Eurekalert - Sandia National Laboratories researchers are moving into the demonstration phase of a novel gas turbine system for power generation, with the promise that thermal-to-electric conversion efficiency will be increased to as much as 50 percent — an improvement of 50 percent for nuclear power stations.
equipped with steam turbines, or a 40 percent improvement for simple gas turbines.

Research focuses on supercritical carbon dioxide (S-CO₂) Brayton-cycle turbines, which typically would be used for bulk thermal and nuclear generation of electricity, including next-generation power reactors. The goal is eventually to replace steam-driven Rankine cycle turbines, which have lower efficiency, are corrosive at high temperature and occupy 30 times as much space because of the need for very large turbines and condensers to dispose of excess steam. The Brayton cycle could yield 20 megawatts of electricity from a package with a volume as small as four cubic meters.

The Brayton cycle, named after George Brayton, originally functioned by heating air in a confined space and then releasing it in a particular direction. The same principle is used to power jet engines today. "This machine is basically a jet engine running on a hot liquid," said principal investigator Steve Wright of Sandia's Advanced Nuclear Concepts group.

A competing system, also at Sandia and using Brayton cycles with helium as the working fluid, is designed to operate at about 925 degrees C and is expected to produce electrical power at 43 percent to 46 percent efficiency. By contrast, the supercritical CO₂ Brayton cycle provides the same efficiency as helium Brayton systems but at a considerably lower temperature (250-300 C). The S-CO₂ equipment is also more compact than that of the helium cycle, which in turn is more compact than the conventional steam cycle.

Operation and Analysis of a Supercritical CO₂ Brayton Cycle (101 pages)

Schematic of supercritical compression loop using a 50 kWe motor driving a radial compressor at 75,000 rpm with a flow rate of 3.51 kg/s
Schematic drawing of the motor-driven S-CO2 compressor. This configuration uses ball bearings and has no turbine.

Simple diagram of the heated un-recuperated supercritical CO2 Brayton loop.

Photo of the heated, but un-recuperated, Brayton Loop. The foreground shows the heaters, the back ground shows the modified S-CO2 test loop with the...
Build new worlds = Go for Greatness
Centauri Dreams
Center for Responsible Nanotech Blog
Coal is really bad
Diamond semiconductors, MNT could break the improvement economic logjam
Electricity rates are skyrocketing
Foresight nanodot
Future Pundit
Instapundit
Kinematic Self-Replicating Machines book online
lifeboat foundation blog
Melanie Swan Futurememes
Methuselah foundation blog
Molecular nanotechnology search engine
nanoparticle drug delivery
Nanotechnology Now
No nukes means more coal
Nuclear Cannon summary
Nuclear Green - Charles Barton
Quantum computer summary
Singularity Hub
Space and nanotechnology
Synthetic biology, DNA/RNA/Protein/self assembly pathway
Thorium Energy
Thorium, mass produced clean nuclear power
Universe Today

Supercritical carbon dioxide Brayton cycle developments at Sandia

turbomachine configured as a turbo-alternator-compressor.

<table>
<thead>
<tr>
<th>Property</th>
<th>Design Point</th>
<th>Vapor Side</th>
<th>Liquid Side</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1 (K)</td>
<td>305.3</td>
<td>295</td>
<td>295</td>
</tr>
<tr>
<td>P1 (kPa)</td>
<td>7690</td>
<td>5000</td>
<td>7690</td>
</tr>
<tr>
<td>H1 (kJ/kg)</td>
<td>309.362923</td>
<td>436.334737</td>
<td>253.5925441</td>
</tr>
<tr>
<td>T2 (K)</td>
<td>324.6592079</td>
<td>316.888781</td>
<td>306.0326581</td>
</tr>
<tr>
<td>P2 (kPa)</td>
<td>139.64</td>
<td>641.477561</td>
<td>1489.44307</td>
</tr>
<tr>
<td>H2 (kJ/kg)</td>
<td>324.313323</td>
<td>450.861694</td>
<td>267.3396258</td>
</tr>
<tr>
<td>T3 (K) Isenthalpic</td>
<td>306.1756619</td>
<td>303.3268813</td>
<td>298.9849653</td>
</tr>
<tr>
<td>P3 (kPa)</td>
<td>776.90</td>
<td>5050</td>
<td>776.9</td>
</tr>
<tr>
<td>H3 (kJ/kg)</td>
<td>324.31</td>
<td>450.861693</td>
<td>267.3396258</td>
</tr>
<tr>
<td>mdot (kg/s)</td>
<td>3.53</td>
<td>1</td>
<td>3.8</td>
</tr>
<tr>
<td>Chiller power (kW)</td>
<td>52.70430916</td>
<td>14.52696599</td>
<td>52.23891056</td>
</tr>
<tr>
<td>RPM (rev. per min.)</td>
<td>75000</td>
<td>7500</td>
<td>7500</td>
</tr>
<tr>
<td>mdotEq (kg/s)</td>
<td>3.5447401</td>
<td>3.785997516</td>
<td>4.31996661</td>
</tr>
<tr>
<td>Pressure Ratio</td>
<td>1.18145031</td>
<td>1.292296512</td>
<td>1.93738183</td>
</tr>
<tr>
<td>dH.Ideal (kJ/kg)</td>
<td>9.91106497</td>
<td>9.643668505</td>
<td>8.754601852</td>
</tr>
<tr>
<td>Efficiency</td>
<td>0.66381019</td>
<td>0.663846444</td>
<td>0.636833477</td>
</tr>
</tbody>
</table>

