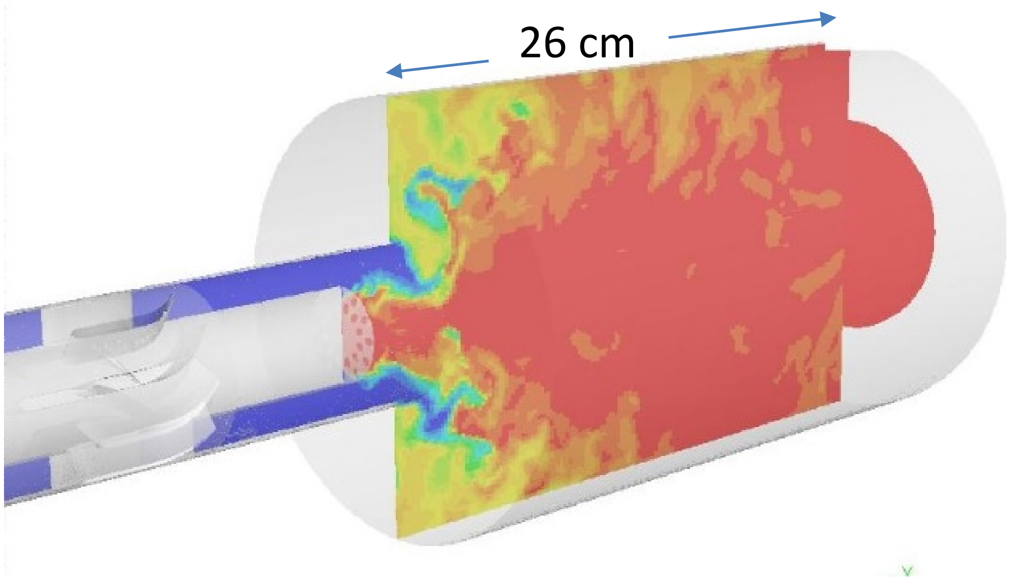
NETL

Oxy-Fuel Combustor Modeling

CFD exploration of high-pressure oxy combustion in a swirl stabilized non-premixed research combustor. What if???

P=300bar
20%O2/80%CO2
T=2050K
Mdot=72 kg/s
180 MW

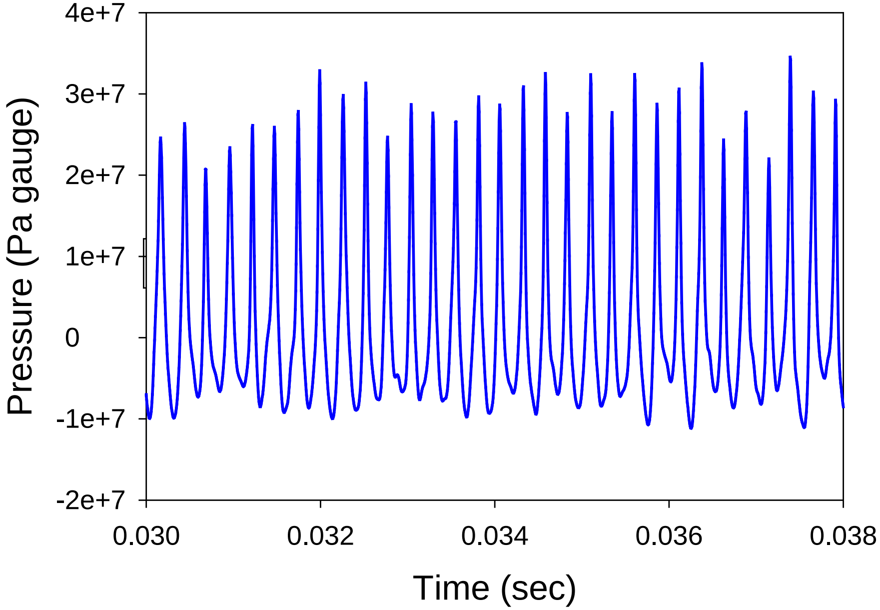
3.3M Cells
LES (Dynamic Smagorinsky)
1-step mechanism

