

Compact Torus-Shaped Organic Rankine Cycle

An Innovative Power Generation System
from Air Squared, Inc.

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Air Squared, Inc. is developing a Compact Torus-Shaped Organic Rankine Cycle (Pat. Pend.) for micro-scale power generation on-site. An Organic Rankine Cycle (ORC) uses organic fluids with a high molecular mass and low boiling point to extract power from low-temperature energy sources. Supported by Small Business Innovation Research (SBIR) funding through the Nation Science Foundation (NSF), the waste-heat to energy device could be used to convert low-grade heat sources - or conventional fuels like natural gas - into usable electric energy.

Current Distributed Energy Generation Landscape

Natural gas and reciprocating engines are common distributed energy technologies - low fuel cost and widespread availability has encouraged adoption globally. However, reliance on nonrenewable resources make both unviable long-term.

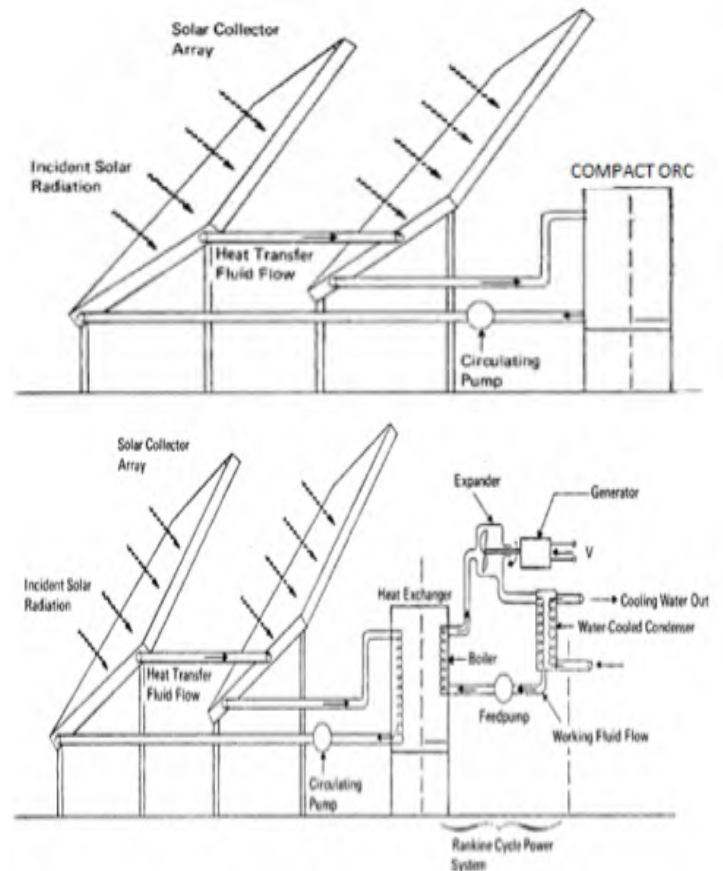
Additionally, concerns over the environmental impact of fossil fuels has made gasoline engines increasing unpopular, with many areas moving to discouraged implantation or ban continued use altogether.

Along with concerns over climate change, strong support for energy security has made solar PV a favored option among renewable distributed

energy technology. Although braced by the global community, PV remains expensive at \$4,000 per kW, finding it hard to compete with diesel and natural gas at less than \$1,000 per kW. Power generation is also intermittent - generally half the day.

Traditional ORCs also offer an opportunity to transition from conventional fuels to renewable energy, but face similar challenges to solar PV. Commercially available systems are constructed in an elementary manner, with each component existing independently, making installation not only costly, but impractical for most locations.

