GE Oil & Gas Steam Turbines

Outlook

- GE Oil & Gas no longer trades under this name and is now part of the Baker Hughes division of GE
- Baker Hughes is selling off its viable divisions prior to separating from GE
- The process by which GE Oil & Gas-derived assets will be either sold or liquidated is already in hand

Orientation

Description. GE Oil & Gas manufactures steam turbines for electrical generation, including combined-cycle installations.

Sponsor. Development of the GE Oil & Gas steam turbines was privately sponsored. GE Oil & Gas no longer trades under this name and is now part of the Baker Hughes division of GE.

Power Class. Power output/ranges of the GE Oil & Gas steam turbines range from 1 to 100 MW, with emphasis on the 10 to 50 MW sector. The GE Triveni joint venture produces steam turbines in the 30-100 MW sector. Higher output steam turbines are produced by GE Energy and are covered in a separate report.

Status. The GE Oil & Gas steam turbines are in production.

Total Produced. Total production of steam turbines by GE Oil & Gas represents 710 mechanical drive units totaling 4,400 MW and 250 power generation units totaling 3,330 MW.

Application. GE Oil & Gas designs and manufactures a complete line of steam turbines for mechanical and generator driver applications. This product line encompasses impulse/reaction-type steam turbines, including multi-valve condensing and multi-valve backpressure steam turbines. These machines are designed for service in chemical, petrochemical, and industrial plants as single drivers or as part of a GE Oil & Gas turboset.

Price Range. Since these turbines are optimized to individual customer requirements, the price range varies.

Competition. These steam turbines compete with steam turbines from Mitsubishi, Doosan-Skoda, Fuji, Fincantieri, LMZ, Siemens, and MAN.

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Contractors

Prime

Baker Hughes (BHGE)	http://www.bhge.com, Via Felice Matteucci, 2, Florence, Italy, Tel: + 39 55 423 211, Fax: + 39 55 423 2800, Prime
Baker Hughes (BHGE)	http://www.bhge.com, Tour Framatome, Cedex 16, Paris La Defense, France, Tel: + 33 1 475 6407, Fax: + 33 1 475 6401, Second Prime
Triveni Turbines Ltd	http://www.triveniturbines.com, 12-A Peenya Industrial Area, 560 058, Bangalore, Karnataka, India, Tel: + 91 8022164000, Fax: + 91 8022164100, Email: mktg@triveniturbines.com, Co-producer

Contractors are invited to submit updated information to Editor, International Contractors, Forecast International, 22 Commerce Road, Newtown, CT 06470, USA; rich.pettibone@forecast1.com

Technical Data

Performance.

Turbine Code	**SC/SAC**	**SNC/SANC**	**A5/A9**	**SDF**
Turbine Type	**Condensing**	**Backpressure**	**Reheat**	**Double Flow**
Power range	2-100 MW	1-50 MW	20-100 MW	5-100 MW
Speed range	3,000-16,000 rpm	3,000-16,000 rpm	3,000-3,600 rpm	3,000-16,000 rpm
Max. live-steam pressure	140 bar	140 bar	140 bar	30 bar
Max. live-steam temp.	540°C	540°C	565°C	300°C
Max. backpressure	n/a	60 bar	n/a	n/a
Steam path	Impulse/Reaction	Impulse/Reaction	Impulse/Reaction	Impulse/Reaction

Turbine Code	**P**	**MP**	**C**	**MC**
Turbine Type	**Backpressure**	**Backpressure**	**Condensing**	**Condensing**
Power range	up to 5 MW	up to 40 MW	up to 6 MW	up to 40 MW
Speed range	up to 16,000 rpm	up to 16,000 rpm	up to 16,000 rpm	up to 16,000 rpm
Max. live-steam pressure	80 bar	150 bar	80 bar	150 bar
Max. live-steam temp.	480°C	540°C	480°C	540°C
Max. backpressure	20 bar	60 bar	n/a	n/a
Steam path	Impulse	Impulse	Impulse	Impulse
Steam injection API 612	No	Yes	Yes	Yes
Steam extraction API 612	No	Yes	Yes	Yes

n/a = not applicable

Design Features. The steam turbine machines are designed in several types, capacities, and steam conditions with a modular construction. The turbines consist of a front, rear, and intermediate section. The intermediate section for each size is standardized. Variations in turbines are achieved by attaching the relevant front and rear sections for optimal performance of the desired application.

