SAND2012-9367P

Exceptional service in the national interest

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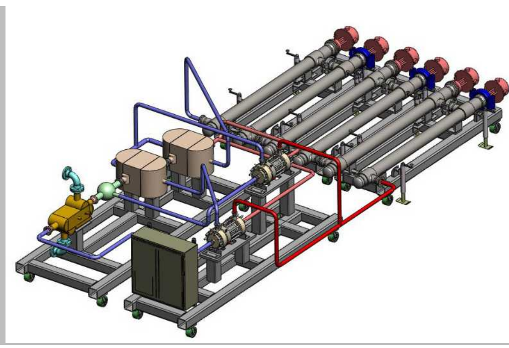
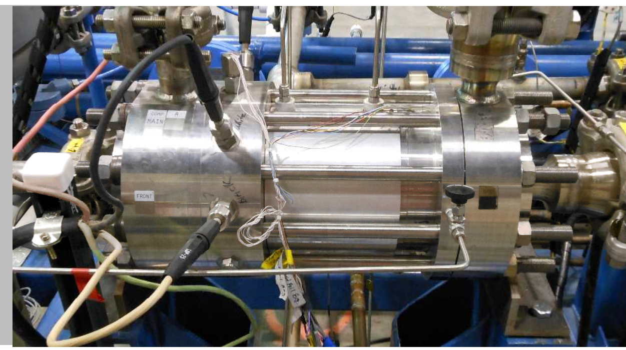
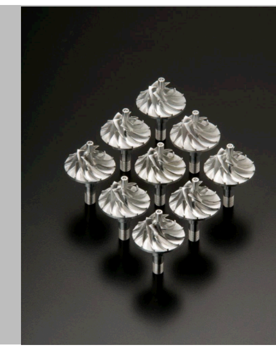

SUPERCRITICAL CO_2 BRAYTON CYCLE PROGRAM DESCRIPTION

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U.S. DEPARTMENT OF ENERGY
NNSA National Nuclear Security Administration

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Advanced Energy Conversion

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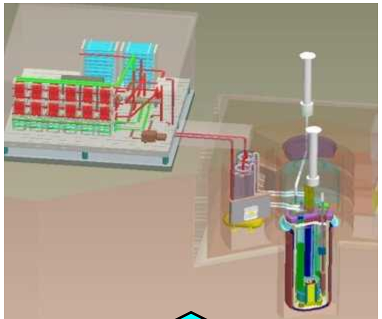
- **Using Supercritical Fluids**
- **Higher Conversion Efficiency**
- **1/10 of the Cost**
- **1/100 of the Plant Volume**