Expected operating conditions of the S-CO2 compression test loop at the design point and on the liquid and vapor sides of the dome.

Wikipedia on the Brayton cycle

The proposed design of a 300 MWe nuclear plant with a supercritical CO2 brayton cycle system (24 pages from 2004)
FURTHER READING

Coverage from 2009 on supercritical CO2 recompression cycle

MIT CANES - Supercritical CO2 Brayton Cycle for Medium Power Applications (2007)

This final report summarizes the results of the study of a supercritical CO2 (SCO2) power cycle for medium power application. The objective of these investigations is to establish a 5 – 30MWe power conversion system for an indirect cycle that (1) achieves high net efficiency in conversion from thermal to electrical energy, (2) is compact with minimum volume and weight, (3) is robust, resilient to accidents and has high long term reliability and performance, and (4) exhibits good controllability and fast response to requested power changes.

Supercritical CO2 Power Cycle Resource Center is a single location for researchers, industry partners, and end users working in the field to find technical papers and information.

Advanced Supercritical Carbon Dioxide Power Cycle Configurations for Use in Concentrating Solar Power Systems

Supercritical CO2 (S-CO2) operated in a closed-loop recompression Brayton cycle offers the potential of equivalent or higher cycle efficiency versus supercritical or superheated steam cycles at temperatures relevant for CSP applications. The S-CO2 pressure is higher than superheated steam but lower than supercritical steam at temperatures of interest. The high pressure required for S-CO2 make application to trough fields difficult and the fluid may be better suited for use in Power Towers. Even circulating high pressure S-CO2 through a large Power Tower would be challenge due to the volume and pressure of fluid being moved. However, a modular power tower design can take advantage of S-CO2’s potential without prohibitive piping costs. In the proposed design a single-phase process using S-CO2 as both heat transfer fluid (HTF) and thermal cycle fluid simplifies the power block machinery and is compatible with

sensible-heat thermal energy storage, if desired. The simpler machinery and compact size of the S-CO₂ process may also reduce the installation, maintenance and operation cost of the system. Brayton-cycle systems using S-CO₂ have smaller weight and volume, lower thermal mass, and less complex power blocks versus Rankine cycles due to the higher density of the fluid and simpler cycle design.

Study of Supercritical Carbon Dioxide Power Cycle for Low Grade Heat Conversion

This paper conducts a comprehensive study on the feasibility of a CO₂-based supercritical power cycle for low-grade heat conversion. Energy and exergy analysis of the cycle were conducted to discuss the obstacles as well as the potentials of using supercritical carbon dioxide as the working. As a working fluid for supercritical Rankine cycle, carbon dioxide has desirable qualities such as low critical temperature, stability, little environmental impact and low cost. However, the low critical temperature might be a disadvantage for the condensation process. Comparison between a carbon dioxide-based supercritical Rankine cycle and an organic fluid-based supercritical Rankine cycle showed that the former needs higher pressure to achieve the same efficiency and a heat recovery system is necessary to desuperheat the turbine exhaust and pre-heat the pressure charged liquid. Important thermophysical property of carbon dioxide, such as its critical point, thermal conductivity, and stability were also discussed. Regarding the thermal efficiency, some organic fluids can outperform carbon dioxide.

