sCO_2 Symposium

Overview of SwRI sCO_2 Power Cycle R&D

Aaron McClung, Ph.D.

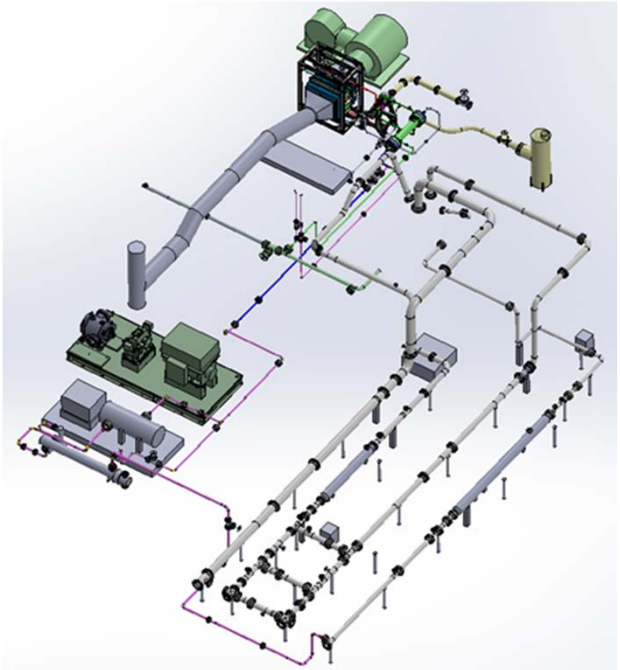
Manager

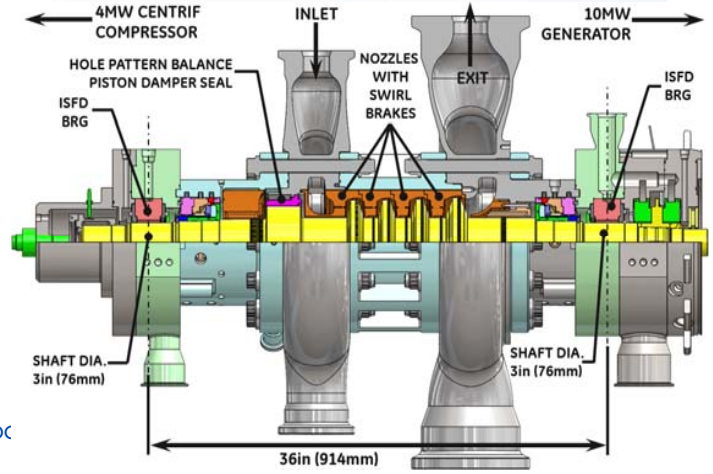
Ongoing sCO_2 Projects at SwRI

- Currently $100M+ in sCO_2 R&D projects
- 25 active projects
- Topics include:
  - Component design and testing
  - Oxyfuel combustion
  - Cycle optimization
  - Pilot plants
  - Gas physical properties
- Testing activities
  - 1 MW Sunshot loop operational
  - 10 MW STEP loop in design phase
  - Additional seals, compressor, and compander testing in the queue

One MW DOE sCO_2 Pilot Loop (SwRI, GE, Thar, + for DOE EERE)

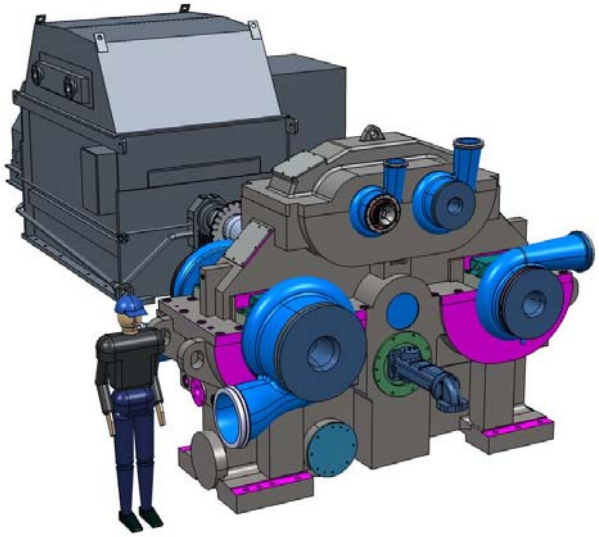
- Demonstrate Utility-Scale sCO_2 Components
- Objective: MW-scale sCO_2 turbo-expander and heat exchanger are a critical step in increasing energy conversion efficiency to >50%, while reducing power block costs
- 1 MW simple recuperated sCO_2 closed loop
- >715 C heat source (fired NG heater)
- Part of $12M DOE SunShot program
- Designed for testing of key MW-sized critical plant components:
  - Equipment (turbine, recuperator)
  - Cycle dynamics and sequencing (startup, shutdown, upsets)



