PEREGRINE
TURBINE TECHNOLOGIES

INTRODUCING THE WORLD'S MOST EFFICIENT POWER CONVERSION HEAT ENGINE

WHITE PAPER

sCO_2 Energy Conversion

STEP Improvement Enabling Efficient Utilization of Micro Reactors

AUTHOR

By R.N. Brooks

Chief Development Officer / Co-Founder, Peregrine Turbine Technologies, LLC.

TOPIC

Breakthrough sCO_2 Energy Conversion Technology to provide step efficiency improvement and key performance advantages not available before now.

SUMMARY OVERVIEW

The development and evolution of a new family of safe, highly efficient, very small nuclear reactors (VSMRs) and micro modular nuclear reactors (MMRs) has progressed substantially over the past decade and is now a very high "energy surety" priority for the US DoD as well as for industrial decarbonization in energy intense applications such as data centers and steel, cement, glass, and other industrial processes.

Peregrine Turbine Technologies has identified significant potential and opportunity for its breakthrough energy conversion technologies in the accelerating VSMR and MMR programs (350 Kw – 10 MW), and a clear intermediate term opportunity in the 30 MW to 100 MW small modular reactor (SMR) range. The Company believes these

applications are where 70% plus of the value and volume opportunities are/will be through 2040.

The MMR and VSMR developers must clear two hurdles to be successful:

1. The first is to develop and gain approvals for their reactor designs including establishing demonstrator units at Idaho National Lab (IDNL) asap. The leading companies have been acknowledged, funded, and are rapidly moving down this track.
2. The second is for their reactors to become financially viable and competitive. The single largest STEP function opportunity to optimize their reactor designs and performance is, by an order of magnitude, the conversion of heat to electricity.

Historically, steam conversion has been the primary technology used with nuclear reactors albeit with low efficiencies, requiring water sources, and other significant operational issues.

- Peregrine Turbine Technologies holds the world's most efficient power conversion heat engine, "the cycle" … the breakthrough technical answer to efficient utilization of microreactors, and small modular nuclear reactors.
    - The PTT system is 1.5X the conversion efficiency of steam with MANY other "mission critical" advantages i.e. dry cooling, black start, size, maintenance.
    - The PTT system is 3X+ the conversion efficiency of modified Air Brayton Cycle gas turbine technologies and again with MANY other "mission critical" advantages
    - PTT sCO_2 conversion system has it DNA roots in Sandia National Laboratories' sCO_2 conversion development program as "the conversion technology" for the coming Advanced Nuclear Reactor deployments.

PTT FIRST MOVER OPPORTUNITY – SCO2 CONVERSION:

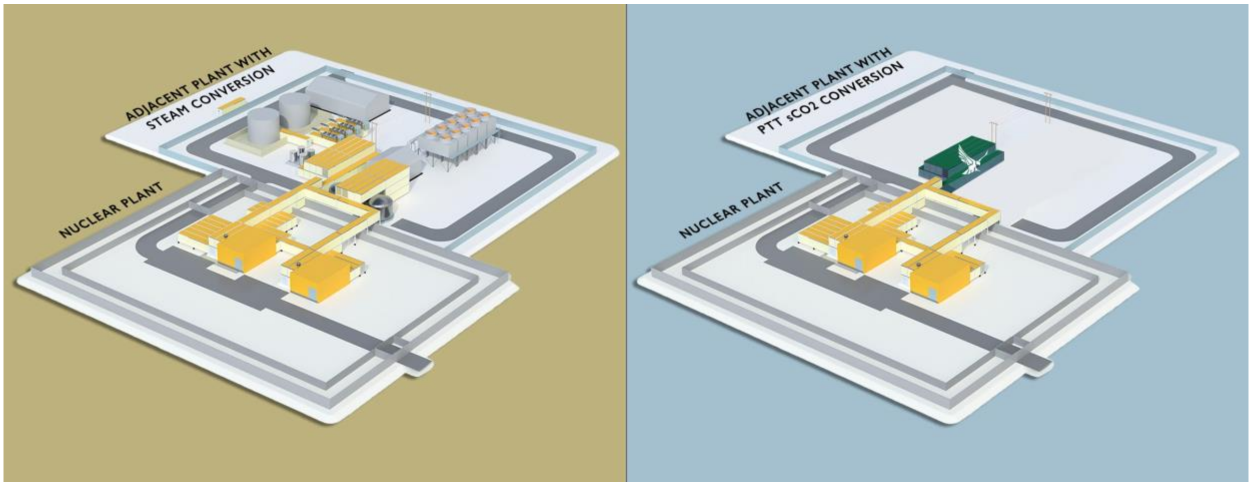
For the past several years, PTT has been working to understand the technology nuances and issues, the players, and the market opportunities, etc. in the rapidly emerging VSMR, MMR and SMR markets. The Company believes its assessments are well founded and is connected to, and working with, multiple lead players. They each have identified the need for sCO_2 conversion and are in early discussions with PTT's team on development options. PTT, SNL and others believe that there are no other sCO_2 conversion options comparable to its systems within the foreseeable 5 to 7 years. The Company has established a nuclear energy systems subsidiary, PTT Nuclear

Energy Systems (PTT NES) with focused resources to continue to advance working relationships, co-development collaboration, and programs with the highest potential players.