Solar Thermal Electricity Generation with and without Compact Torus-Shaped ORC

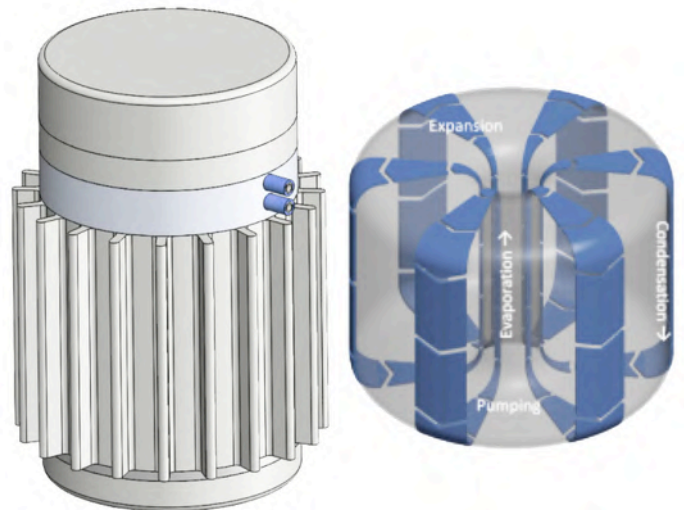


A Distributed Energy Generation Innovation

At roughly the size of a home air conditioner, the Compact Torus-Shaped ORC can use natural gas as a heat source when gas prices are low, then switch to alternative sources when gas prices are high. The novel design integrates all components in a closed cylindrical container, where the working fluid flows about a torus in a poloidal direction, significantly reducing system size and complexity - and in-turn cost. At \$3,000 per kW and a payback period between three to four years, residential and commercial markets finally have a distributed energy technology that is sustainable, flexible, and affordable.

The Compact Torus-Shaped ORC is similar to a traditional steam cycle. It utilizes an organic fluid, with a secondary fluid in the evaporation process, while ambient air or ground source cooling act as the condenser. The unit has a vertical stacked arrangement, with the high-pressure side in the center and top, and the low-pressure side on the outside and bottom.

Having completed custom scroll developments for several ORC projects over a wide range of conditions and working fluids, the Compact Torus-Shaped ORC leverages Air Squared's significant scroll design experience. By using scroll components to run the pump, expander, and generator off a common shaft, the compact arrangement is made possible, while also providing increased efficiency, low vibration and noise, valve free mechanism, and oil-free or oil lubricated operation.



Compact Torus-Shaped ORC with Refrigerant Flow

As a Distributed Energy Generation Technology, the Compact Torus-Shaped ORC Can Be Used in Several Ways

- **Combined Heat and Power**
Lowers energy costs and improves system reliability.
- **Peak Shaving**
Lowers peak-period energy costs.
- **Standby Power**
Mitigates economic losses due to grid outage and satisfies critical needs.
- **Stand-Alone**
Provides energy production in areas not connected to the grid.

Moving Forward to Phase II

For over twenty years Air Squared has supported clean energy initiatives by providing oil-free scroll solutions for use in PEM and SOFC fuel cell, diesel engine emission recovery, natural gas production, and waste heat recovery. With Phase I SBIR funding through the NSF for development of the Compact Torus-Shaped ORC in 2014, Air Squared remains dedicated to alternative energy solutions.

The Phase I SBIR includes development and testing of the heat exchangers. The heat exchangers are the most critical component of the project, as they take up the most area in an ORC, offering the biggest opportunity to improve the

device's footprint. Initially, an external pump and a needle valve will be used for testing instead of the scroll pump and scroll expander respectively.

A SBIR Phase II through the NSF program will ensure Compact Torus-Shaped ORC development continues. The Phase II award will see further realization of the device, with incorporation of the scroll expander and pump, as well as simulated testing for several conditions. Potential customers and technology partners can assist Air Squared's Phase II SBIR efforts by offering a Letter of Support. Please contact info@airsquared.com for details.

About Air Squared

Air Squared, Inc. is the industry leader in oil-free scroll design and manufacturing. By introducing a simple design with fewer moving parts, scroll technology has established itself as a highly efficient, very reliable, cost-effective alternative. Through a growing line of compressor, vacuum pumps, and expanders, Air Squared makes the many advantages of oil-free scroll technology available to OEMs worldwide. Learn more scroll technology innovations from Air Squared at <http://airsquared.com>.



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