High Power Density Turbine Based Generation Systems

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Candent Company Background
About Candent Technologies: A lean, experienced, and expert team of technical, program management, and business development personnel.

Each member has 20 or more years experience in the design, development, qualification/certification, management, production and support of all types of gas turbines, but particularly small and low cost turbine engine systems, having been involved in the design and/or development of more than a dozen successful engines.

Sampling of Candent Team’s Engine Experience

- **Allison Model 150**
  - Low Cost - High Performance Turbojet designed and on test in 22 weeks

- **Model 250**

- **T800**

- **Under Armor APU**
  - for the M1A2 Tank

- **T56/501**

- **Low Cost Expendable Engines for Missiles and UAV’s**

- **GP7200**

- **T406/AE1107/2100**

*Strong background and knowledge base including small engines*
About Candent Technologies

• **Who we are:** A lean, highly experienced, and expert gas turbine engine team, based in Mt Comfort, Indiana

• **What we are doing:** Presently developing high efficiency, low cost, small gas turbine engines, for military and civil power generation and propulsion systems
  – Simple Brayton Cycle systems from 350 kW to 2,250 kW in size
  – Specific fuel consumption 20-35% better than state of the art small turbine engines (<1,000 kW size) and competitive with similar size diesels
  – Microturbine systems, recuperated and simple cycle, from 10 kW up to 350 kW

• **Current DOE Projects:** Phase II SBIR program, started September 2011, to design and test critical components for an advanced technology, high efficiency, low cost gas turbine powered genset
  – Simple cycle system with a Rankine “Bottoming Cycle” steam system to recover exhaust waste energy
  – Turbine shaft direct drive, high speed generators
  – Capable of producing 1,500 kW
  – High thermal efficiency goal set at 50%

• **Current DOD Projects:** Navy (NSWC-CD) Phase I SBIR program to define a main gas turbine exhaust waste heat recovery system, started March 2011

**Using available and proven technology – no inventions required**
**Candent Technologies Technical Capability**

**Gas Turbine Performance, PD, Detail Design and CAD Modeling Capability**

**Aerodynamic Design and CFD Analysis**

**Static and Dynamic Structural Analysis**

**Secondary Flow and Heat Transfer**

**High Speed Shaft Dynamics**

**Sea Level Test Cell Facility**

**State of the art system and component design and analysis capabilities**
High Power Density: The Gas Turbine Solution
Increased Deployment of Modern Warfare Systems Will Require More Power Generation Capability

• The sophistication of current and future weapon systems will continue to increase the requirements for electrical power
  – Individual Warfighter size
  – Tactical force size/land vehicle/tactical naval craft mounted
  – Base size/large vehicle/naval vessel
• While modern systems are more efficient, they are more numerous
• Logistics support for power generation systems is also increasing
  – Fuel Stocks Inventories
  – Transportation
  – Maintenance
• Power generation design continuously driven to
  – Higher Power density
  – Improved Mobility
  – Higher Efficiency
  – Higher Reliability
  – Improved Maintainability
  – Lower Cost

More high power density generation needed by deployed units
Turbines Provide Very High Power Density Efficiently and at Cost Effective Rates

• Gas turbine specific power is much higher than similarly power rated reciprocating engines
  – Lighter overall system weight by an order of magnitude
  – Smaller volume by factor of at least 4 to 5 vs. piston engine genset
• Candent advanced technology gas turbine has fuel efficiency comparable to diesels of same power
• High speed generators at turbine output shaft speed eliminate need for heavy gearboxes, minimize system complexity
• Multi-fuel capability of gas turbines easily allows great flexibility in use of available fuels, i.e. diesel, jet, kerosene, bio fuel, natural gas, propane, methane, etc.
• Gas turbine MTBO much longer than piston engine gensets, typically in excess of 20,000 hr
• Gas turbine has lower life cycle cost than comparable piston engine
  – Significantly less scheduled and unscheduled maintenance
  – Longer MTBO
  – Similar acquisition cost as diesels

Advanced Technology Gas Turbines Offer Viable Solution
Gas Turbine Power to Weight Advantage

Power vs Weight: Power Generation Module

Candent Turbine C214PMG, 2,500 lb

Diesel Gensets
Gas Turbine Large Mobile Power Genset
Candent Advanced Technology Impact

- Larger gensets, 350kW-2.0MW would also greatly benefit from Candent’s advanced technology gas turbines
  - High pressure ratio provides higher efficiency
  - Fuel burn comparable to similar power rated diesels
  - Inherently more reliable
  - High power density minimizes weight and size, provides highly enhanced mobility
  - Longer MTBO than diesels, by at least 100%
  - Lower Scheduled and Unscheduled maintenance

- Candent is developing more efficient gas turbine under DoE sponsorship
  - Engine core testing scheduled for 1Q12
  - System thermal efficiency goal is 50%

- Larger gas turbines use state of the art technology hot section airfoil and cooling designs, achieve competitive fuel burn

_Candent’s advanced technology enables genset high power density with competitive fuel consumption and system costs_
Candent Comparison versus Current Technology

