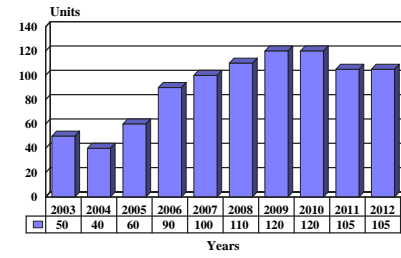


Pratt & Whitney Power Systems/ Turbo Genset Microturbines - Archived 6/2004

Outlook

- Deregulation of the US power utility market has opened wide-ranging opportunities for small power-output machines
- First order for ST5 was for 100 machines for delivery in one year
- At 450 kW, this machine should not feel threatened by the more standard microturbines whose power is 100 kW or less

10 Year Unit Production Forecast
2003 - 2012



Orientation

Description. The ST5 is a single-shaft, free-turbine Microturbine developing about 450 kW (base rating) in simple-cycle duty.

Note: We are treating the PWPS ST5 machine as a microturbine since we believe that it functions more as a microturbine than as a more traditional small gas turbine machine for electrical generation.

Sponsor. The ST5 was privately developed by the prime manufacturer.

The ST5-equipped DTE Energy Technologies generator set is designated ENT 400 (see below).

Power Class. The approximate power output of the ST5 is just above 450 kW (base rating) in simple-cycle duty (see below for output performance parameters).

Status. In production. The first 400 kW generator system was completed and delivered in March 2001. The basic ST5 machine became available in early 2002.

Total Produced. At the start of 2004, at least 85 ST5 machines are estimated to have been fabricated.

Application. Electrical generation, most notably for distributed generation.

Price Range. Estimated in 2004 calendar year US dollars at \$270,000-\$300,000, or about \$600-\$650 per kW, for early production units. The price is expected to drop as high production volume is attained.

Competition. The ST5, at about 450 kW, competes mainly with such mainstream gas turbine machines as the Daihatsu DT-4. At slightly higher ratings are the Kawasaki Heavy Industries S2A-01 and the Vericor ASE8 gas turbine machines.

Contractors

Pratt & Whitney Power Systems, UTC PWPS, [http:// www.pratt-whitney.com](http://www.pratt-whitney.com), 1165 Northchase Parkway, Suite 300, Marietta, GA 30067 United States, Tel: 1 (770) 859-1999, Fax: 1 (770) 859-9099, Prime

Technical Data

Design Features. Among the design features of the UTC PWPS ST5 are the following:

Intake. Radial air intake.

Compressor. Single-stage centrifugal compressor.

Combustor. Single-can low-emissions combustor. A gas fuel nozzle is currently used; a liquid fuel nozzle will follow.

Turbine. A single compressor turbine and a single power turbine, each being a single-stage axial type, mechanically unconnected.

Governor/Power Electronics. The governor/power electronics system for the ENT 400 is being supplied by Turbo Genset Company Ltd of the UK.

Standard Equipment. Additional standard equipment includes exhaust gas temperature thermocouples, a

Dimensions. Approximate dimensions and weights of the PWPS ST5 for electrical generation are as follows (where listed, first data are for the machine in simple-cycle duty; second data are for the machine in recuperated duty):

APPLICATION = ELECTRICAL GENERATION

	<u>Metric Units</u>	<u>English Units</u>
Length	1,099 mm / 1,359 mm	43.267 inches / 53.5 inches
Width	597 mm	23.5 inches
Height	1,537 mm / 2,255 mm	60.51 inches / 88.8 inches
Weight, dry	800 kg / ,800 kg	800 pounds / 1,800 pounds

starter drive, and a compressor-rotor speed probe. Woodward is integrating a fuel system that includes a patented metering valve and control system for accurate flow control.

Optional Equipment. Recuperator, fuel system, engine fuel control, and ignition exciter.