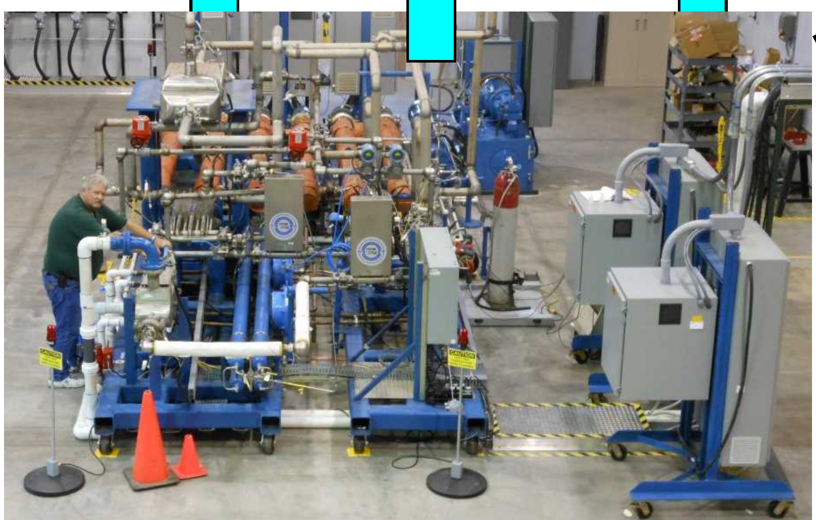
Nuclear

Fossil

Concentrated Solar

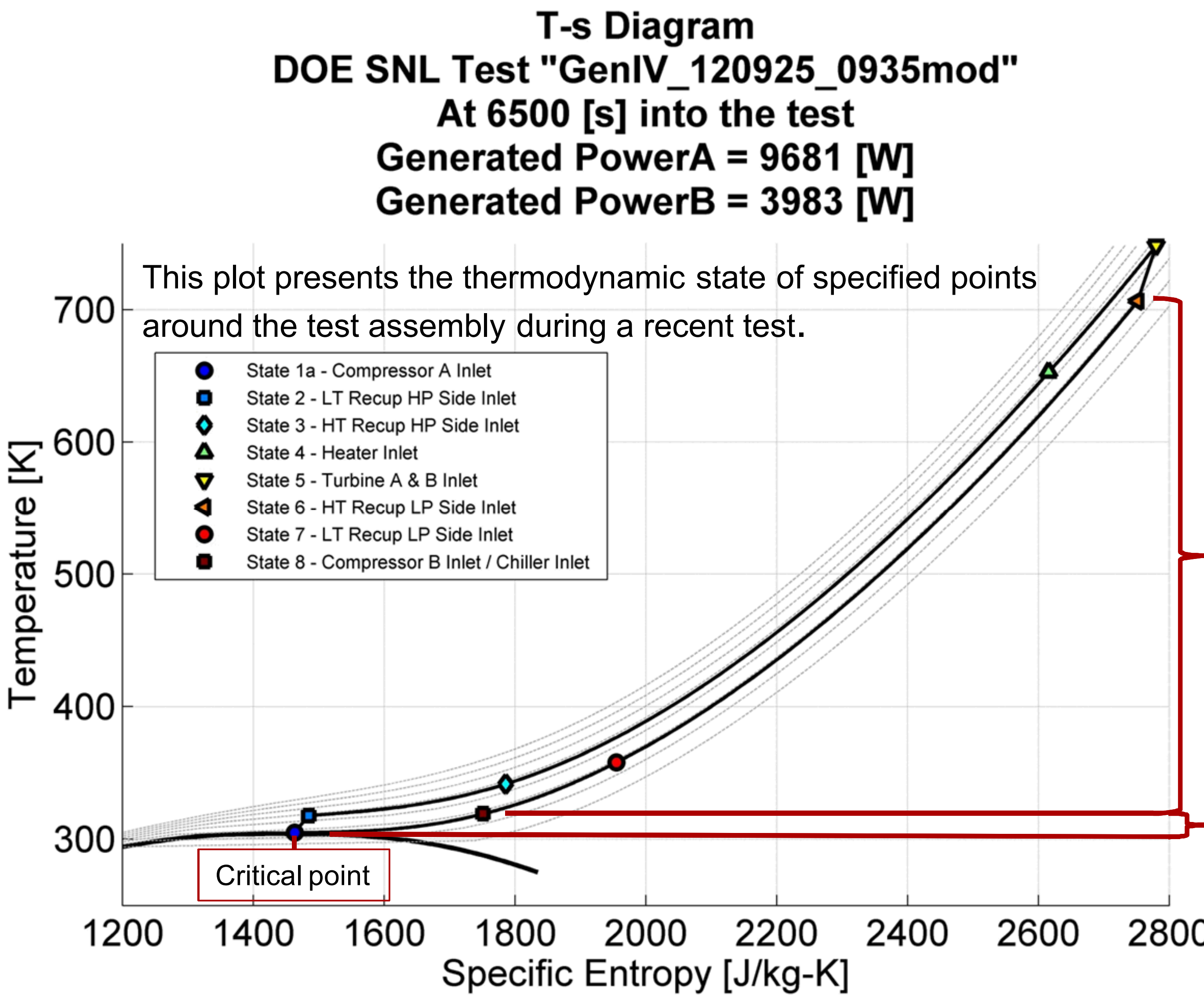
Geothermal

Turbomachinery



Industrial Heat

Primary Advantage over Steam Cycle



This much heat energy that remains in the low pressure SCO2 is transferred into the cold, high pressure flow from the compressors.

This much heat energy is rejected to maintain the operating point.

