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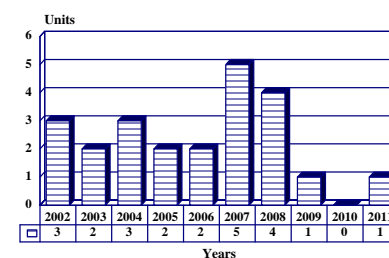
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Siemens Westinghouse W251 - Archived 5/2003

Outlook

- Sales expected to arise, but in blocks of ones, twos, and threes
- FiatAvio projected to build the majority of machines in the decade
- Dry low NOx feature on the machine should continue to be appealing to developing nations

10 Year Unit Production Forecast
2002 - 2011



Orientation

Description. The W251 (Model 251) is a single-shaft, axial-flow heavy industrial gas turbine, with cold end power drive, in the 45-55 MW class. The machine is available for 50 Hz and 60 Hz operation. (**Note:** The machine model prefix “CW” referred to Canadian Westinghouse models.)

Sponsor. The W251 was privately developed by Westinghouse.

Contractors/Manufacturers. The prime manufacturer is Siemens AG, Power Generation Group (KWU), Siemens Westinghouse Power Corporation (SWPC), Orlando, Florida, USA.

Production Location. The W251 is produced in Hamilton, Ontario, Canada, and in Turin, Italy (by FiatAvio).

Associates/Licensees/Packagers. Firms that are or have been involved in the W251 with SWPC include the following:

- ACEC; Charleroi, Belgium (packager only).
- FiatAvio SpA, Gas Turbine Division; Turin, Italy.
- Mitsubishi Heavy Industries Ltd; Tokyo, Japan.
- Rolls-Royce plc, Industrial and Marine Gas Turbines Limited; Ansty, Coventry, UK.

Power Class. The W251B11/12 is rated at approximately 49.5 MW.

Status. The machine remains in low-level production.

Total Produced. At the start of 2003, slightly more than 400 W251 machines (including W-251s and CW-251s) are estimated to have been built, including machines by licensees and affiliates (including MW251s and TG20s).

Application. The current application is utility and industrial power generation, including cogeneration and combined-cycle installations. A total of 15 machines have been built and installed as mechanical load drivers, including one MW-252. The W251 is not currently offered for mechanical load drives.

Price Range. Estimated in 2003 US dollars at \$13.5-\$15.5 million for a basic gas turbine-equipped electrical generating package.

Competition. In the electrical generation arena, the SWPC W251 competes against the GEAE M&I LM6000PC Sprint, UTC PWPS FT8 TwinPac, and the Rolls-Royce Industrial Trent.

Technical Data

Design Features. Among the design features of the SWPC W251B11/12 are the following:

Intake. Air enters radially and turns 90° for entry into the compressor. Various filtration and sound suppression equipment available. Variable inlet guide vanes.

Compressor. Eighteen or 19 axial stages provide an overall compression ratio of 11:1-15.3:1 (15.3:1 for W251B12). The rotor is supported by two pressure-lubricated tilting-pad journal bearings – one forward of the compressor and one aft of the turbine – but shielded from high temperatures; they are accessible from the outside for inspection and replacement. The compressor casing is split horizontally to form a base and cover. Stators are integral with the respective halves of the cover. Air mass flow is approximately 385 lb/sec (174.6 kg/sec) for the W251B12. The rotor speed of the 19-stage unit is about 5,425 rpm.

Combustor. Eight combustor baskets are ringed conically between the compressor and turbine and are axially canted slightly outward. These are formed by stainless steel rings perforated for positive air swirl and are equipped with dual nozzles in each chamber. Combustors are enclosed within an outer casing. The engine is capable of operation on a wide range of gaseous and liquid fuels, as well as dual-fuel operation. Provision is made for injecting steam or water for NOx suppression. Twin igniters are standard equipment. Dry low NOx combustors are also offered.

Turbines. A three-stage axial turbine directly drives the gas compressor and the load shaft, which extends forward through the intake plenum. The turbines are built up of individual disks, with blades set with fir-tree roots. Both the disks and blade roots are air cooled, but the turbine operates at moderate temperatures. The turbine casing is split horizontally and can be lifted off to expose the turbines in place. Turbine diaphragms are also made in segments to allow their removal with the rotor in place. Stage 1 blades are cast in Udimet 500 or IN738 in higher powered variants. Vanes are also cast and HIPed in X-45 alloy.