TECHNOLOGY

Peregrine's sCO_2 (super critical carbon dioxide) turbine systems are a safe and efficient means of converting nuclear energy into electrical power. The high energy density of sCO_2 systems is 30X greater that equivalent steam plants, are 30% - 50% more efficient, are air cooled (no water cooling required), require no high-level licensed operators, have significantly fewer wear parts, and are specifically designed for ease of field maintainability.

The Company believes that its sCO_2 system addresses the current challenge for Adjacent Plant heat to power generation involving large, complex, and inefficient steam turbines requiring significant water sources, extensive infrastructure and maintenance, licensed operator support and high costs.



The breakthrough power conversion efficiency of PTT's heat engine provides a step increase in reactor electric power output, with a thermal to electric conversion efficiency of 30-33% for steam system compared to 45% for a Peregrine Heat Engine. This increase in conversion efficiency effectively uprates reactor output, and significantly lowers $/MWe.

This breakthrough efficiency was not by accident, but rather by design and significant investment in iterative engineering product design work. Given the necessity to provide integration of power conversion and heat transfer attributes into reactor design, we and the leading developers, feel early integration of “the cycle” into such efforts is prudent and necessary for flexible and rapid fielding. Hence, the formation of PTT NES is in anticipation of collaborative efforts for the first “balance of plant” building block upon which microreactor output will be oriented.

The genesis of the work at Sandia’s Brayton Lab for sCO_2 power conversion was intended for advanced nuclear applications. PTT’s sCO_2 technologies have both benefited from and advanced that endeavor.

BACKGROUND

PTT is a Maine limited liability company formed in April 2012 focused on the development and deployment of advanced sCO_2 turbine power generation, energy storage and propulsion systems. Additional company information can be found at www.peregrineturbine.com. PTT has developed proprietary, sCO_2 enabled, energy conversion systems (thermal and electrical) capable of producing power at or near the point of use, operating on local/regional fuels and heat sources, with minimal transmission and distribution infrastructure and associated line losses inherent in central or remote generating plants.

The Company has received awards from the Air Force Research Lab (AFRL), the Office of Naval Research (ONR), and the Maine Technology Institute (MTI) in support of its leading development of Brayton cycle sCO_2 gas turbine development for energy conversion. The Company has developed strong collaborations and working relationships with key suppliers that supplement the Company’s own resources. Key supplier relationships include turbomachinery component fabrication, diffusion bonding, chemical etching, power electronics and permanent magnet generator design and manufacturing. PTT also holds a long-term CRADA with Sandia National Laboratories (SNL) for support in the development, testing, and de-risking of its sCO_2 turbomachinery and has put over 500 hours of runtime on its Gen I sCO_2 turbopump.

PTT’s senior leadership team collectively has over 250 years of successful, demonstrated management of complex technologies, systems, products and operations with companies and organizations ranging from GE, Rolls Royce, Pratt and Whitney, Sundstrand, and Solar Turbines to Allied Signal, General Signal, Great Northern Paper Company, American Capital, The Department of Energy, The Naval Nuclear Propulsion Program, Naval Reactors and Sandia National Lab. The Company is built on the principles of fact-based decision making and collective best thinking, providing it with a strong capacity and experience base to lead this emerging technology from concept to market penetration.

PTT has raised more than $32M, mostly from private individuals and family offices. Our corporate headquarters are located at 29 South Point Drive, Wiscasset, ME. Our test facilities are located at the Wiscasset airport at 96 Chewonki Neck Rd, Wiscasset, ME. Our future manufacturing operations are planned for a large recently reconditioned facility located at 125 North Main Street, Pittsfield Maine. PTT intends to remain a Maine based, Maine operated, Maine and USA centric company.

After 10 years of R&D and product development, the Company is in the final stages of commercial component and system level Proof-of-Concept testing (TRL-6) and is working to field commercial scale demonstrators. We anticipate a defendable transition to a TRL-7 product upon completion of this test program and the fielding of two demonstration plants in 2024-2025 which will finalize our commercial entry (TRL 8/9) into the power conversion market.