Supercritical CO_2 Cycle Applicable to Most Thermal Sources

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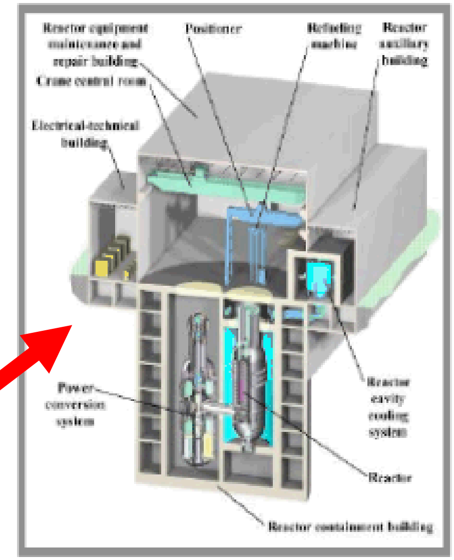
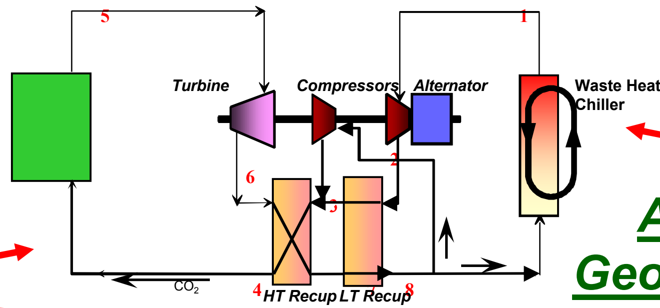
Nuclear
(Gas, Sodium, Water)



Solar

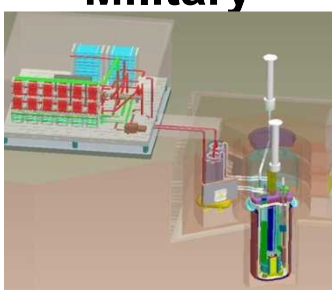
DOE-NE Advanced Reactors

Supercritical CO_2 Brayton Cycle



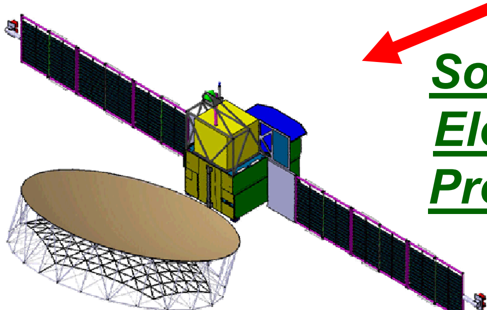
SunShot Power Cycle

Military



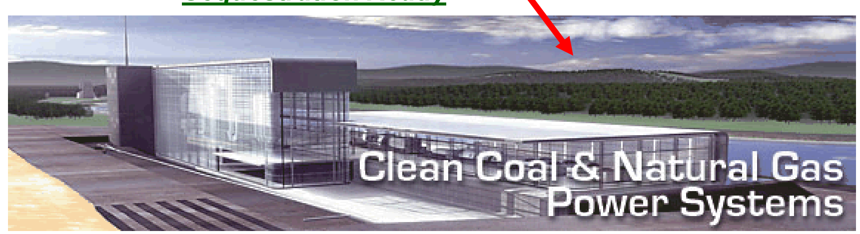
CONUS Marine Mobile?

ARRA Geothermal

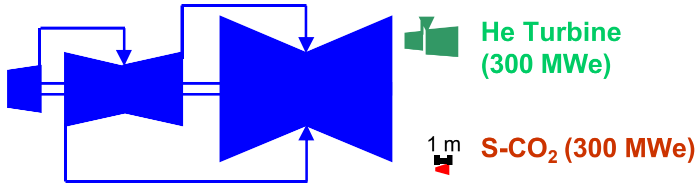


Solar Elec. Prop.

