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PW Power Systems ST6

Outlook

- Production has apparently ceased
- ST6 was not included in most recent company literature
- Primary application was marine propulsion

Orientation

Description. The ST6 machine is a simple-cycle, twin-shaft, axial-centrifugal-flow, aeroderivative I&M gas turbine engine.

Sponsor. The UTC Pratt & Whitney Power Systems (now PW Power Systems) ST6 gas turbine series was privately developed by the prime contractor.

Power Class. The power output of the current machines in the PWPS ST6 gas turbine series (single-unit configurations) is as follows:

Application Area	Power Output
Generation	679-848 kW
Mechanical Drive	910-1,137 hp
Marine Propulsion	810-984 hp

Status. Production appears to have ceased.

Total Produced. At the start of 2015, more than 780 PWPS ST6 industrial gas turbines had been produced and installed, including machines in Japan.

Application. PWPS ST6 series machines have primarily been used for marine propulsion as well as for several novel installations.

Price Range. The ST6, at about 850 kW for electrical generation, ranges in price from $775,000 to $800,000 (2015 U.S. dollars). At about 1,140 bhp for mechanical load drive, the ST6 ranges in price from $650,000 to $725,000. The price of a marine unit is estimated at $615,000.

For mechanical drive, the price covers a gas-fired gas turbine (without driven equipment) with gearbox, skid, enclosure, inlet and exhaust ducts and exhaust silencer; basic turbine controls; fire protection; starting systems; and a conventional combustion system.

With reference to combined-cycle plants, prices cover a basic gas-fired combined-cycle plant having a gas turbine (usually a DLN-equipped machine), an unfired multi-pressure HRSG without bypass stack, a multi-pressure condensing steam turbine, an electric generator, a step-up transformer, water-cooled heat rejection equipment, standard controls, a starting system, and plant auxiliaries.

Competition. The ST6 has no direct competition.

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Contractors

Prime

PW Power Systems, a subsidiary of MHI	http://www.pwps.com, 628 Hebron Ave, Ste 400, Glastonbury, CT 06033 United States, Tel: + 1 (860) 633-2616, Fax: + 1 (860) 368-5535, Email: lucia.maffucci@pwps.com, Prime
Ebara Corp	http://www.ebara.co.jp/en, 11-1 Haneda Asahi-cho, Ohta-ku, Tokyo, Japan, Tel: + 81 3 3745 6111, Fax: + 81 3 3745 3356, Licensee

Subcontractor

Continental Controls Corp	http://www.continentalcontrols.com, 8845 Recho Rd, San Diego, CA 92121 United States, Tel: + 1 (858) 453-9880, Fax: + 1 (858) 453-5078 (Fuel Valves)
Meggitt Control Systems	http://www.stewart-warner.com, 3 Industrial Dr, Troy, IN 17601 United States, Tel: + 1 (812) 547-7071, Fax: + 1 (812) 547-2488, Email: infotroy@meggitt.com (Fuel Heater)

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Technical Data

Dimensions.

	Length	Width	Height	Weight
ST6L-794/-795	1,230mm	440mm	480mm	104 kg
ST6L-812/-813	1,280mm	440mm	470mm	136 kg

Performance.

ELECTRICAL GENERATION

Model	Output (ISO)	Heat Rate	Pressure Ratio	Mass Flow	EGT
ST6L-795	678 kW	14,575 kJ/KWh	7.4:1	3.2 kg/sec	589°C
ST6L-813	848 kW	13,846 kJ/KWh	8.5:1	3.9 kg/sec	566°C

MECHANICAL DRIVE & MARINE PROPULSION

Model	Use	Output (ISO)	Heat Rate	Pressure Ratio	Mass Flow	EGT
ST6L-794	MP	810 hp	10,514 Btu/bhp-hr	7.0:1	3.1 kg/sec	561°C
ST6L-795	MD	909 hp	10,301 Btu/bhp-hr	7.4:1	3.2 kg/sec	589°C
ST6L-812	MP	984 hp	10,137 Btu/bhp-hr	8.0:1	3.7 kg/sec	542°C
ST6L-813	MD	1,137 hp	9,786 Btu/bhp-hr	8.5:1	3.9 kg/sec	566°C

MP = Marine propulsion
MD = Mechanical drive

Design Features.