Peregrine's transformational energy conversion technology is enabled by the unique properties of supercritical carbon dioxide (sCO_2), its patented and unique Brayton thermal cycle (the only high efficiency Brayton Cycle for air-combustible fuels), and its advanced heat exchanger designs. The Company's Intellectual Property (IP) includes eight domestic patents with multiple complementary foreign patents, extensive performance and design data and operational experience. The Company and energy experts also believe that PTT is 5 to 7 years ahead of other sCO_2 commercialization efforts and the only one working on distributed energy (DE) level products and commercialization.

The PTT power conversion cycle uses supercritical carbon dioxide as a working fluid where the CO_2 is maintained above its critical point through the cycle. sCO_2 has groundbreaking attributes as a working fluid – not least of which is its benign nature – with flow characteristics close to the critical point that, combined with its favorable density and heat transfer properties, allow for electric power conversion efficiencies approaching 50%, far exceeding the traditional Rankine cycle steam efficiencies in the low 30% range.

PTT's system has many advantages over incumbent steam and ORC technologies including the ability for remote operation without costly on site, licensed operators. It has 30X the power density of the

	NUCLEAR POWERED CONVERSION CYCLE		
Parameter	PTT sCO_2	Conventional Steam	Air Brayton Cycle (Air/NG)
Specific Power: Design achieves high specific power	✓	⊖	⊖
Efficiency: High efficiency at low TIT	✓	⊖	⊖
Dry Cooling: Closed cycle system	✓	⊗	✓
Packaging: Small footprint	✓	⊗	✓
Number of Parts: Small and simple in construction	✓	⊗	⊗
Maintainability: Modular- packaged as field replaceable cartridge	✓	⊗	⊗
Reliability: High reliability & fewer parts	✓	⊖	⊗
Maturity: TRL	⊖	✓	✓

Assumptions:
Reactor Collant He • Intermediate HX to transfer heat to the conversion cycle • Gas turbine inlet is near ambient pressure

current best available steam conversion technology, equating to less complexity, lower costs, and a smaller footprint.

As a closed loop Brayton cycle, it also permits the management of compressor inlet conditions, which is of great importance when designing power conversion systems because it offers the ability to accommodate cycle changes to fit the process conditions without changing the critical rotating equipment. This unique capability is significant as it allows the cycle to be optimized for the application. Further, because it is a closed loop cycle, the cycle pressure ratio can also be controlled to optimize efficiency for the power demand, and only clean gas circulates within the turbomachinery.

For additional and larger scale applications, the power block of the system is modular, can be ganged in 1MWe increments, and can be deployed in up to 5MWe MultiPaks. PTT's design specifically concentrated on this modular construction and frame size. This modularity is enabled by the power density and small size of the turbomachinery and compact heat exchangers, not through any sacrifices in efficiency or specific costs of the power block unit. The Company has established an Advanced Concepts group tasked with beginning the work to field a 10 MWe system.

Peregrine believes it's proposed demonstration projects will enable multiple use cases for our heat-source agnostic technologies and the central role they will play in making power systems more efficient. In particular, that its' sCO_2 systems will bring efficient, clean energy solutions for industries with remote and/or unreliable grids, for public and corporate power-purchase applications, for military mission surety, and for other ancillary support for system stability needs. Further, a clear case for the core task of capacity provisioning, optimizing transmission and distribution algorithms in bulk power systems and energy shifting is already evident.

The Company has combined and demonstrated its breakthrough sCO_2 technology with a newly developed thermal storage medium, miscibility gap alloy (MGA), which uses phase change technology to store significant energy as heat at high round trip efficiencies, and in a safe and easy manner without capacity degradation.

The Company believes the projected improvements in efficiency and emissions, fast ramp (turn up/down) capability, combined heat/power/cooling applications, application specific configurability, and reduced maintenance and repair costs resulting from the application of its proven breakthrough sCO_2 technology are about to change the nature of, and equitable access to, power generation, energy storage, and propulsion.

Specifically, it anticipates deployment of its' sCO_2 MGA LDES (Long Duration Energy Storage) will significantly improve unsubsidized levelized cost of storage (LCOS) in 1 – 20 MW/10+ MWhr behind the meter applications including such attributes and services as

arbitrage applications, load following, wind and solar curtailment optimization, capacity and reserve applications, and peak shaving. In addition, PTT believes the flexible and configurable power block and thermal energy storage systems will enable value stacking of services to allow a level of service optimization in newly developing capacity and storage markets for grid services.