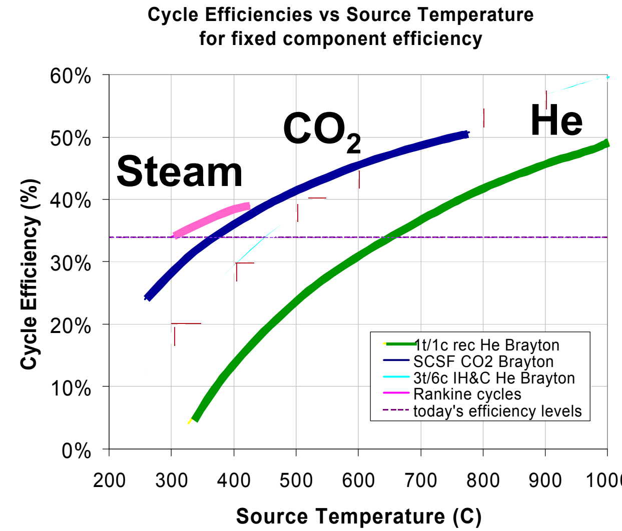
Fossil
Sequestration Ready

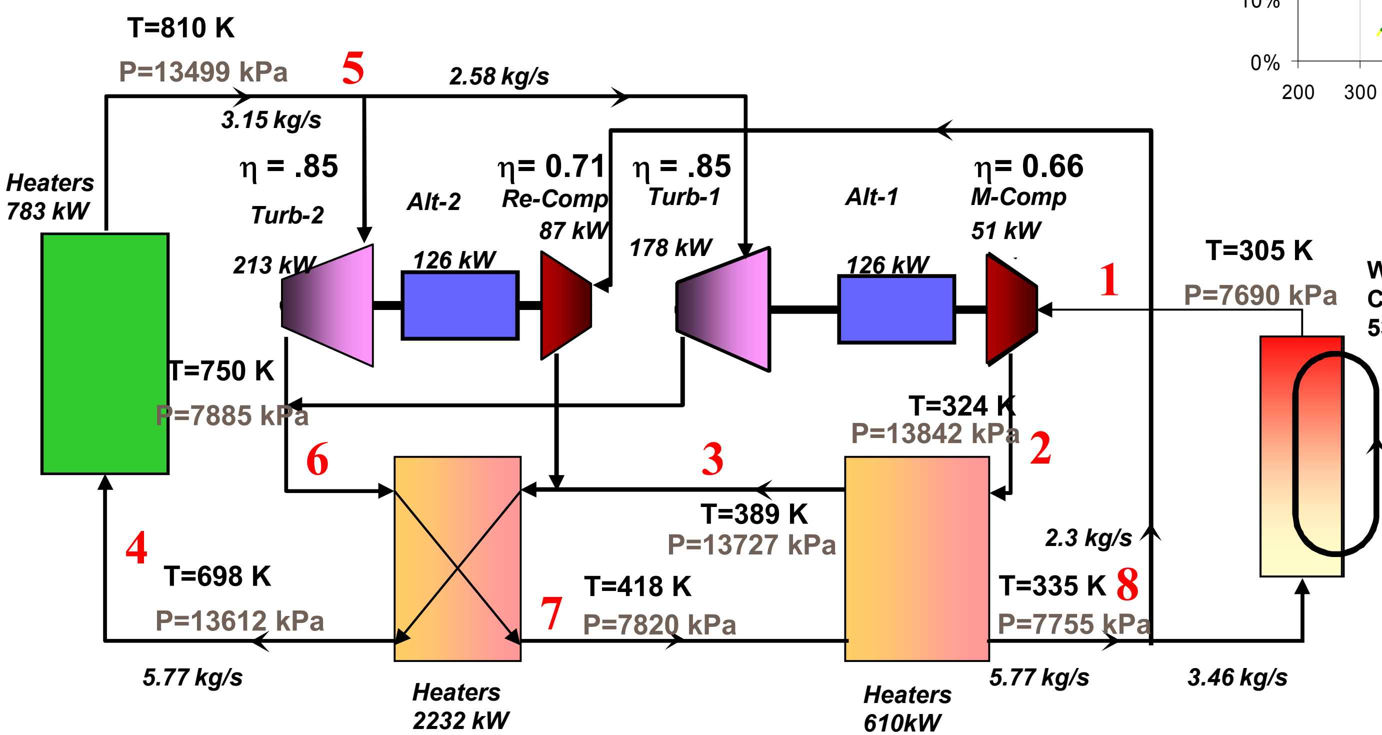


SNL/DOE Design Target for Proof-of-Principle Split-Flow Re-compression S-CO_2 Brayton Cycle



High Density Means Very Small Power Conversion System
Non-Ideal Gas Means Higher Efficiency at Moderate Temperature





High Efficiency at Lower Temp
(Due to Non-Ideal Gas Props)