Approximate dimensions and weights of the ST5-equipped ENT 400 Mini-Turbine Generator are as follows:

APPLICATION = ENT 400 MINI TURBINE

	<u>Metric Units</u>	<u>English Units</u>
Length	381 cm	150 inches
Width	218 cm	86 inches
Height	247 cm	97.6 inches
Weight, unrecuperated	3.856 metric tons (3,856 kg)	8,500 pounds
Weight, recuperated	4.309 metric tons (4,309 kg)	9,500 pounds

Performance. Approximate performance parameters of the PWPS ST5 for electrical generation include the following:

APPLICATION = ELECTRICAL GENERATION

	<u>Simple-Cycle Base Rating</u>		<u>Recuperated Base Rating</u>	
	<u>Metric Units</u>	<u>English Units</u>	<u>Metric Units</u>	<u>English Units</u>
Power Output	457 kW	613 shp	395 kW	530 shp
Efficiency	23.5%	23.5%	32.7%	32.7%
Heat Rate	15,245 kJ/kWh	14,449 Btu/kWh	11,000 kJ/kWh	10,425 Btu/kWh
Mass Flow	2.3 kg/sec	5.07 lb/sec	2.22 kg/sec	4.89 lb/sec
	<u>Simple-Cycle Peak Rating</u>		<u>Recuperated Peak Rating</u>	
	<u>Metric Units</u>	<u>English Units</u>	<u>Metric Units</u>	<u>English Units</u>
Power Output	563 kW	755 shp	492 kW	660 shp
Efficiency	24.6%	24.6%	34.4%	34.4%
Heat Rate	15,245 kJ/kWh	14,449 Btu/kWh	11,000 kJ/kWh	10,425 Btu/kWh
Mass Flow	2.46 kg/sec	5.4 lb/sec	2.37 kg/sec	5.2 lb/sec

The ST5-equipped ENT 400 Mini-Turbine Generator has the following performance parameters:

ENT 400 ELECTRICAL GENERATION

	<u>Unrecuperated Simple-Cycle</u>	<u>Recuperated</u>
Rated Electrical Output		
@ -1.1°C	397 kWe	397 kWe
@ 15°C	343 kWe	340 kWe
@ 35°C	270 kWe	267 kWe
Heat Rate (LHV)		
@ -1.1°C	11,439 Btu/kW-hr	16,619 Btu/kW-hr
@ 15°C	12,009 Btu/kW-hr	17,760 Btu/kW-hr
@ 35°C	13,158 Btu/kW-hr	19,769 Btu/kW-hr
Efficiency		
@ -1.1°C	29.8%	20.5%
@ 15°C	28.4%	19.2%
@ 35°C	25.9%	17.3%
Exhaust Data for CHP: Flow Rate/Temperature		
@ -1.1°C	8,662 kg/h/328°C	8,662 kg/h/545°C
@ 15°C	8,009 kg/h/345°C	7,845 kg/h/568°C
@ 35°C	7,191 kg/h /363°C	7,191 kg/h/584°C

Other parameters applying to all ST5-equipped ENT 400s

Output Voltage	480/227 volts, 3 Phase, 50/60 Hz
Emissions (at ISO)	
NOx	less than 9 ppmv (0.21 g/kWh)
CO	less than 20 ppmv (0.47 g/kWh)
SOx	less than 1 ppmv (0.02 g/kWh)

Variants/Upgrades

At the start of 2004, no variants or upgrades of the ST5 were reported to be in development. It should be noted, however, that PWPS has announced that the ST5

“engine family” would be offered at power levels from 250 kW up to 600 kW.

Program Review

General. The prime manufacturer is United Technologies Corporation, UTC Power, Pratt & Whitney Power Systems (PWPS), Windsor, Connecticut, USA. The ST5 manufacturer was previously known as Pratt & Whitney Canada (P&WC).

PWPS’s marketing and sales offices are located in Marietta, Georgia, USA. The ST5 machine is produced in Longueuil, Quebec, Canada.

The following firms are or have been affiliated with PWPS on the ST5 and ENT 400 programs:

- DTE Energy Technologies Incorporated; Farmington Hills, Michigan, USA.

- Ebara Corporation, Turbine Business Development Department; Tokyo, Japan.
- Turbo Genset Company Limited; West Drayton, Middlesex, UK.

Background. The PWPS ST5 is a small gas turbine, referred to by PWPS as a “miniturbine,” developing about 450 kW. It has a power shaft speed of 30,000 rpm and a pressure ratio of about 8.0:1. The machine has a gas path design based on other gas turbine turboshaft engines. The high efficiency of the ST5 simple-cycle version is significantly enhanced by the addition of an optional recuperator.

The machine is being offered for simple-cycle duty and recuperated duty for peaking and baseload applications; the simple-cycle units are expected to be mostly used as standby peakers since they need to be able to start quickly, while the recuperated units are expected to be the choice for baseload applications.