Compressor. Three-stage axial and single-stage centrifugal compressor producing pressure ratios of 6.9:1 to 10.4:1. Axial-flow stages have SS stator and rotor blades, and single-sided centrifugal stage is of Ti alloy. One-piece casing/radial diffuser is of SS alloy.

Combustor. Stainless-steel annular, reverse-flow combustor, 14 pressure jet nozzles, single spark ignition.

Compressor Turbine. A single axial-flow, uncooled turbine drives the compressor spool at speeds between 30,000 and 33,000 rpm.

Power Turbine. A single-stage (-794/-795) or twin-stage (-813) power turbine operates at design speeds of 30,000-33,000 rpm. Exhaust temperature is in the range of 514°C-589°C.

Gearbox. Integral gearbox is supplied with output speeds of 1,700, 1,900, 2,200, 6,188, and 6,000 rpm.

Bearings. Two roller bearings and two ball bearings.

Control System. Solid-state electronic control with hydromechanical fuel system.

Variants/Upgrades

ST6. The ST6 is a variant of the PT6 that was originally developed as a powerplant for the United Aircraft Corporation (UAC) TurboTrain power cars, but later developed as a stationary power generator and auxiliary power unit.

ST6B. The ST6B-62 was a 550-bhp (410-kW) version of the PT6 developed for use in the STP-Paxton Turbocar, raced in the 1967 Indianapolis 500.

STN 6/76. The STN 6/76 was a 500-bhp (370-kW) version of the PT6 developed for use in the Lotus 56, raced in the 1968 Indianapolis 500 and later in Formula One races, in 1971.

ST6T-76 Twin-Pac. Beyond single gas generator variants, Pratt offers the Twin-Pac variant, the ST6T-76, which, driving an output shaft through a common gearbox, produces up to 1,850 shp in continuous power at 6,600 rpm (and 1,440 shp normally). The combination gearbox incorporates automatic clutches that permit operation of one side independent of the other. A torquemeter for each powerplant provides for automatic power sharing.

PW-14MV. The PW-14MV is a vertical-type ST6 gas turbine that comes in a Twin-Pac package using two engines. Since the PW-14MV is a twin-shaft gas turbine, it is suitable for use as a drive for rotary machines. One feature of the PW-14MV is that it is constructed and arranged to minimize installation space, as it is placed directly above a vertical-shaft pump.

Packagers

Turbosystems Inc. Later known as Sulzer Turbosystems Inc, Turbosystems offered the ST6 in several compression set packages. The 700-hp (522-kW) TC-7 combined all existing versions of the ST6 with its own controls and centrifugal compressor. The higher-power variants with the TC-9A and TC-9B designations that became available in 1975 offer up to 960 shp continuous and 1,075 shp maximum power. Twin powerplant units, the TC-9AT and TC-9BT, also became available in 1975. This firm is no longer involved in production of the PWPS ST6 series of machines.

Ebara Corporation. In 1989, Ebara Corporation in Tokyo signed an agreement with several of United Technologies' divisions. One of the agreements called for Ebara to package, distribute, and service Pratt & Whitney Canada's ST6 series machines for electric power generation and mechanical drive, including cogeneration and combined-cycle cogeneration packages. Ebara concentrated on the ST6-79 and ST6-81 machines that have thermal efficiencies in the 23.8 to 25.5 percent range. The current models in the Ebara product line range from the PW-4M through the PW-14MV.

Ebara marketed the ST6 for emergency standby genset applications, turbo-powered pumps and blowers, compressor drives, and small combined-cycle plants (for process steam, heat, or absorption chiller refrigeration). The Japanese company did not manufacture any of the ST6's components. Ebara was PWPS's chief packager and provider of ST6 installations in the Pacific Rim/Asia region. It installed at least 52 ST6 series machines.