Casings. Small casings have two bearing housings directly flanged to the casing itself, resulting in automatic mutual alignment. The casing is horizontally split and manufactured of cast steel; for condensing models, the exhaust casing is cast iron or fabricated steel attached via a vertical flange to the high-pressure casing. The casing is supported by rigid legs to the rear and flexible legs in front to allow for casing thermal expansion. Valve chambers are shaped directly into the casing.

Large casings are either horizontally split or barrel type. In backpressure models, each half-casing is made of one-piece cast steel construction. Condensing turbine outer casings are made of cast steel (high-pressure section) bolted with a vertical flange to a cast-iron or fabricated-steel low-pressure section. The high-pressure section is composed of either low-alloy steel for medium-steam pressure and temperatures or medium-alloy steel for high-steam pressure and temperatures.

Rotors. Small shafts are low-alloy steel forging. The easily interchangeable seals at the end, interstage, and balancing drum are the statoric labyrinth four-lobed spring-loaded type. This type of variable-geometry seal prevents rotor blocking in case of thermal bending of the rotor end or the casing. Seals can be made of 13 percent chromium steel or Ni-RESIST copper cast iron.

Large shafts are made of forged steel, with the discs of the impulse stage being integral with the shaft. Generally, the thrust collar is also integral, but it may be shrunk for special applications. Two materials may be used: low-alloy steel for low-pressure/temperature applications and high-alloy 13 percent chromium steel for high-pressure/temperature applications. For special applications, shafts have been produced with integral coupling flanges.

Nozzles. The impulse-stage nozzles are inserted into a slot machined in the inner casing. Two airfoils of several sizes and two stack angles have been standardized. The nozzle is constructed of either 13 percent chromium steel with molybdenum and vanadium for temperatures over 350°C (662°F), or 13 percent chromium steel for lower temperatures.

Blades. Stator blades consist of welded, horizontally split diaphragms supported by the casing. Moving blades are impulse type with an integral shroud and hammer or fork root, depending on the speed. The blades feature tangential entry and are mounted on discs integral to the shaft. Condensing models are equipped in the low-pressure section with a standard three-stage family of condensing blades. The blades of the reaction stages have the same airfoil as the moving blades at 50 percent of the reaction ratio. The blades, which are cantilevered in the blade carriers and held together by a riveted shroud, are made of 13 percent chromium steel.

Moving blades of the impulse stages have straddle roots, while the cylindrical blades of the reaction stages have T roots. Both types have integral shrouds. Impulse and reaction airfoils have been standardized, with the most appropriate size and stack angle selected based on application. The last group of two or three stages in condensing turbines has been standardized into low-, medium-, and high-speed applications. The moving blades in these stages, which have twisted airfoils, are all equipped with a damping wire to limit alternate bending stresses.

The last-stage moving blade is forged with a straddle root. Two materials are standard for the blades: for temperatures over 350°C, 13 percent chromium steel with molybdenum and vanadium is used; for lower temperatures, 13 percent chromium steel is used. Wetness removal devices are provided and/or leading edges are flame-hardened to help reduce erosion of the leading edges.

Steam Chest. The small steam chest is fabricated from cast steel, and is connected to the casing by a bolted flange, which, according to GE, allows the control valves to be inspected quickly and easily. The large steam chest is integrally cast with the upper half-casing.

Regulating Valves. The valve stems are chromium-hardened by the detonation gun process. The shape of the cones is optimized so that a quasi-linear ratio between steam flow and valve lift results in the best operation of the control system. The two valves at the end of the bar open simultaneously for uniform heating of the casing during startup. The remaining valves open in sequence to optimize the forces on the rotor that are produced by the steam in the impulse stage.

For generator driver applications, the cones of the first two valves are shaped for easy turbo-unit synchronization in no-load conditions. The valves are actuated by a lever that is connected to the two-valve stem, and are closed by a spring. The force of a power piston acts against steam forces on the valves and the spring force on the lever. The valves automatically close in the event of oil failure. The same system is applied to control the steam flow to intermediate- or low-pressure turbine sections when impulse stages are provided. Sections equipped with reaction stages only are throttle controlled; the valves are a double-seat type with a pressure-balanced cone due to their large size, but are actuated in the same way.

Emergency Stop Valves. Small turbines are equipped with one trip valve. This valve is a push-to-close, steam-assisted, hydraulically preloaded spring type, and is provided with an on-line exerciser. The overspeed device is electronically redundant, though a mechanical trip bolt can be supplied upon request. A standard instrument package is supplied for monitoring radial vibration, axial displacement, and bearing white metal temperature.