Affiliated Firms. The following firms are working with PWPS on its ST5 or with DTE on its ENT 400:

DTE Energy Technologies. PWPS established a cooperative agreement with DTE Energy Technologies, a firm that has developed a complete distributed generation package based on the ST5.

The DTE turbine-based package is known as the ENT 400 (or ENT 400 Mini-Turbine Generating Set). The unit has a noise level of less than 65 dBA @ 35 feet (10 m), a normal starting time of 420 seconds to full load (cold engine), a voltage regulation adjustment of ± 5 percent, a frequency stability of ± 0.1 percent, and a maintenance TBO of 32,000 hours.

The ENT 400 is part of the “T” series mini-turbine product family from energy|now™ – the comprehensive portfolio of best-of-breed distributed generation products and services from DTE Energy Technologies.

The project team for the ENT 400 is led by DTE, and includes PWPS and Turbo Genset Company Ltd (see

the dimensions and performance parameters of the ENT 400 above).

In November 2000, PWPS announced that it would supply DTE with 100 ST5 gas turbines for the ENT 400. Those machines were delivered over a 12-month period that started in early 2002.

DTE Energy Technologies is a diversified high-technology company that offers a broad range of products and services intended to solve the energy-related challenges of commercial, residential and industrial customers. DTE’s major operating subsidiary is Detroit Edison, a company that supplies power to over two million customers in Michigan.

Turbo Genset Company limited. This UK firm has a strong commercial partnership with DTE Energy Technologies. It has a long-term agreement to supply 400 kW alternators and associated power electronics.

Ebara Corporation. Ebara in Japan acts as a packager of the ST5 under the designation PW-4E. The firm handles PWPS machines through the FT8 at 25.5 MW (single-unit rating). The agreement with the Japanese company is assumed to have territorial bounds for the ST5-equipped package.

Funding

No Canadian or US government funding specifically pertaining to the PWPS ST5 gas turbine machine has been identified.

Recent Contracts

Note that no major identifiable Canadian or US government military contracts specifically pertaining to the PWPS ST5 gas turbine machine have been awarded or received in the recent past.

<u>Contractor</u>	<u>Award (\$ millions)</u>	<u>Date/Description</u>
DTE Energy	N/A	Nov 2000 – 100 ST5 machines for delivery in 2002 and 2003.

Timetable

<u>Month</u>	<u>Year</u>	<u>Major Development</u>
Dec	1999	PWPS announces launch of ST5 engine family
Mar	2000	MoU to develop ENT 400 released
Nov	2000	Woodward announces that it will supply ENT 400’s fuel system PWPS announces that it will supply 100 ST5s to DTE
Mar	2001	Turbo Genset announces delivery of its 400-kW generator system
Early	2002	PWPS begins shipping ST5s to DTE
Thru	2012	Continued production of PWPS ST5 machine; ongoing search for additional applications

Worldwide Distribution

At the start of 2003, at least 85 ST5 machines are estimated to have been fabricated. The vast majority of those units are in **Canada** and the **US**.

Forecast Rationale

The UTC Power PWPS ST5 engine is a new move for PWPS into the distributed generation (DG) arena. Its 450 kW machine is being offered for both simple-cycle duty and recuperated duty for peaking and baseload applications. With its older ST6 series machines, PWPS is no stranger to the arena of low-power-output gas turbine machines.

Sales of the small turbine for both roles should benefit from PWPS's prominent position in the field of high-performance small gas turbine machines, as well as from the very large base of Pratt & Whitney aero engines and larger PWPS industrial machines.

The DG arena is set to grow markedly in the next decade. At this point in time, we are projecting that

total production of PWPS's ST5 will grow from about 40-50 units in 2003-2004 to about 120 units in 2009 and 2010. In the decade extending through the year 2012, we project that PWPS will build 900 ST5s. The ST5's first official home is in the DTE Energy ENT 400 Mini-Turbine Generator package.

At 450 kW, this machine should not feel the sales and marketing pressure of the more standard microturbines, machines whose power outputs are 100 kW or less. Indeed, in the microturbine arena, the ST5 does not compete against the likes of the Capstone 30 kW and 60 kW machines.

Ten-Year Outlook

ESTIMATED CALENDAR YEAR PRODUCTION

Engine/Machine	Application	thru 2002	High Confidence Level			Good Confidence Level			Speculative			Total 2003-2012	
			2003	2004	2005	2006	2007	2008	2009	2010	2011		2012
UTC PWPS ST5	GENERATION	85	50	40	60	90	100	110	120	120	105	105	900