Program Review

Background. Based on the success of the Pratt & Whitney Canada PT6 series of turboprop and turboshaft aviation engines, the ST6 series of industrial and marine gas turbines drew heavily on the inherent reliability and durability of the PT6 heritage.

The ST6 is a variant of the PT6 that was originally developed as a powerplant for the Beech 18 aircraft, but it was quickly developed as a stationary power generator and auxiliary power unit. By 2001, the 40th anniversary of its maiden flight, more than 36,000 PT6As had been delivered (not including the engine's other versions). The engine is used in over 100 different applications.

Early in the development of the aviation versions, Pratt & Whitney Canada, earlier known as United Aircraft of Canada, also embarked upon development of land-based and marine variants of the PT6.

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The ST6 design was first used in a non-aeronautical application in 1962. In 1966, the Thunderbird, a 10-meter boat owned by racing-boat champion Jim Wynn, used two ST6 engines. It was one of only two boats out of 31 to complete the Sam Griffith Memorial Race on February 22, 1966, and although it came in first, it was denied official recognition, as it was considered experimental. The turbine-engine-powered TurboTrain was designed to provide passenger service between New York and Boston, and was supposed to be a centerpiece at Expo 67. Although it was not completed in time for the Expo, by 1973 it was regularly traveling at speeds of nearly 193 kilometers in the Montreal-Toronto corridor. In 1978, the president of STP, Andy Granatelli, installed an ST6 in his custom-made Corvette after the USAC banned the engine's use in STP's Indy cars.

Since that time, the ST6 series of gas turbine machines has been adapted for more than 35 unique types of installations (including surface vehicular power and airborne APUs). This series also holds a prominent role in marine power, largely due to PWPS's development of drive systems that adapt to the marine role, including straight drive, V-drive, and strut-drive systems with controllable pitch propellers, as well as water jet propulsion systems.

Maritime Applications

The first deliveries of the ST6 were made in 1965, for the HMCS *Bras D'Or*, in which the PWPS ST6A-53 machine functioned as a generator and hydraulic drive.

LACV-30. The U.S. Army initiated a program in the early 1970s to design a new craft to provide ship-to-shore logistics support. Craft to be replaced included the old LARC-5 and LARC-15, which could access only 17 percent of the world's beach areas and were unusually slow and vulnerable.

In 1975, the U.S. Army Mobility Equipment Research and Development Command (MERADCOM) awarded (then) Bell Aerospace Textron a contract for work on the prototype vehicle, later designated LACV-30 (Lighter, Amphibian Air Cushion Vehicle). The ACV's power was provided by twin Pratt & Whitney Canada ST6T-76 Twin-Pac gas turbine engines driving centrifugal lift fans and variable-pitch propellers. The prime mission for the LACV-30 was to move cargo ashore and inland rapidly and efficiently when port facilities were unavailable. Each vessel had a payload of 25 to 30 tons (22.7 to 27.3 metric tons) and an endurance of 8.5 hours at a cruise speed of 40 knots (74 kmph).

Through FY85, 26 vessels were funded at a cost of over $160 million. No funds have been sought since FY86. All vessels were delivered, used for a brief period, and then sold or scrapped. For the LACV-30 application, a total of 81 ST6T-76s were delivered in the 1975-1985 timeframe, including spare engines.

EDO Mk 105 Airborne Minesweeping System. In January 1996, EDO Corporation received a contract from the U.S. Navy in the first phase of a multiyear program to upgrade the Mk 105 Mod 4 system.

The EDO Corp Mk 105 system consists of a towed, unmanned hydrofoil platform on which is mounted a gas turbine generator set and a pair of 183-meter-long cables dragged underwater behind the platform. Electric power from the gas turbine generator set is fed to the cables; the electric current that circulates through the seawater between the two cables generates an underwater magnetic field that serves to detonate non-contact influence mines at a safe distance from the platform. The Mk 105 system is controlled via a multiplexing link by an operator in a Sikorsky MH-53E helicopter.