Control System. The units are equipped with a Westinghouse Powerlogic II, a microprocessor control system based on the Westinghouse WDPF system which provides automatic operation for startup, loading, continuous operation, and shutdown. The system continuously monitors all inputs and can perform auto shutdown in the event of malfunction.

Bearings. The W251 single-rotor shaft is supported by two tilting-pad bearings. The thrust bearing is a Glacier directionally lubricated, double-acting tilting-shoe type.

Accessories. Starting is normally by an electric motor and torque converter, but other systems are available. A wide range of optional equipment is available, including cooling packages, inlet and exhaust systems, fire protection systems, and black start capability.

Dimensions. Approximate dimensions and weight of a W251 gas turbine machine are as follows:

	Metric Units	English Units
Length	9.5 meters (9,5 m)	31.2 feet
Width	3.7 meters (3,7 m)	12.1 feet
Height	4.1 meters (4,1 m)	13.4 feet
Weight	80 metric tons (80 000 kg)	176,370 pounds

Performance. Performance parameters of the W251 for electric generator drive (continuous output at ISO conditions, no inlet/exhaust losses; natural gas fuel) are as follows:

Machine	Output (kW)	Output (kJ/kWh)	Pressure Ratio	Mass Flow (kg/sec)	EGT °C
W251B11A/12A (SWPC)	49,500	11,024	15.3	174.6	514
TG20B11/12 (FiatAvio)	49,177	11,040	14.0	174.3	522

Variants/Upgrades

W251. The designation W251 (W-251) refers to the early W251 (W-251), some of which were built by

Westinghouse in Canada. This is the current overall designation of the gas turbine series.

W251B10. The designation W251B10 refers to early W251 machines rated at 41.2-41.4 MW.

W251B11A/12A. The designation W251B11/12 refers to the most recent 49.5-MW machine. The B11A is available for 50 Hz operation, while the B12A is available for 60 Hz operation.

MW251. The designation MW251 (MW-251) refers to the Model 251 built in Japan by Mitsubishi Heavy Industries.

TG20B11/12. The designation TG20B11/12 refers to the Model 251B11/12 built in Italy by FiatAvio.

Program Review

Background. The Siemens Westinghouse W251 (W-251) arose in the late 1960s at the then Westinghouse Electric Corporation's facility in Concordville, Pennsylvania.

The machine is a single-shaft heavy industrial turbine, offered in both generation and mechanical drive configurations, and is a derivative of the Westinghouse W191/301 series that was developed in the late 1950s for industrial power generation. The advent of the W251 and the larger Westinghouse design, the W501, ultimately led to the cessation of W191 and W301 production. When produced in Canada, the W251 had the designation CW251.

The W251 was first sold in 1967, when three early ECONOPACs were sold to Detroit Edison Company in Michigan. While those units were rated at 18.5 MW, further development has brought the W251 up to its current level of 49.5 MW.

W251 Installations.

ECONOPAC. A popular package has been the ECONOPAC system, consisting of the gas turbine, generator, controls, and accessories mounted on a skid. Normally, the W251 drives an air-cooled generator through a main gear at 3,600 rpm for 60 Hz (3,000 rpm for 50 Hz) operation with an output rating of 39,222 kVA (ISO). ECONOPACs are simple-cycle machines and incorporate silencing and filtration equipment per customer requirement.

The total package covers an area of 111 ft x 33 ft x 26 ft (33.83 m x 10.06 m x 7.93 m), and is of modular construction for ease of erection and transport.

W251B12 ECONOPAC performance parameters for base rating at ISO Conditions on natural gas fuel (with no injection) are as follows:

<u>Parameter</u>	<u>Rating</u>
Plant Net Power	49.2-49.5 MW
Plant Heat Rate	11,014 kJ/kWh (LHV)
Exhaust Flow	175 kg/sec
Exhaust Temperature	520°C

ECONOPACs can be easily converted to combined-cycle operation.

PACE Systems. ECONOPACs can be coupled into multiple-unit systems with waste heat recovery boilers for combined-cycle operation. Termed PACE (for Power At Combined Efficiency) by Westinghouse, these units have high thermal efficiencies for baseload generation. Among the configurations that have been sold and reported by Westinghouse are combustion turbine/heat recovery plants for repowering, under the unit designation PACE 30 (one W251 machine). Three PACE 30 plants were sold: one (30.3 MW of total power) to Southwestern Public Service Company (plant now retired), and two units (31.2 MW and 32.99 MW) to the Central Iowa Power Corporation for installation in Creston, Iowa.