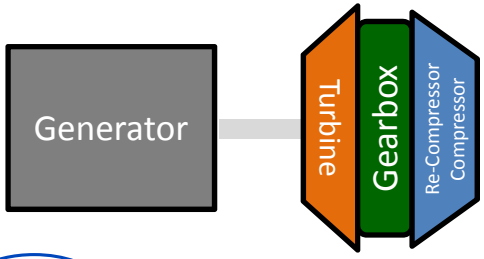


Ultra High Efficiency Integrally-Geared sCO_2 Compander (SwRI, Hanwa for DOE EERE)

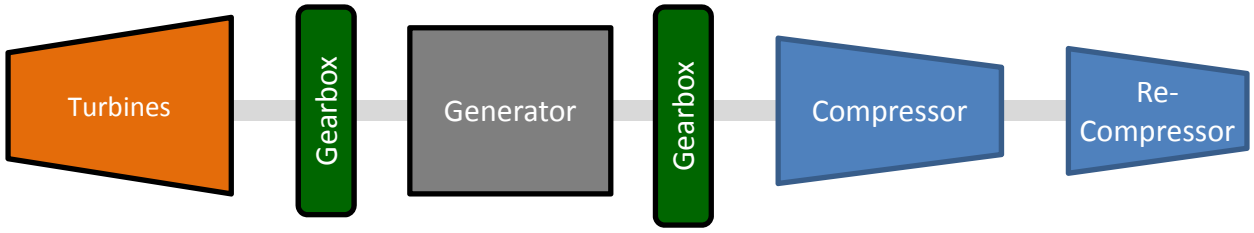
- Design a sCO_2 integrally geared compander (IGC)
  - Combining compression and expansion stages into a single integrally geared housing connected to a low speed motor/generator.
- Benefits:
  - Reduced footprint
  - Potential cost reduction up to 35%
  - Utilizes a low speed commercially available driver/generator
  - Modular (Small Industrial [5MW] to Small Utility [50 MW])
  - High efficiency over a range of operating conditions
  - Improved cycle controllability
  - Reduced mechanical complexity ➔ improved reliability and reduced maintenance



Typical IGC Package



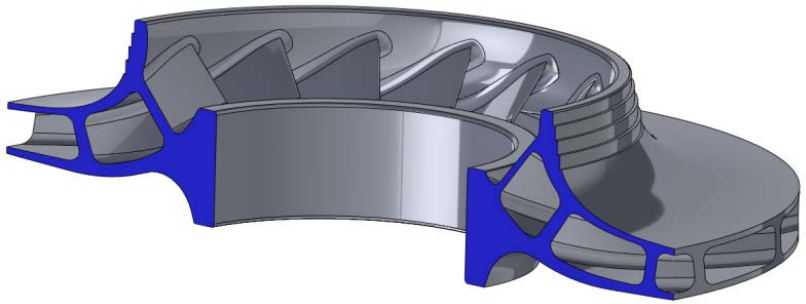
Conventional Turbomachinery Train



GE-Apollo High-Efficiency sCO2 Centrifugal Compressor Development (GE, SwRI for DOE EERE)