The Mk 105 system was employed to clear minefields in numerous operations, including the Red Sea, Haiphong Harbor, the Suez Canal, and the Persian Gulf during Operation Desert Shield/Desert Storm.

In January 1996, the ST6L-813 engine was selected to power the EDO Corp Mk 105 Airborne Minesweeping System upgrade. The Mk 105 Mod 4 conversions of Mod 2 entered service in 2001-2002. They were designed for ease of maintenance. The system uses the higher-powered PWPS ST6L-813 offering 75 percent more output.

Vertical Installation Pump Packages. Several ST6 machines have been sold to Japan for use as drivers on emergency flood-control pumps. Ebara, PWPS's partner, designed, developed, and manufactured these packages. Typically, the packages included horizontally mounted engines and gearboxes driving a vertical pump through an angled gear; however, Ebara wanted to simplify the design and install the prime mover vertically, thus eliminating the angled gear.

Modifications were made to the lubrication oil system to scavenge oil from the main engine bearings and seal those bearing cavities as necessary. Ebara built modified hardware into the packages and performed extensive testing with the engines at its facility in Japan.

The vertical pump package machines offer power ranging from 375 to 1,960 kW and use a combination of two engines through one gearbox, up to 3,920 kW.

P2 Energy Subsidiary Formed

In November 2000, Pratt & Whitney Power Systems formed P2 Energy, a wholly owned subsidiary that was

intended to provide customers with industrial power systems ranging from 300 kW to 50 MW, and services to support the systems through their complete life cycle. The newly formed company was intended to be the primary marketing and sales channel for Pratt & Whitney Power Systems' FT8 industrial gas turbines. It was also responsible for marketing and sales of the ST5, ST6, ST18, ST30, and ST40 product lines.

Funding

The ST6 was originally funded by Pratt & Whitney as a commercial development. Subsequently, a long string of experimental applications were funded by a variety of commercial interests. The U.S. Navy funded the LACV-30 and Mk 105 programs.

Contracts/Orders & Options

Contractor	Award ($ millions)	Date/Description
Exelis	13.0	Feb 2014 – Contract to provide Naval Surface Warfare Center with depot-level repair, maintenance, and modifications for two mine defense systems fielded with the U.S. Navy.

Timetable

Month	Year	Major Development
	1962	First design work on ST6 performed
	1965	First marine use of ST6, on *Bras D'Or*
	1966	Automotive uses of ST6 start
	1970	ST6 adopted for LACV-30 program
	1986	LACV-30 program ends
	1989	P&W signs licensing agreement with Ebara
	1996	ST6 engine selected to provide power for Mk 105 mine clearance system
Nov	2000	P2 Power Systems formed
	2012	MHI purchase of Pratt & Whitney Power Systems announced
May	2013	MHI completes acquisition of Pratt & Whitney Power Systems

Worldwide Distribution/Inventories

Country	Year Installed	Total
Canada	1966 (3), 1967 (1), 1968 (1), 1972 (1), 1973 (2)	8
China	1975	1
Israel	1981	2
Japan	1991	1
Russia	1978	1
U.S.	1980-1990 (60), 1990 (1), 1995-2005 (40)	101
Total		**114**

Forecast Rationale

The ST6 does not appear to have emulated the success of the PT-6 turboprop aircraft engine from which it is derived. It has made its major impact in the maritime area, where it provided propulsion power for the LACV-30 cargo craft and the Mk 105 mine clearance system. The ST6's sales have been limited to a few experimental applications and a handful of engines purchased for specific requirements. Indeed, the ST6 is not even mentioned in the most recent corporate literature, and even in older documents, reference to the ST6 is limited.

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In the absence of any solid data or news of ST6 supply contracts, we conclude that no production of this gas turbine is occurring at this time. Unless this situation changes, this report will be archived next year.

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