If you liked this article, please give it a quick review on ycombinator or StumbleUpon. Thanks

Add New Comment

Showing 7 comments

Sort by Popular now  Subscribe by email  Subscribe by RSS
More efficiency is nice to have, but would it be worth the complication in an MSR which should already be very economic? Perhaps using any surplus thermal heat from small MSRs to provide CHP would be a better way to go.

i suppose you could add a relief valve in the salt system so it can be drained and stored i.e. Even if the CO2 were to rupture and flood the salt loop you could open this valve and the salt would be forced into a holding tank. If CO2 is mixed it can be filtered out right. Once whatever broke is fixed pump the salt back in.

This is really interesting; I just worry that applying this to Gen-IV MSR might push us back to needing high-pressure environments: the first article linked calls for temps above 500°C and pressures above 7.6 MPa (75 atm).

I guess the issue is lessened for PWRs, since they need high pressure anyway (although I don't know if they need that much pressure).

Yeah, you can't have super-critical CO2 without having enough pressure to reach the critical part of CO2s phase diagram. But the containment vessel needed to contain the CO2 in case of catastrophic system failure would still be a lot smaller (and hence a lot cheaper) than the one for a steam system. and only the turbine subsystem would need to be pressurized. You still wouldn't need the containment vessel to contain radioactive material, just shrapnel and blast from a turbine failure.

Of course, the safety regs don't take MSR characteristics into account, they just require a containment building, period.
This should have no impact on a MSR. The salt loop transfers heat to another loop (e.g. CO2) but the two don't mix for obvious reasons. The salt can be at atmospheric pressure and the second loop which is not open can be at high pressure. Heat goes from the hot salt through the metal in the pipe salt loop pipe into the CO2.

Either way this is a pretty amazing development. Way to go engineers!

What if there is a leak in the CO2 pipe where it passes through the fuel salt? That would pressurize the fuel salt loop. Or is there a non-fuel salt loop in between the fuel loop and the CO2 (gas) loop?

I don't know the exact details of how a future MSR will build its heat exchanger but there are several simple options for dealing with this:

1. Add another salt loop, design it to fail gracefully if for some reason CO2 gets in.
2. Trust the work we do with creating steel tubing that is durable. Keep in mind that we build whole steel reactor assemblies (reactor, heat exchanger tubing) that can deal with these stresses.
3-n. Consult a mechanical engineer/nuclear engineer for ideas three through n (inclusive).
Thin Coating of nanowires will boost thermoelectric...

Carnival of Nuclear Energy 41

Poverty Statistics and estimates and definitions

Infinera achieves One Terabit per Second Data Rate...

China Godson Chip Roadmap and 15 other technology...

Update on Taiwan and China relations and Asia free...

Living without Cable or Satellite Television

► 02/20 - 02/27 (55)
► 02/13 - 02/20 (57)
► 02/06 - 02/13 (50)
► 01/30 - 02/06 (79)
► 01/23 - 01/30 (73)
► 01/16 - 01/23 (65)
► 01/09 - 01/16 (70)
► 01/02 - 01/09 (57)

► 2010 (2289)
► 2009 (1346)
► 2008 (857)
► 2007 (954)
► 2006 (824)
► 2005 (59)
► 1999 (2)
Nextbigfuture is the Lifeboat Foundation Technology Research News Website. The Lifeboat Foundation is a nonprofit nongovernmental organization dedicated to encouraging scientific advancements while helping humanity survive existential risks and possible misuse of increasingly powerful technologies, including genetic engineering, nanotechnology, and robotics/AI, as we move towards a technological singularity. Technology is an important factor in solving and creating many of the Lifeboat relevant issues.

The site is part of the Lifeboat Foundation Research Department

Editor/Authors are:
Brian Wang, Director of Research.
Sander Olson, Interviews and other articles
Phil Wolff, Communications and social technologist.
Alvin Wang. Computer, technology, social networking, and social media expert.

Contact: brian dot wang at lifeboat.com
biomarkers (46) cameras (46) colonization (46) wealth (45) adiabatic quantum computer (43) performance enhancement (41) air pollution (39) myostatin inhibitors (34) faster than Moore's Law (31) atomically precise manufacturing (29) blacklight power (23) winterberg (20) zettaflop (17)