PROJECT OBJECTIVES

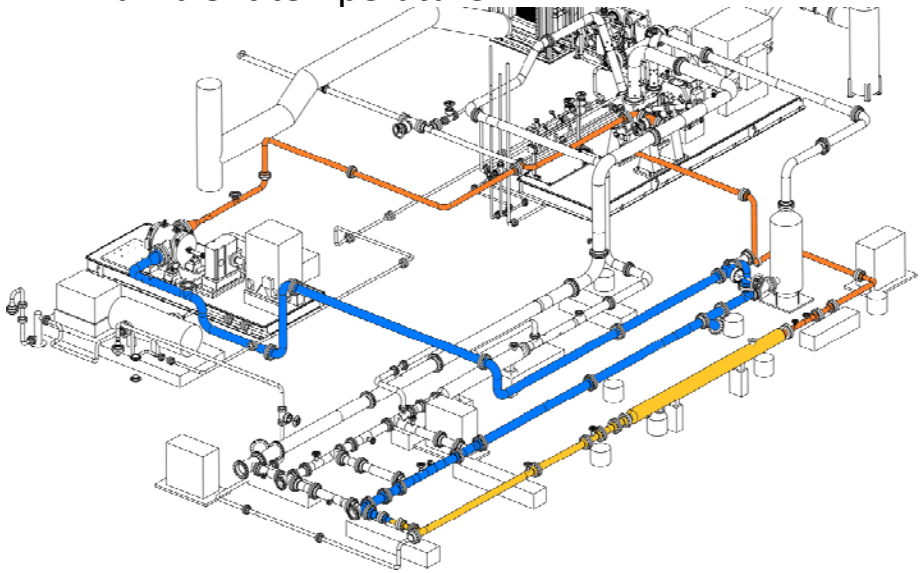
- Develop high-efficiency sCO2 compression system
  - Main Compressor Efficiency of 80%
  - Preliminary Design completion June 2016
  - Go/no-go decision point after Phase 1 (June 2017)
- High efficiency centrifugal impeller
- Variable IGV/OGV



- Advanced aerodynamic design provided by GE will be implemented into the detail compressor design provided by SwRI.

KEY RESULTS AND OUTCOMES

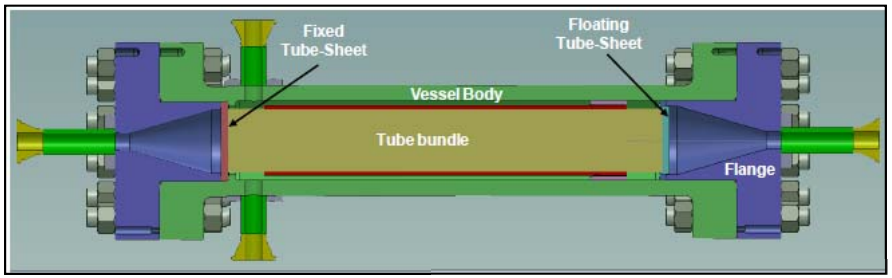
- Full scale testing of a 10 MWe SCO2 Compressors
- Extended flow range to accommodate swings in ambient temperature

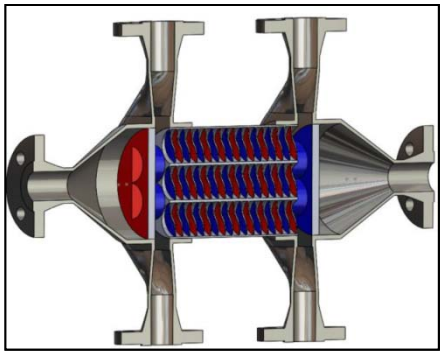


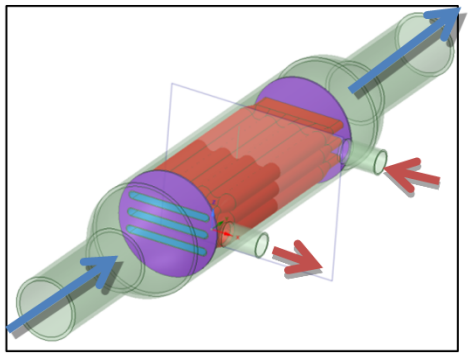
- SwRI SCO2 Test Facility will provide verify compressor mechanical and aerodynamic performance over a range of operating conditions