Candent simple cycle engines have fuel consumption consistent with heavier recuperated engines

Data for graph from Sahm & Rosfjord UTRC Presentation to Second DOE/UN, International Conference and Workshop on Hybrid Power Systems, 17 April 2002

Higher Pressure Ratio Provides “Big Engine” Performance
Large (900kW) Mobile Power Genset Application

- Current Power Genset: MEP-PU-810A
  - Power 840 kW
  - Weight - 25,600 lbs
  - Length - 21.1 ft
  - Thermal Efficiency ~ 33%
  - C-130 Transportable

- Candent Turbine Power System
  - Power 900 kW
  - Weight - 2,500 lbs (est.)
  - Length - 12 ft
  - Thermal Efficiency ~ 33%
  - Competitive first cost, lower LCC
  - Transportable in C-27, C-130, V-22, UH-47

Smaller, lighter, more easily transported system with same fuel consumption as diesel MEP- PU-810A
Microturbine Based Tactical Genset
Microturbine Genset Solutions

- The standard military 30kW genset is the MEP 805/815
  - Diesel Powered
  - 30kW, 110 VAC, 60 Hz, 3 Phase
  - 88 cu ft
  - 3,000 lb
  - The MEP 815 is the 400 Hz version

- Candent has designed a microturbine genset to the requirements of the MEP805/815
  - Utilizes turbine hardware previously designed and tested under Army contract to Candent
  - Adds recuperator system to enhance efficiency
  - Uses high speed (turbine output shaft rpm) generator
  - Under 200 lbs (minus fuel tank) and 9 cu ft
  - Small and light enough to install in HMMWV, or MRAP
  - Small enough to install in tactical and SOC riverine or naval craft, 21 ft and up, including new vehicles such as CCM and USSV

*Current systems are effective but are NOT high power density designs*
20-40 kW Marine/Land Generator Specifications

Candent Technologies design is a microturbine based, 20-40 kW Advanced Marine/Land Generator system:

Generator Specifications

- **Power Rating:** 20-40 kW (50 kW de-rated to 40 kW)
- **AC Power:** 20-40 kW, 110/208 VAC, 3 Phase, 60 Hz
- **DC Power:** Optional 10 kW, 24 VDC, with 10-30 kW AC
- **Speed:** 75,000 rpm
- **Shock Loads:** 25g (40g peak)
- **Materials:** Capable of surviving marine environment

**Other:**
The generator will also be used during the start mode for engine starting using a 24V battery.

*A high speed generator means lower weight and volume*
Microturbine Genset Components

Microturbines with recuperator and high speed generator provide highly efficient power in a very small package.
High Power Density 20-40 kW Microturbine Genset

20-40 kW Genset

- Est. Weight: < 200 lb
- Est. Volume: < 9 cu ft
- Fuel Consumption: 1.5-2.8 gal/hr
- Multi Fuel Capable

Acoustic Enclosure Not Shown

Estimated Dimensions

Compact and reliable power generation system
Fuel Consumption Same as Similar Size Diesel

- Flat SFC curve down to 30% power
  - Allows system to be oversized and have greater capability for minimal weight penalty
  - SFC and GPH are about the same as similar sized diesel
  - Power off-load capability of up to 40 kw even on a hot day

![Graphs showing HP vs SFC and Fuel Consumption GPH vs KW Output]
Microturbine Genset Advantages

• Smaller, lighter more mobile power
  – At least 80% lighter than conventional diesel system
  – Smaller logistics transportation footprint
  – Transportable in more aircraft types, including smaller rotorcraft

• Rugged design
  – Capable of being used in high shock environment, i.e. off the road, or in high speed boats, or shocks due to explosive detonations in water or land

• High reliability and low maintenance
  – No oil change interval, top up as required
  – Long life, over 40,000 hrs.
  – Minimal on location maintenance
    • Air filter cleaning when prompted by system

• Fuel consumption on par with diesels of similar size
  – No increase in fuel logistics tail required for fuel stocks

High power density in a smaller, more mobile package
Summary and Conclusions
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• **Increased deployment of modern warfare systems will require more power generation capability in the field to support the Warfighter**
  – Candent’s advanced turbine technology provides viable solutions
    • Lighter, smaller, highly mobile systems
    • Multi-fuel capable systems provide high flexibility
    • Cost effective and competitive

• **Technology is applicable to microturbine sizes from 20kW to 350kW, and in larger sizes up to 2.25MW**

• **Physical size enables installation in:**
  – Small land vehicles such as the HMMWV or the MRAP
  – Small boats such as the 11m RIB / CCM, SOC-R, USV, or Mark V / CCH types, or similar sizes
  – Large naval vessels

• **Candent gas turbine technology is cost effective and competitive**
  – Acquisition costs competitive with similar power diesel systems
  – Turbine system Life Cycle Cost is lower due to longer TBO’s and substantially lower scheduled and unscheduled maintenance costs
  – Turbine system substantially enhances maintainability, supportability and readiness

**Gas turbine based gensets offer viable, highly reliable, highly mobile, cost effective high power density solutions**
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