The Company's data from current testing of our Gen II design has validated a number of our technological innovations first envisioned during our Gen I turbomachinery testing at SNL's Brayton Lab, where we have worked collaboratively under a CRADA for nearly a decade. We have integrated commercial grade high quality PLCs for the control systems and have a robust integrated test system underway to complete specific milestones that build on step-by-step testing and refinement, data collection, validation of performance characteristics and equipment, culminating in systems integration. PTT has significantly de-risked our technology at both the component and system level with the goal of strengthening our move to first-of-kind siting and commercial demonstrators.

Among the recent successes of our Proof-of-Concept test program was the world's first start and run of a sCO_2 Brayton Cycle Turbine powered from phase change thermal energy storage. This included the successful "Black Start" of the Peregrine Gen II 5.5:1 pressure ratio Turbopump, the key component in Peregrines patented modular, high efficiency, high power density, energy conversion cycle. This also demonstrated the successful operation of our Gen II PTT sCO_2 Turbopump. (PTT's Gen I turbopump has over 500 hours of operation and testing at Sandia National Laboratories. Our Gen II turbopump has improved and proprietary nozzle and wheel configurations.) This testing also resulted in a demonstrated successful quick-stop (2 seconds) shutdown of sCO2 system. (Prior shutdown testing at SNL was 1 minute 50 seconds.) Our integrated engineering and design team is obtaining significant run-time data for early-stage control and data collection systems, all in support of our Structured Proof of Concept (POC) Milestone Testing Regimen at our Wiscasset Maine testing facility prior to demonstrator build-out.

PTT believes our power cycle provides the exact utility needed for microreactor systems designed for the future grid, and the transition to get there – to include utilization of our thermal energy storage system to absorb and manage fluctuations in reactor power production/electric demand. It offers a way of integrating and providing flexibility to the entire energy system, comprising power, heat, and other forms of energy.

Further, as generating capacity shifts to greater distributed energy utilization – as high as 30-50% in ten years by some estimations - , PTT systems hold high technical application to serve as the microgrid building block of the future grid. FERC Order 2222 set the foundation for distributed energy resources and micro-grids. As this future unfolds, PTT believes the unique ability of these smaller grid systems to aggregate distributed energy resources at the control level and integrate with centralized control system, lends itself to a system architecture based on a PTT/Thermal Energy Storage system coupled to a microreactor as the central node of a microgrid. Such a configuration would increase resiliency, support decarbonization, enhance equity and decrease costs.

Given our partnership/CRADA with SNL and internal testing, PTT believes that we have already retired significant technical risk and are well down the de-risking curve necessary to successfully demonstrate commercial viability. Our leadership and engineering team hails from professional high-end industrial and commercial engineering concerns and has integrated cost drivers and supply chain management efficiencies early into the design. As decarbonization of the power sector and variable renewable energy continues to be deployed at larger penetrations, PTT is convinced our technology will track the broader LDES deployment market closely with efficiency cost reductions and scaling. Our technology is intended for that purpose, with no foreign dependencies, critical mineral, or rare earth components.

We further assign great value to developing applications for microreactors in conjunction with our thermal energy storage system directly coupled to our heat engine. We believe this opens use cases for decay heat removal, load following, emergency electrical generation and reactor transient “dampening.” We are interested in, and are, pursuing development work with designers and labs to evaluate methods for advancing reactor dynamics, and safety applications, though thermodynamic coupling to a heat sink which effectively serves as a direct conversion source for electricity at a high efficiency.

We have identified that our technology holds significant cost reduction potential and that further enhancements will only serve to increase the efficiencies we are already seeing as we continue with Gen III and Gen IV design improvements.

We currently are under NDA or in conversations with multiple reactor developers, across a range of reactor designs, sizes, fuels, and coolants. These developers have expressed interest in utilizing our technology across the many market opportunities in which microreactors have applications. These include: mobile applications (our systems are designed for standard road movement modularity), military installations, combined heat and power systems, support to energy intensive industries such as mining, hydrogen and ammonia production, remote markets with high energy costs, value added manufacturing, such as refining and to fill gaps and supplement areas of high renewable energy penetration, and grid end points. Further, we are in discussion with the world's largest operator of data centers.

Refined in the SNL Brayton Lab, we believe our proprietary technology and products are five to seven years ahead of the closest competitor and are uniquely positioned to meet the platforms for advances in microreactor utilization. Both opportunities and barriers for microreactors are evident in the path ahead. We firmly believe our DNA as "the cycle" of choice in the early development stages of the advanced reactor movement will enhance opportunities and help eliminate these barriers, provide a step opportunity and advantage to make microreactor's cost and performance competitive.