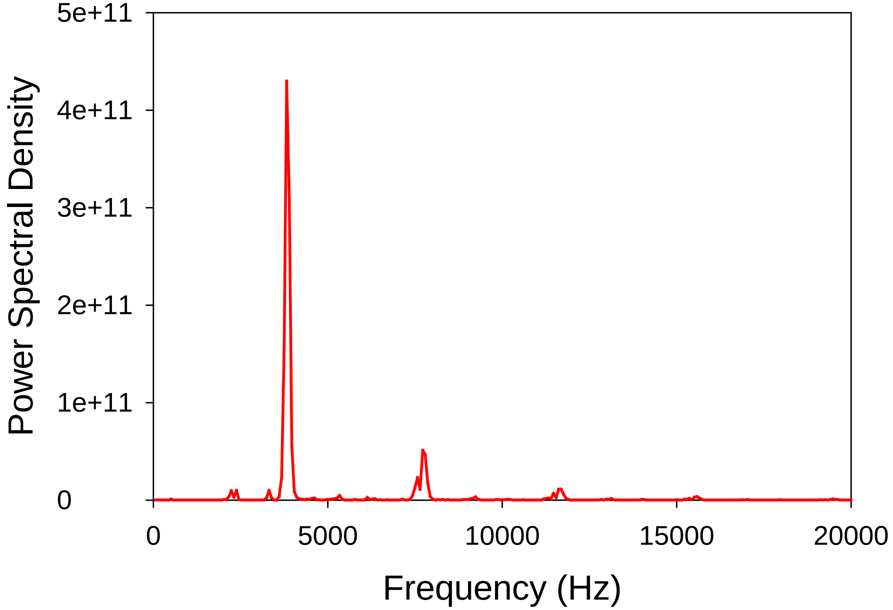


- Compressible LES formulation allows for simulation of combustion dynamics.

Oxy-Fuel Combustor Modeling

FFT analysis of pressure trace at combustor wall.