Larger turbines are equipped with an emergency stop valve on each live-steam inlet flange. The valve is a push-to-close type, and is provided with a small pilot valve that pressurizes the control valve chest, making differential pressure zero on the main valve so that it may be opened with minimal force. This allows the oil section to be small, thereby reducing inertia in favor of a fast closing. The valve is closed by spring without oil ejection. Steam pressure acts on the valve cone to accelerate closure.

Bearings. Bearing housings are fabricated from cast steel. The small size of these turbines allows the bearing housings to be directly flanged to the casing, resulting in automatic mutual alignment. Radial

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channels for air cooling are provided in the flange to reduce heat flow from the casing to the bearing housing. The thrust bearing is the double-action, single-collar self-equalizing Kingsbury type.

Lube and Control Oil Systems. A force-feed lube oil system helps ensure that the journal and thrust bearings – and, in generator driver applications, the gear, couplings, and generator – are properly lubricated. The electronic governor is supplied by Woodward and Tri-Sen, and may have different redundancy configurations and be custom engineered.

Operational Characteristics. GE Oil & Gas manufactures a complete line of multi-valve, multi-stage, special-purpose steam turbines of the condensing, extraction condensing, backpressure, and extraction backpressure types. The turbines are based on a building block principle, with speeds between 2,800 and 16,000 rpm. Initial steam conditions (bar/°C) as high as 140/540 are employed.

The production line also includes turbines for high power output and high speed to drive synthesis compressors in ammonia/urea, methanol, and ethanol plants. In the generator driver application, the production line also includes turbines for combined-cycle plants and energy recovery plants. Turbine/compressor, turbine/pump, and turbine/generation units with steam condensers can be supplied.

GE Oil & Gas has its own in-house test facility, and subjects all turbine components to a rigorous series of tests to guarantee compliance with design characteristics. Casings are X-rayed and submitted to hydraulic tests, while blades and shafts are checked by ultrasonic and magnetic-particle testing. Overspeed testing is performed on complete rotors. All mechanical drives, and some generator turbines, are mechanically tested before delivery. The facility is equipped with a 15-MW steam plant with live-steam conditions (bar/°C) of 55/500. When a complete turbo unit is supplied, mechanical string tests can be conducted on the complete train. Full-load, full-pressure tests with a steam balance may be carried out to the limits of the facility's test capacity.

Variants/Upgrades

SC and SAC Condensing Turbines. The power range is 2-100 MW, with speeds from 3,000 to 16,000 rpm. Maximum live-steam conditions (bar/°C) are 140/540. Condensing turbines are applied as mechanical and generator devices. The last section of two or three stages is completely standardized, with the moving blades having twisted airfoils. There are three standard families for low-, medium-, and high-speed applications. Each family has eight sizes (28, 36, 45, 56, 63, 71, 80, and 90 MW) to accommodate a variety of needs. The exhaust casing may be directed up or down, and an axial exhaust flange is available. Condensing turbines, which are used for extracting and/or injecting steam at intermediate pressures, run most efficiently when the number of stages for each blade carrier is adjusted to match the injection or extraction requirements.

SDF Double-Flow Turbines. Power is in the range of 5-100 MW, with speeds from 3,000 to 16,000 rpm. This series has a live-steam pressure/temperature up to bar/°C of 30/300. The blade carriers and exhaust casing for the smaller sizes are made from castings, while larger sizes are made of fabricated steel. This turbine has a double exhaust, and is used when the ratio between exhaust volume flow and speed is very high.

Double-flow condensing turbines have been used in mechanical drive applications as the second casing in a double-casing turbine design because of the high rotating speed required by the compressors. A double exhaust turbine may be required because of the large condensing flow caused by the recovery of low-pressure steam in conjunction with low condensing pressures.

This series is also used in geothermal applications where high steam volumes result from the low enthalpy of available steam. Due to the high steam volumes handled, this model is equipped with reaction stages only, in addition to tall blades to optimize efficiency. The stages operate using controlled throttling via external valves. The casing has four inlet flanges: two on the upper half and two on the lower half.

SNC and SANC Backpressure Turbines. Power is in the range of 1-50 MW, with speeds from 3,000-1,600 rpm. Maximum live-steam conditions (bar/°C) are 140/540. Backpressure turbines are applied as mechanical and generator drivers. In refinery applications, the turbines are installed between two steam lines of different pressures, with the exhaust steam generally being used for plant requirements. In cogeneration applications, they are used to expand steam to atmospheric pressure in a hot condenser that is used as a heat exchanger to produce hot water. They are occasionally employed as the first casing in a double-casing turbine for high-speed, high-power, high-vacuum applications, with a crossover pipe used to inject or extract steam at constant pressure.