The Sandia test assembly

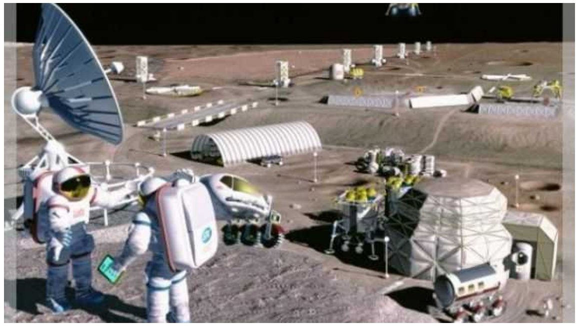
Status of the DOE Program

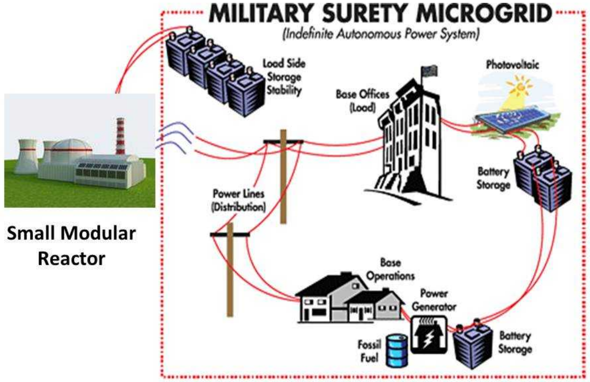
- **Sandia/DOE-NE S-CO_2 Program has Operating S-CO_2 Turbo-Machinery Test Loops**
  - Multiple Operational Loops and Flexible Configurations – Brayton Laboratory
  - These are currently among the leading S-CO_2 power production loops in the world
    - Other Loops are : (Japan TIT, Czech Republic, Echogen)
  - Power Production in multiple loop configurations

- **Multiple "Paying" Customers**
  - DOE-NE, Industry, Solar, Geo Thermal, Fossil
  - Over $13M Invested since 2006 (DOE-NE)
- **Advanced S-CO_2 Options Look Very Promising**
  - Condensing, Advanced Cycles, Natural Circulation, Dry Heat Rejection
- **Current Effort**
  - Demonstrate theoretical efficiency in the 1 MW_{th} Split Flow Loop
  - Demonstrate Fluid Mixtures, Other Supercritical Fluids, Advanced Cycles and Condensing Cycle for Dry Heat Rejection
  - Scale up Demonstration Program to 10 MWe for operation in 2014 with SunShot Program

DOE-NE R&D Goals

- Demonstration of the theoretical gross efficiency of the supercritical CO2 Brayton Cycle in FY13
- Operational characteristics of a same cycle (includes start-up, shut-down, transient response, load following and full operational model) expected mid-FY15
- Demonstration of commercial grade 10-MWe simple S-CO2 Brayton cycle with dry heat rejecti (50% DOE – 50% industry)
- Optimization of 10-MWe S-CO2 Brayton cycle in FY18. (Industry 50%, DOE- NE 10%, DOE-FE 20%, DOE-EERE 20%)
- After FY18 and beyond only industrial support.

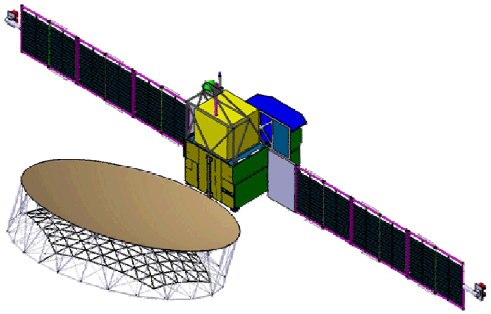


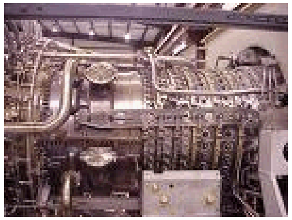


Commercialization Goals

Industry Funded Projects

- Commercialization of 1-5 MWe S-CO2 Brayton Cycle in 2014 (applications: geothermal, solar, waste heat recovery)
- Commercialization of 5-15 MWe S-CO2 Brayton Cycle in 2016 (Power peaking systems)
- Optimized S-CO2 Brayton Cycle systems (cost and life cycle) in 2018 (Smart Secure Grid Systems)
- Commercialization of <300MWe optimized systems for (clean coal, SMRs, advanced power cycles)





SCO2 Advantages with SMRs

- Scalable to match practically any power demands
  - SMRs of different sizes could be coupled
- Adaptable to a wide range of heat sources and source temperatures
  - Application with both LWR-type and novel SMR designs
- Adaptable as a topping or bottoming cycle
- Demonstrated load following capability
  - With proper SMR, could operate by power demand
- Extremely small turbomachinery vs. steam power equipment
  - More easily transported to remote locations
- Benign, cheap, ubiquitous operating fluid
  - Noncorrosive, nonflammable
- Efficiencies remain high with dry cooling
  - Desert applications, etc.
- Extremely low noise levels in all equipment
- Very few moving parts in the high temperature flow sections
- Maximum operating pressures are roughly 20 MPa
  - Supercritical and ultrasupercritical steam plants that operate at 25 – 35 MPa
- Hundreds of thousands of hours experience over decades of operation with this cycle with other fluids (Germany, mid 20th century)
  - Demonstrated high availability