Domestic Market. About 105 W251 systems, including the PACE 30 units, were installed in the US. US utilities placed most of the orders, but later the trend was toward foreign sales.

Foreign Markets. The Middle East and North Africa have been major overseas markets, although South American and Asian/Far Eastern customers have also placed orders. Three relatively recent sales for ECONOPAC W251s for Colombia join others in service in Ecuador and Brazil. About 20 units have been installed in Saudi Arabia, while a smaller number have been installed in Indonesia. More than 300 units have been installed outside the US.

Westinghouse Canada. Westinghouse in Canada was given total responsibility for the W251 line in 1983 when Westinghouse Electric in the US decided to reduce the US Combustion Turbine Division's risk exposure. Marketing, production, and sales efforts for all engines, with the present exception of the W501, were transferred to the Canadian unit. In 1990, Westinghouse in the US again took over full responsibility for all gas turbine machines, including machines with the "CW" prefix.

W251 Compressor Redesign. Compared to its immediate predecessor, the W251B12 compressor has new inlet guide vanes, new airfoils on the first two stages, and restaggered stators on all but two of the downstream stages. The performance improvement was achieved by a 0.5 inch (12.7 mm) increase in the compressor inlet outer radius, double circular arc airfoil

profiles in the first two stages, and optimized restagger of most of the downstream stators.

The three-stage turbine incorporates two modifications. First, by film cooling the shrouds with compressor delivery air, the cooling of the Stage 1 stator is enhanced. To provide the film cooling, two rows of holes on the outer platform and one row on the inner platform are electrochemically machined at 30° to the surface. Second, to improve the Stage 1 turbine blade service life at the increased firing temperature, the blade cooling design is upgraded with the addition of turbulators to the radial cooling holes.

In March 1991, the first 46.5-MW W251B12 entered commercial service at the Boise Cascade paper mill in Fort Francis, Ontario, Canada. The W251B11/12 is rated at 49.5 MW.

Barge-Mounted Power Plants. Westinghouse, in conjunction with other manufacturing firms, has mounted power plant configurations using the W251B11/12 combustion turbine in a simple-cycle mode on board large barges. Orders have arisen for such power plants from Malaysia (for four gas turbines) and Ghana (for three gas turbines).

W251 Licensees. The Westinghouse/ SWPC W251 gas turbine model has been manufactured or packaged by the following firms:

ACEC. The then ACEC in Belgium packaged 29 W251 systems for Asian, African, European, and Middle Eastern customers, in both generation and mechanical drive applications. It offered single-turbine combined-cycle COCY 50 and twin-turbine COCY 100 units. *This firm is no longer active with the W251.*

FiatAvio. FiatAvio SpA, Energy Business Unit, Gas Turbine Division (formerly Fiat TTG SpA), began to offer Westinghouse industrial turbines in 1954. It has offered single-turbine combined-cycle CC50 and

twin-turbine CC100 models, with more recent emphasis on the latter configuration. FiatAvio now offers the CC50 model based on the GEAE M&I LM6000 for both 50 Hz and 60 Hz operation.

We estimate that slightly more than 120 W251s (designated TG20 by Fiat) have been installed in the Middle East, Europe, Africa, North and South America.

Mitsubishi Heavy Industries. The MW251 is the Mitsubishi designation for the Westinghouse unit, which was packaged as a generation system. Mitsubishi has had meager success in selling the W251 (seven machines sold in Japan).

Mitsubishi assembled just under 25 MW251s for generation use, including one prototype MW252 (MW-252) reconfigured for mechanical drive application. Customer nations of the Mitsubishi-built/ packaged machines include Bangladesh (3), India (4), Japan (7), Kuwait (4), Nigeria (1), and Pakistan (3). *This firm is no longer active with the W251.*

Thomassen International by. The Rheden-based firm built one W251 unit which was installed in 1967 for use by the Dutch State Mines. At the time, Thomassen was a part of ACEC. *It is no longer active with the W251.*

Rolls-Royce. In June 1992, Westinghouse and Rolls-Royce entered into a cooperative agreement to increase the competitiveness of each firm's products by offering customers improved performance, reliability, maintainability, lead times, and lower costs. This series of improvements was achieved through a two-way technology transfer. Westinghouse has extended its product range by developing ECONOPACs based on RB211 and Trent aeroderivative technology. In addition, Rolls-Royce has strengthened its position through the distribution, manufacturing, and sourcing of the Westinghouse product line. *Note: The two-firm agreement has since ceased. This firm is no longer active with the W251.*

Funding

No Canadian, US, or German government funding pertaining to the Siemens Westinghouse W251 machine has been identified.