Backpressure turbines can be used to inject and/or extract steam at intermediate pressures by adjusting the

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number of blade carriers and stages of each blade carrier to match the injection and/or extraction requirements with the best turbine efficiency.

A5 and A9 Reheat Turbines. The power output for the two models is in the range of 20-100 MW, with speeds from 3,000 to 3,600 rpm. This series has a live-steam pressure/temperature up to bar/°C of 140/565.

P Series Backpressure. The P Series engines are impulse steam turbines with a single inlet valve and a backpressure exhaust designed to drive low-power machinery. These steam turbines are commonly used for compressor driving in petrochemical and refinery applications, for power generation, or to provide emergency power in nuclear power plants.

MP Series Backpressure. This series consists of impulse steam turbines with multiple inlet valves as well as a backpressure exhaust designed to drive variable-speed machinery such as compressors, fans, blowers, pumps, and generators. Applications include petrochemical and refinery plants, power plants or CHP plants burning fossil fuels, sugar refineries, and garbage incineration.

C Series Condensing. The C Series impulse steam turbines have a single inlet valve with vacuum-condensed steam at the turbine outlet. These turbines are used to drive low-power machinery. They are commonly used for compressor driving in petrochemical and refinery applications, for power generation, and for heat recovery processes such as household garbage and waste incineration.

MC Series Condensing. The MC Series engines are impulse steam turbines with multiple inlet valves and vacuum-condensed steam at the turbine outlet to increase cycle efficiency. These machines are designed to drive variable-speed machinery such as compressors, fans, blowers, pumps, and generators. These turbines are suitable for petrochemical and refinery plants, sugar refineries, incinerators, and power plants or CHP plants burning fossil fuels. They can also be used to provide waste energy in heat recovery plants.

The MC Series turbines offer controlled extraction, a supplementary regulating action that allows the production of heat and mechanical power to be optimized based on the requirements of the application.

Program Review

Nuovo Pignone, a manufacturer of machinery, equipment, and plants for the oil, natural gas, chemical, and electric power industries, entered the mechanical equipment field in the 1900s. It is a supplier of modular systems for compression and pumping for the hydrocarbon and process industries, as well as a supplier of complete electric power generation and cogeneration plants. The head office, R&D department, and main machinery factory of this Italian entity are located in Florence.

Nuovo Pignone began manufacturing steam turbines in 1969, with the first model, the G300, installed in Italy. The machine types include backpressure, condensing, double-flow condensing, extraction, and double extraction for use in power generation.

GE acquired Nuovo Pignone in 1994, and has since continued to expand its oil and gas business through partnerships with other industry leaders. Production facilities are located at six sites in Italy: Florence (main plant and corporate headquarters, plus two manufacturing facilities), Vibo Valentia, Bari, Massa, Porto Recanati, and Talamona. Production in France takes place in Le Creusot.

Thermodyn produced steam turbines since 1903 and designed, manufactures, and services centrifugal compressors, reciprocating compressors, and steam turbines. It also supplied steam turbines for French nuclear submarines. GE Nuovo Pignone purchased Thermodyn from Framatome in 2000.

In 2010, GE Oil & Gas and Triveni Turbine Ltd formed a joint venture known as GE Triveni Ltd (GETL) to offer a portfolio of steam turbine products of 30.1 MW to 100 MW for the global industrial power generation market. Triveni Turbine Ltd is a leading industrial steam turbine manufacturer, with a dominant market share of over 60 percent in India. Over 2,500 steam turbines supplied by Triveni have been installed across 18 industries in over 50 countries, including nations in Europe, Africa, Central and Latin America, and Southeast Asia, as well as in member countries of the South Asian Association for Regional Cooperation (SAARC).

The joint venture uses proven GE Oil & Gas technology and engineering design for all steam turbines in its range. GETL turbines are being manufactured in the state-of-the-art Triveni Turbine Ltd manufacturing unit at Bengaluru, India, and are marketed under the GE Triveni brand name.

These corporate acquisitions allowed GE Oil & Gas to assume its present role as a primary supplier to the oil and gas exploration, recovery, and processing industries. An early step in the development of the

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division was integrating the steam turbines it was producing with aeroderivative gas turbines to produce a new range of combined-cycle plants. GE Oil & Gas developed tailor-made steam turbines specifically designed for combined-cycle operation with LM6000 gas turbines. These geared, compact, and factory-packaged units were designed to yield the best possible combined-cycle efficiency with the flexibility of frequent start and rapid loading. These machines are suitable both for 50 Hz and 60 Hz cycles.