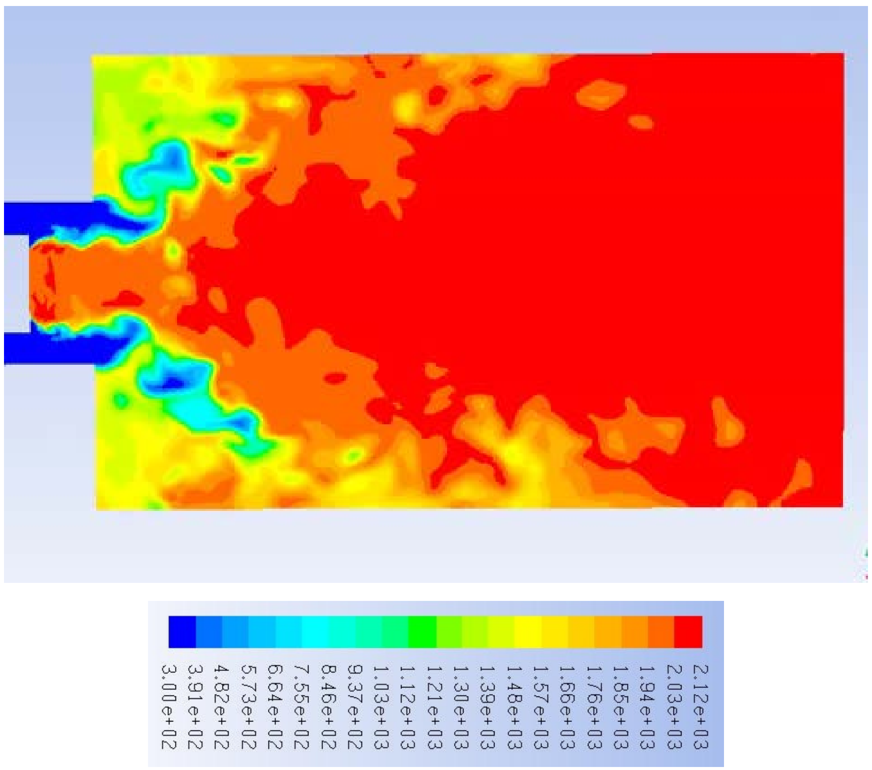




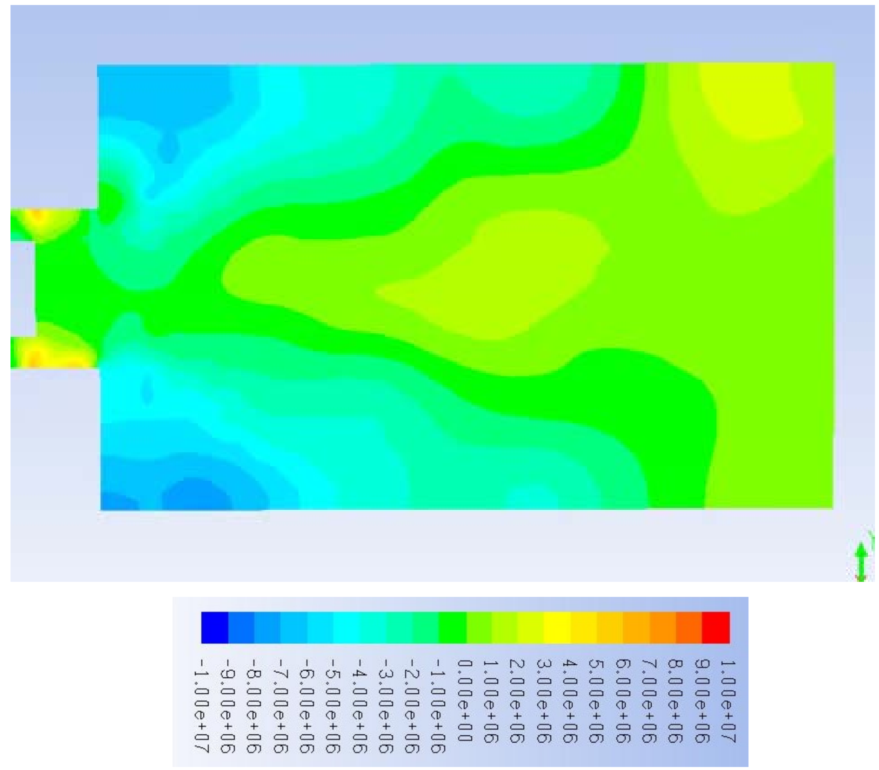
- Spontaneous thermo-acoustic instability @ 4000 Hz observed – azimuthal or "spinning" mode.
- Peak-to-peak pressure amplitude ~ 80% of mean combustor pressure. P_{avg}=4,500 psi, P_{pp}=3,600 psi.

Oxy-Fuel Combustor Modeling

Temperature (K)



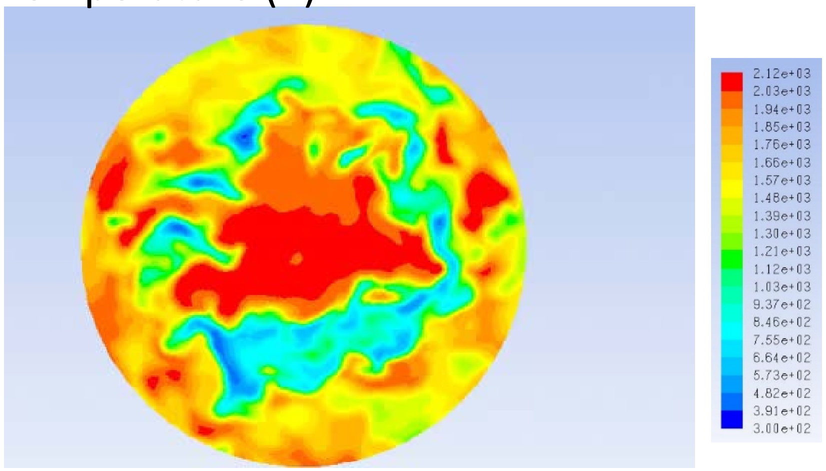
Pressure (Pa gauge)



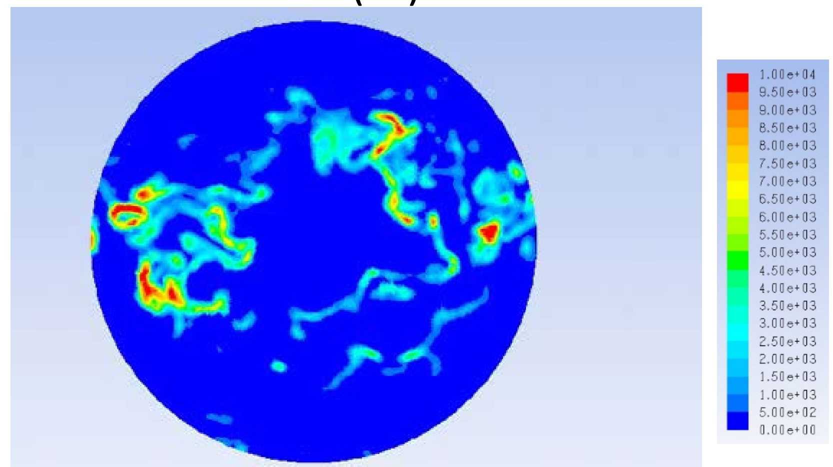
- Temperature and pressure contours at limit cycle operation.