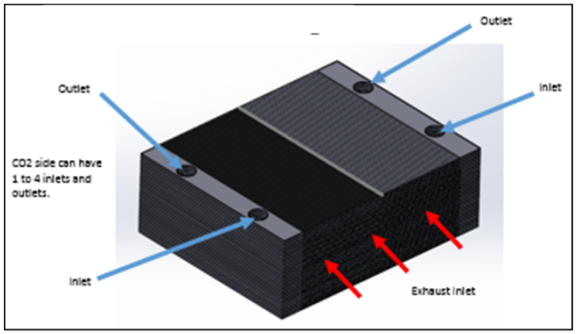
Advancing High Temperature Recuperator Technology (Thar, SwRI, ORNL, Georgia Tech for DOE NETL)

- Developing a 47MWth compact, high-temperature recuperator for the 10MWe STEP Facility
- Address critical design, materials, and fabrication challenges
  - Target 96% thermal effectiveness
- Significantly improve the recuperator cost, performance, and scalability
  - Scalable from 10 to 1,000 MWe cycle configurations



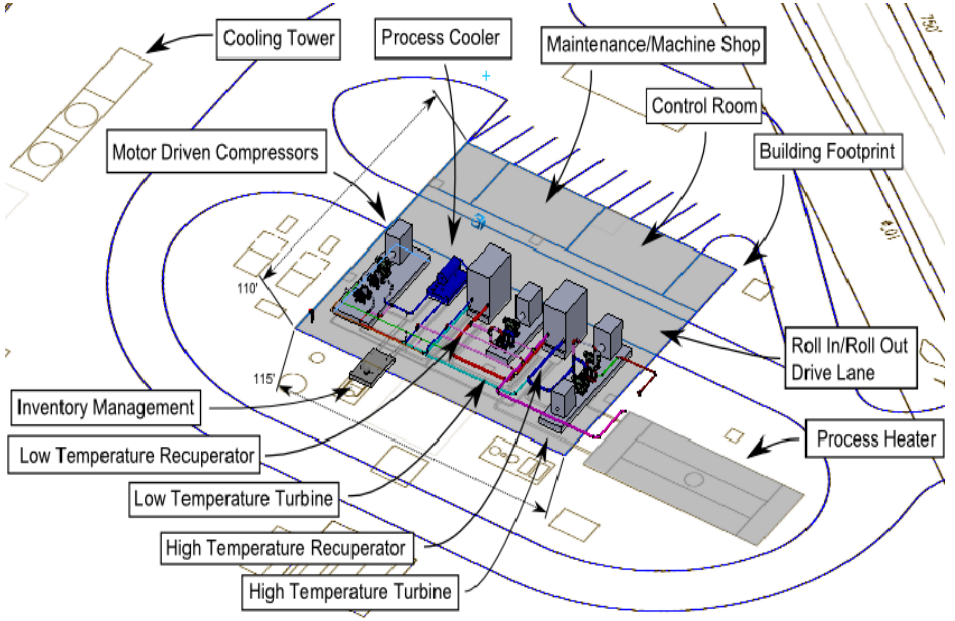






