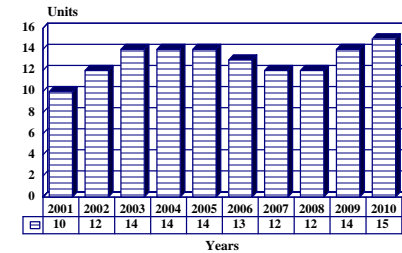


General Electric GE-2 – Archived 09/2002

Outlook

- Small cogeneration applications in processing plants expected to be a particularly attractive niche for this machine
- Deregulated electricity climate expected to aid in sales punch
- GE umbrella also likely to open doors worldwide

10 Year Unit Production Forecast
2001 - 2010



Orientation

Description. High-efficiency, single-shaft, centrifugal-flow industrial gas turbine machine in the 2 MW class.

Please note that this report focuses on the General Electric GE-2. Information regarding the GEPS Oil & Gas (Nuovo Pignone entity) PGT2 is included as it impacts the GE-2.

Sponsor. The GE-2 was privately developed by the then Nuovo Pignone SpA (now a part of GEPS Oil & Gas) under the designation PGT 2. For the purpose of this report, the designation PGT 2 is referred to as the PGT2.

Contractors/Manufacturers. The prime manufacturer is GE Power Systems' GEPS Oil & Gas (Nuovo Pignone entity) Florence, Italy. Production takes place in Florence, Italy.

Power Class. The power output of the GE-2 machine is 2.0-2.25 MW.

Status. In production.

Total Produced. As of 2001, less than 25 machines are estimated to have been built, all for electric power generation.

Application. Electric power generation, primarily for base load generation. Among the machine's prime places for installation are in paper mills and brick furnaces, plus ceramic, textile and food industries. Mechanical load drive applications may develop within the forecast period of this report.

Price Range. Estimated in 2001 dollars at \$1.4-\$1.65 million for a gas turbine-equipped electric power generation package.

Competition. In the electric power generation arena, the GE-2 most actively competes against the Dresser-Rand KG2-3E and the UTC Pratt & Whitney Canada ST18.

Other machines in that approximate power class include old designs such as the Turbomeca Bi-Bastan VII and the Yanmar AT270C.

Technical Data

Design Features. Design features of the GE-2 machine include the following:

Compressor. Two-stage centrifugal compressor. Impellers are made of alloyed steel. Adjustable inlet guide vanes can be added to optimize efficiency at part loads when the machine is used in a regenerative-cycle installation. The overall pressure is 12.5:1.

Combustor. A single, vertically aligned reverse-flow combustor mounted on the casing, capable of burning a wide variety of liquid or gas fuels, or both, in a dual-fuel arrangement.

Turbine. Two-stage axial turbine design. Both stages are high-efficiency, reaction, axial type, with the axial exhaust having an efficient, conical diffuser. Stator and

rotor blades are made of investment castings of high-temperature superalloys; forged discs. Stationary nozzles and the Stage 1 rotor blades feature an air cooling system. Turbine speed is 22,500 rpm.

Bearings. Rotor is held by two sliding bearings accessible at both ends.

Control System. A compact microprocessor system with control, monitoring and protection functions has been designed to make the GE-2 fully automatic.

Dimensions. Approximate dimensions and weights of a GE-2 package (including the generator and filters) are as follows:

	<u>SI Units</u>	<u>English Units</u>
Length	5.5 meters	18.04 feet
Width	3.8 meters	12.46 feet
Height	2.3 meters	7.54 feet
Weight	12 metric tons	26,455 pounds

Performance. Approximate performance specifications of the GE-2 gas turbine machine are as follows (ISO conditions, natural gas fuel):

	<u>SI Units</u>	<u>English Units</u>
Output	2,000 kWe	2,682 shp
Heat Rate	14,440 kJ/kWh	10,208 Btu/hp-hr
Exhaust Flow	10.7 kg/sec	23.58 lb/sec
Exhaust Temperature	525°C	977°F

Variants/Upgrades

Among the major variants of the GE-2 (GEPS Oil & Gas [Nuovo Pignone-developed PGT2]) machine are the following:

GE-2. The current designation, given to the machine in 2000. In a simple-cycle version it is rated at 2.0 MW.

GE-2R. The GE-2R version has been used for the basic machine in a regenerative-cycle configuration. It is rated at 1.87 MW.

PGT2. The PGT2, as the machine was originally known, is the basic machine in a simple-cycle duty.

Program Review

Background. The Nuovo Pignone (now an entity of GEPS Oil & Gas) PGT2, today known as GE-2, is a 2.0-2.25 MW machine intended for the electric power generation market. The program was revealed in early 1989. Testing of the first prototype began in 1991. A year later, the prototype testing program had been completed, and by the end of 1994 the first production-standard machine was run. The machine was publicly introduced in 1995 and became commercially available the following year.

With a baseload airflow of 10-11 kg/sec and a design speed of 22,500 rpm, the machine has an ISO baseload generator output of 2,000 kWe on natural gas fuel, with a baseload heat rate of 14,400 kJ/kWh (10,208

Btu/hp-hr), making it suitable for 50 Hz or 60 Hz generation with a reduction gearbox. The machine undoubtedly inherits much of its design from the GE Power Systems/Nuovo Pignone MS1002 and the Nuovo Pignone PGT10 programs (see separate "General Electric GE-10" report).

In a departure from previous gas turbine machine designs, the GE-2 features a two-stage centrifugal compressor, as opposed to other NP machines which feature an axial design. The two-stage axial turbine is coupled with the compressor on a single shaft. A user option of adjustable inlet guide vanes is available to optimize part-load efficiency, especially in the optional

regenerative-cycle installation (with the regenerative-cycle machine designated GE-2R).