Oxy-Fuel Combustor Modeling

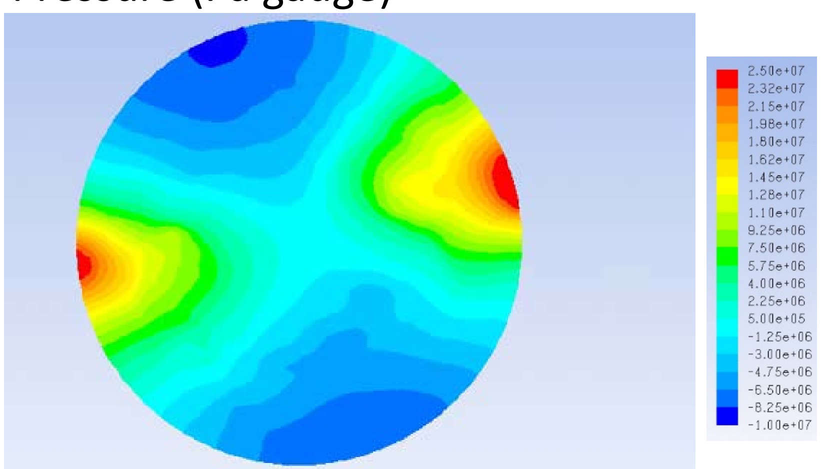
Temperature (K)



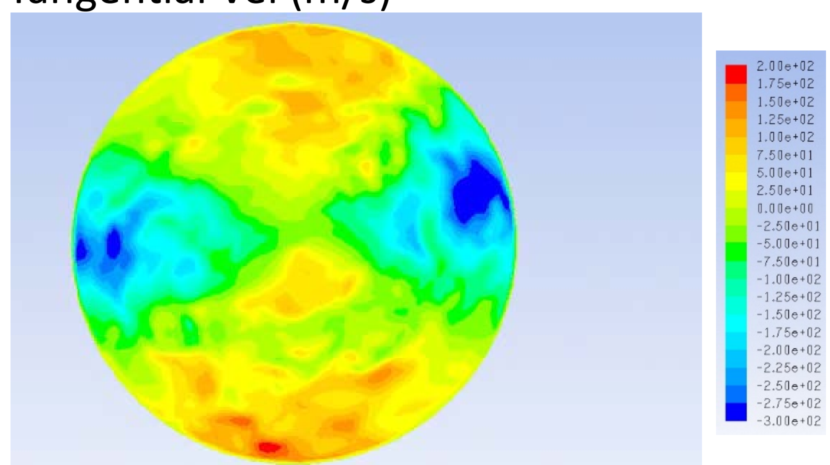
Heat of Reaction (W)

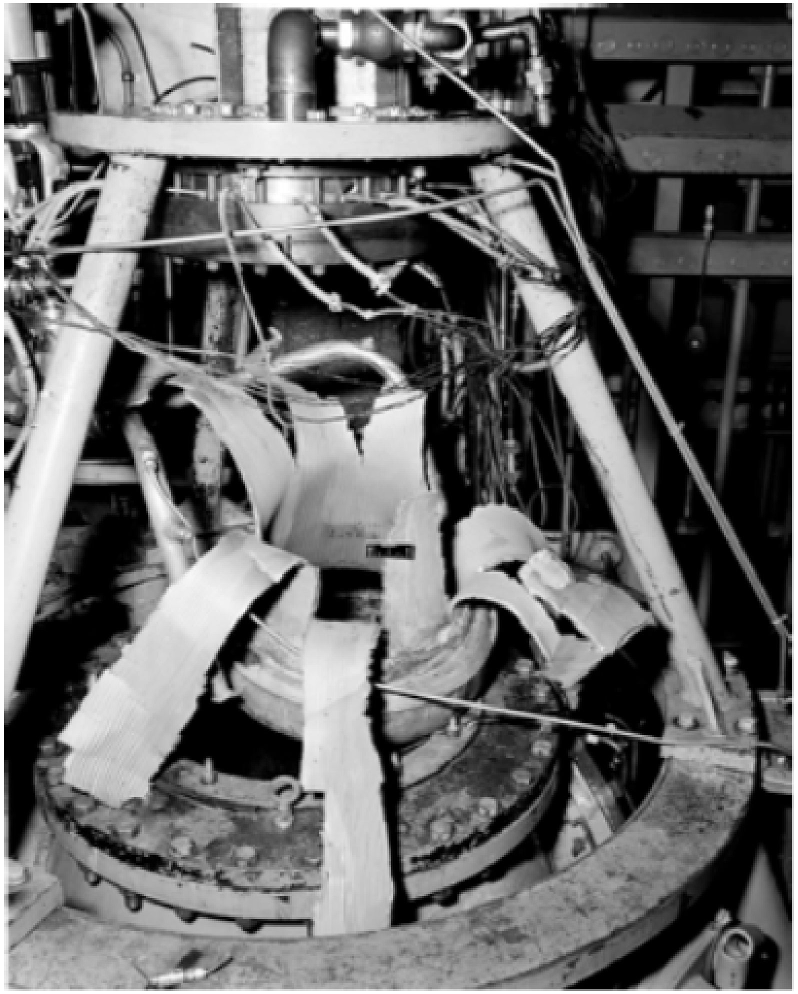


Pressure (Pa gauge)



Tangential Vel (m/s)





Liquid rocket engine (NASA 1957)

Liquid rocket engine (NASA 1963)