10 MW DOE STEP Pilot Plant Project
Demonstrate Utility-Scale sCO_2 Plant

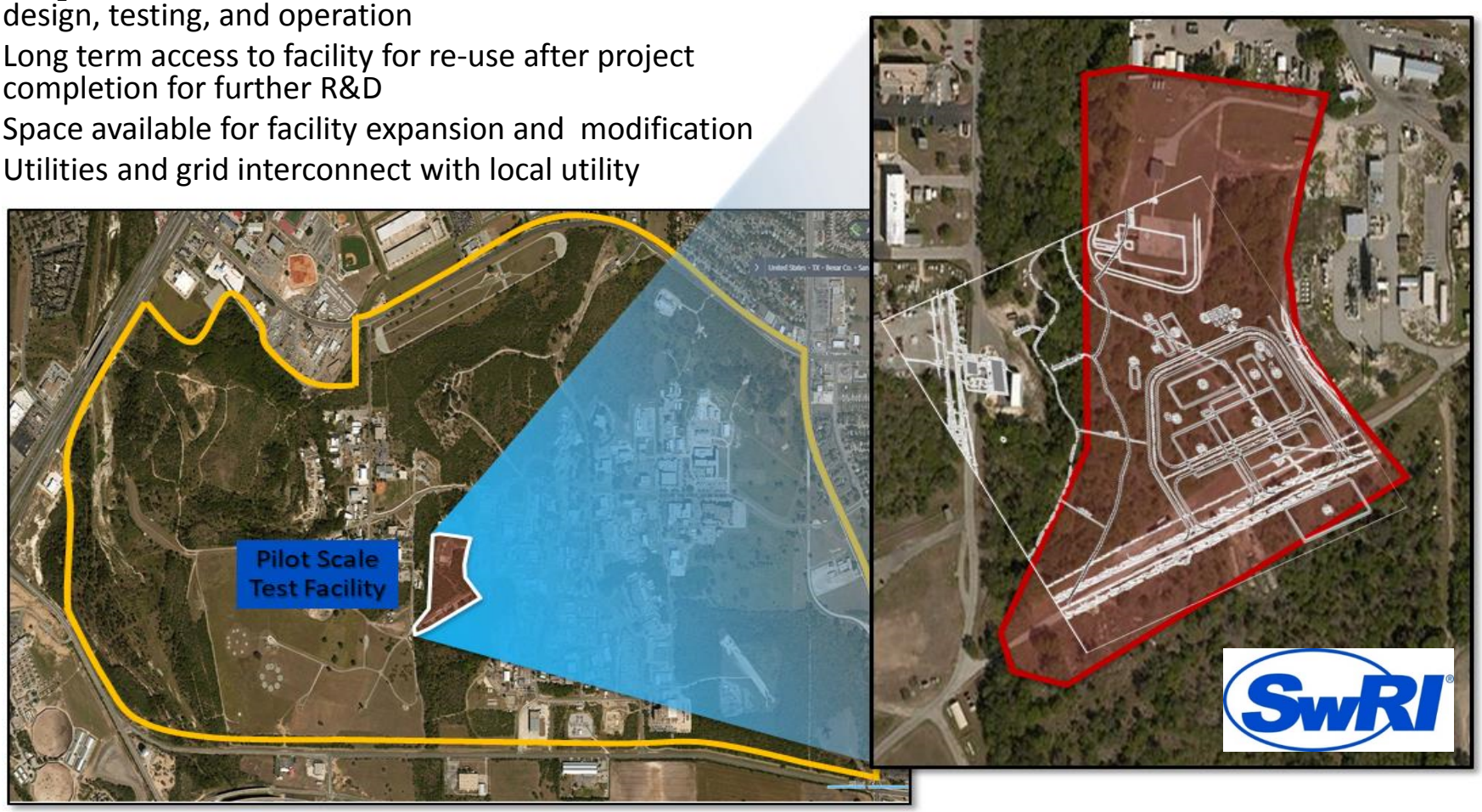
- Pilot and demonstration plant located at SwRI
- Partnering with GE and GTI
- Six year project valued $113 million ($80M DOE, $33M Industry)
- Scheduled to be operational 2020
- Testing both 550C and >700C temperature operation



STEP
A U.S. DEPARTMENT OF ENERGY PROJECT
GTI • SwRI • GE Global

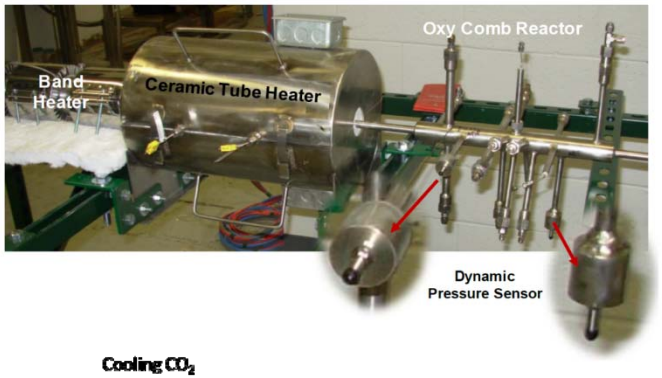
STEP 10 MW Test Facility to Support Long Term sCO_2 Technology Development