A compact microprocessor system with control, monitoring, and protection functions has been designed to make the machine fully automatic. The system monitors the machine's major functions – start-up, shutdown, power take-off, etc., – with pickups installed on the machine. The system also carries out the control sequences (start-up of pumps, fans, etc.).

Applications and Uses. The machine's axial-flow exhaust and high baseload exhaust temperature position it well for small cogeneration plant applications. By recovering heat from the exhaust gas, the GE-2 machine can supply up to 4.3 thermal MW with a simple cycle or 3.8 thermal MW with a regenerative cycle to produce steam, hot water or heat for process. NP has designed a compact cogeneration package around the new machine, including the gas turbine, reduction gear, electric generator, system controls and auxiliaries, inlet filter/silencer, enclosure, and heat recovery boiler.

Cogeneration. Data released by NP for the GE-2 in industrial cogeneration use are as follows (simple cycle, ISO conditions, natural gas):

Application = Cogeneration	Rating
Electrical Power Output	2,000 kWe
Thermal Power Available ^(a)	4,810 kWt
Inlet Fuel Power	8,000 kWt
Steam Production ^(b)	6.0 tons/hr
Thermal Power Output ^(c)	4,300 kWt

^(a)Stack temperature 100°C.

^(b)12 bar - 250°C single pressure level.

^(c)Condensate temperature 95°C.

Nuovo Pignone's subsidiary, Turbotecnica (Florence, Italy), was set up by the company as a main contractor-supplier of turbogenerator units and complete power plants under turnkey contracts.

Marketing Agreements. Nuovo Pignone signed a cooperative technology agreement with Halla Engineering & Heavy Industries, Seoul, Korea, covering industrial gas turbines in the 2-10 MW range. The agreement called for Halla to build Pignone technology gas turbines for sale to the Korean market and to neighboring countries in Asia. Presumably, the license covered the Pignone-developed GE-2, PGT5, and PGT10 machines. Halla agreed to build, package and sell the machines for electrical power generation, cogeneration and combined-cycle cogeneration, and

compressor and pump mechanical drive services. No information has been available with which to deduce if Halla has in fact sold any GE-2/PGT2 machines.

Background. Among the more noteworthy events in the recent past regarding the GE-2 and/or PGT2 include the following:

Name Change Seals GE Parenthood. In spring 2000, the PGT 2/5/10 lineup was renamed GE-2/5/10, in an apparent move to emphasize the corporate ownership of Nuovo by General Electric.

Funding

Italian Government and US Government funding specifically pertaining to the PGT2 and the GE-2, if any, has not been identified.

Recent Contracts

No major identifiable government contracts specifically pertaining to the PGT2 or GE-2 have been awarded or received in the recent past.

Timetable

Among the major events in the PGT2/GE-2 program are the following:

<u>Month</u>	<u>Year</u>	<u>Major Development</u>
Early	1989	PGT2 program revealed
Mid	1991	Testing of first prototype machine begins
	1992	Prototype testing program completed
Late	1994	First production-standard machine run – endurance testing begins
	1995	Public introduction
	1996	Machine commercially available
Spring	2000	Name change to GE-2
Thru	2010	Continued production/aftermarket support of GE-2 projected

Worldwide Distribution

As of 2001, less than 25 15 PGT2/GE-2 machines are assumed to have been fabricated. All machines are believed to be in **Italy**.

Forecast Rationale

In Europe and the Middle East regions, GEPS Oil & Gas (formerly Nuovo Pignone), has established an excellent reputation with its machines and its service. It can offer the smaller machine as part of large-scale projects, especially through the auspices of Turbotecnica, and through the overall umbrella of GEPS and GEAE M&I.

The machine's initial market thrust is electric power generation, most notable for baseload power generation. Given the machine's output parameters including its axial-flow exhaust and high baseload exhaust temperature, it is a good candidate for small cogeneration plant applications, particularly in such industries as pulp and paper, textiles production and cement. Because of the machine's small size, it may find application in the mechanical drive arena for small process plants or gas compression duty.

Much of the future growth of this machine is based on expectations in the deregulated North American power

market. The 2 MW output of this machine makes it well suited for localized applications, competing in many instances against widely publicized fuel cells and even against the highest ends of the microturbine power spectrum.

The distributed power generation prospects – especially in America and in other countries with similar market dynamics – lend credence to the belief that this machine could become very popular in the market scenarios of today and tomorrow. The big GE name should also give the product high visibility, the only negative factor being the tough competition that comes from the likes of Solar and Pratt & Whitney Canada.

Given that much of the power generation growth in the future is expected to be in the cogeneration and combined-cycle cogeneration sectors, we are projecting that an estimated 130 machines will be built through 2010. Of that total, 35-40 machines are expected to be utilized in the cogeneration arena.

Ten-Year Outlook

ESTIMATED CALENDAR YEAR PRODUCTION

Engine /Machine	Application	thru 2000	High Confidence Level				Good Confidence			Speculative			Total 2001-2010	
			2001	2002	2003	2004	2005	2006	2007	2008	2009	2010		
GEPS OIL & GAS (NUOVO PIGNONE)														
GE-2	GENERATION	23	10	12	14	14	14	13	12	12	14	15	130	
GE-2	MECHANICAL DRIVE	-		Production could occur as soon as this application is garnered.										-
TOTAL PRODUCTION		23	10	12	14	14	14	13	12	12	14	15	130	