Recent Contracts

No major military contracts involving the Siemens Westinghouse W251 are known to have been awarded in the recent past.

<u>Contractor</u>	<u>Award (amount)</u>	<u>Date/Description</u>
Inchon Airport	N/A	Sep 1999 – Two W251Bs to drive generators for airport self-generation in South Korea. Machines were delivered by the end of 1999.

Androscoggin N/A Sep 1998 – Three W251Bs, three HRSGs, and one Westinghouse 40 MW steam turbine for a power plant in Maine. Machines went on line in 1999.

Timetable

<u>Month</u>	<u>Year</u>	<u>Major Development</u>
	1961	Development of W251 begun
	1967	First W251 entered operation at Detroit Edison
	1970	PACE systems became available
	1971	Fiat TG20 became available
	1973	W251B for mechanical drive became available
	1981	PACE 2511/3/4 units became available
	1983	W251 program transferred to Canada
	1984	Fiat announcement of TG20 uprating made
	1986	Model 251B10 compressor fully tested
	1989	Westinghouse Canada announced Model 251B12
Mar	1991	First Model 251B12 machine entered commercial service
Jun	1993	Westinghouse, Rolls-Royce signed agreement
	1995	First order placed for gas turbines for barge-mounted power plants
Jun	1996	Six ECONOPAC units ordered for Pakistan
Thru	2012	Continued production/availability of Model 251 projected

Worldwide Distribution

As of 2002, slightly more than 400 Siemens Westinghouse W251 (W-251, Model 251) machines had been built and installed in over 25 countries and territories worldwide. Large-use customer nations include the **US** (100+), **Saudi Arabia** (20+), and **Japan** (10+).

Forecast Rationale

The production life cycle of the Siemens Westinghouse W251 (Model 251) is slowing down as newer and more efficient turbines enter the already-crowded marketplace. Despite its age, however, the venerable W251 (most specifically, the W251B11/12) continues to have strong selling points, including the fact that it is relatively inexpensive compared to newer models, making it appealing to customers in developing countries or to others on restricted budgets, and that SWPC offers a dry low NOx system fittable to the machine, giving operators the ability to operate a low NOx system without the expense of a water treatment facility, which is frequently unavailable or extremely expensive. In addition, the W251 is freer (as opposed to the LM6000PC Sprint) from political and economic constraints as to what countries can and cannot purchase the machine.

We continue to feel that the combination of the machine's low price and dry low NOx capability will result in sales of the W251B11/12 model for several more years, although in orders of just a few machines each time. The W251 should continue to be made available for combined-cycle installation in both single-and double-W251 (Model 251) configurations.

In our updated forecast for the decade extending in 2011, we project that 23 machines will be built, all for power generation application. Of that total, Fiat is expected to manufacture 15 machines for 50 Hz installation worldwide.

While the turbine has been justifiably trumpeted for use on power barges, no orders have been placed in the past several years with SWPC or its affiliated companies.

Ten-Year Outlook

ESTIMATED CALENDAR YEAR PRODUCTION

High Confidence Level

Good Confidence Level

Speculative

Total

Engine /Machine	Application	thru 2001	2002	2003	2005	2005	2006	2007	2008	2009	2010	2011	2002-2011	
SIEMENS WESTINGHOUSE POWER CORP														
W251B11/12 (a)	GENERATION	217	1	1	2	1	0	2	1	0	0	0	8	
W251	MECHANICAL DRIVE	1			Machine is no longer offered for mechanical drive applications.									-
Subtotal - SWPC		218	1	1	2	1	0	2	1	0	0	0	8	
MITSUBISHI HEAVY INDUSTRIES														
MW-251	GENERATION	23											-	
MW-252	MECHANICAL DRIVE	1											-	
Subtotal -MHI		24											-	
ACEC														
W-251	GENERATION	33											-	
W-251	MECHANICAL DRIVE	13											-	
Subtotal - ACEC		46											-	
FIAT AVIO SpA														
TG20B11/12	GENERATION	120	2	1	1	1	2	3	3	1	0	1	15	
TOTAL PRODUCTION		410	3	2	3	2	2	5	4	1	0	1	23	

(a) "Thru 2001" total includes all W251s (Model 251s, W-251s, and CW251s/CW-251s) for power generation.