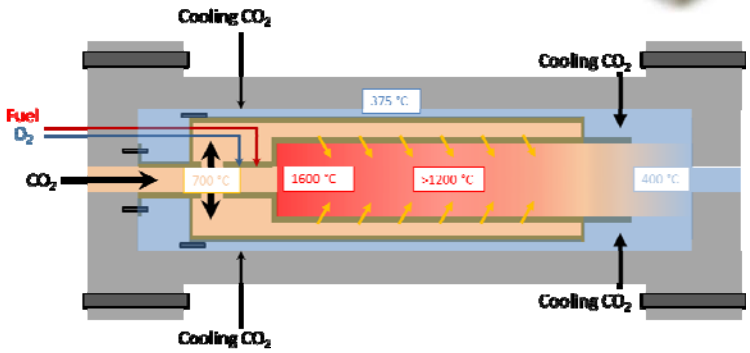
- Open access facility operated by an industry neutral entity
- sCO_2 subject matter experts available on site to support design, testing, and operation
- Long term access to facility for re-use after project completion for further R&D
- Space available for facility expansion and modification
- Utilities and grid interconnect with local utility

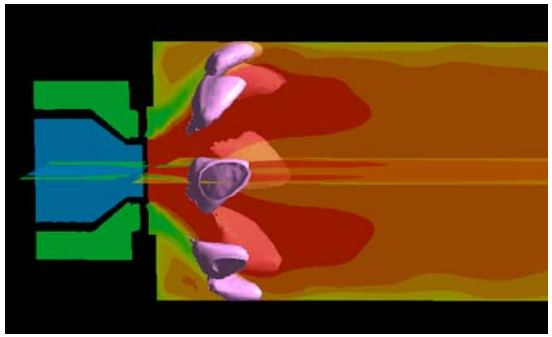


High Inlet Temperature Combustor for Direct Fired Supercritical Oxy-Combustion (SwRI, Thar for DOE NETL)

- Detailed design of supercritical oxy-fuel combustor from initial Phase I design
  - Design of water separation from combustion products
- Fabricated and assemble combustor test loop utilizing existing hardware at SwRI
- Test campaign to understand combustion processes and combustor performance

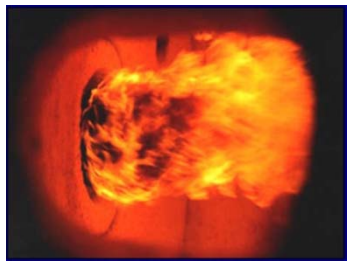




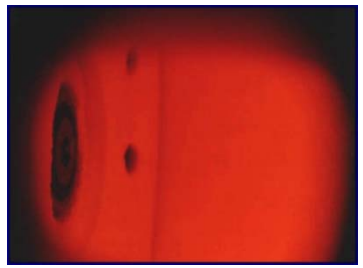


Flameless Pressurized Oxy-Combustion Pilot Plant Planning (SwRI, ITEA for DOE NETL)

- Pressurized atmosphere of water and CO_2 prevents traditional flame fronts
  - FPO combustion is more locally controllable with more uniform temperatures and improved efficiency
- Almost zero carbon content in incombustible products
  - Traditional: flying and falling ash particles must be filtered and collected from gas stream
  - FPO: slag with near-zero carbon content drains out the bottom of the combustor
- Development of a 50 MWth pilot power plant
  - Team from ITEA, EPRI, GE Global Research, and Jacobs
  - Site selection, preliminary drawings and cost estimates for pilot plant
  - Scale up from existing pilot technology
  - Design of a durable turbomachine in atmosphere of CO_2 and water
  - Design of an efficient once-through steam generator

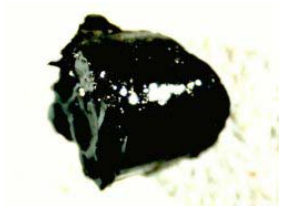


Traditional Combustion with Flame Front



Flameless Pressurized Combustion

Traditional Combustor Products: Particulate



FPO Combustor Products: Near-zero slag