In 2017, GE Oil & Gas was merged with Baker Hughes, a GE oilfield services giant. As a result, GE Oil & Gas became part of Baker Hughes, a GE company or BHGE for short. In 2018, BHGE elected to sell its Natural Gas Solutions (NGS) division, which contains much of the old GE Oil & Gas, in two related transactions. In one transaction, the NGS product line will be sold to First Reserve, an energy-focused private equity firm. That deal will transfer about 450 employees in eight countries — including three manufacturing sites in North America and the U.K. — to First Reserve.

In the other deal, Italy-based Pietro Fiorentini SpA will acquire the Talamona, Italy, branch of the NGS product line from Baker Hughes GE. About 40 employees and a manufacturing site in Talamona are included in the deal. Together these two sales are valued at around $375 million.

These sales were the result of a year-long strategic review by GE, which concluded that there should be an orderly separation from BHGE over the next two to three years and that GE Healthcare should be transformed into a stand-alone company. GE gained nearly $10 billion in value following the announcement.

Funding

The gas turbines currently produced by GE Oil & Gas were originally designed by the Italian Nuovo Pignone group and the French Thermodyn division of Framatome. The Italian products were developed using corporate resources. The situation regarding the Thermodyn products is more complex, since it is probable that major French government funding was received for the products intended for the French submarine fleet, and this may also have supported other steam turbine developments. Since these two companies were absorbed by GE Oil & Gas, it is probable that subsequent developments were funded using corporate resources.

Contracts/Orders & Options

Contractor	Award ($ millions)	Date/Description
GE Oil & Gas	N/A	Sep 2016 – Order for third natural gas liquefaction train for the Tangguh LNG facility, including GE Oil & Gas heat recovery steam generators.

N/A = Not Available

Timetable

Month	Year	Major Development
	1994	General Electric acquires over 80 percent of the stock of Nuovo Pignone
	1998	GE acquires full ownership of Nuovo Pignone
Jul	2000	GE Nuovo Pignone acquires Thermodyn from Framatome SA
May	2009	GE's High Efficiency, Advanced Technology (HEAT) steam turbine technology joins the Ecomagination portfolio
	2010	GE Triveni joint venture formed
Dec	2013	GE Oil & Gas acquires Allen Gearing Solutions, a privately held manufacturer of gears for industrial and marine applications
Aug	2016	Major service facility opened in Takoradi, Ghana
	2017	GE Oil & Gas merged with Baker Hughes to form BHGE
Jul	2018	BHGE starts selling off assets acquired from the old GE Oil & Gas

Worldwide Distribution/Inventories

Country	Year of Installation	Number
Algeria	2007 (2)	2
Argentina	1998 (1), 2007 (1)	2
Australia	1997 (1), 2000 (1), 2003 (1), 2009 (1)	4
Belarus	1998	1
Brazil	2002	2
Canada	2011	1
Chile	1997 (1), 1999 (1), 2004 (1)	3
China	1997 (2), 1998 (1), 1999 (2), 2003 (2), 2007 (1)	8
Colombia	1997 (1), 1998 (2)	3
Cyprus	1999 (1), 2000 (1), 2005 (1), 2009 (1), 2011 (1)	5
Ecuador	1997	1
Finland	1997	1
France	1997 (2), 1998 (2), 1999 (1), 2001 (1), 2002 (3)	9
Germany	1997	1
Greece	2002	1
Hungary	2011	1
India	1998 (1), 2001 (1), 2002 (5), 2003 (2), 2006 (1)	10
Indonesia	2004 (1), 2011 (1), 2012 (1)	3
Iran	1997 (1), 1999 (1)	2
Israel	1999 (1), 2002 (2), 2015 (1)	4
Italy	1999 (2), 2003 (7), 2004 (2), 2005 (4)	15
Japan	1997 (2), 2000 (1), 2001 (1), 2004 (1), 2005 (1), 2006 (1), 2007 (1), 2010 (1)	9
Korea	1998 (1), 2000 (1), 2006 (1)	3
Lebanon	1998 (1), 1999 (1)	2
Malaysia	2003	2
Mexico	2002 (2), 2003 (1), 2014 (1), 2015 (1)	5
Morocco	2000	1
Nigeria	2005 (1), 2007 (1)	2
Oman	2003 (1), 2007 (1)	2
Pakistan	2000	1
Philippines	1997 (1), 2015 (1), 2016 (3), 2017 (3)	8
Poland	2001 (1), 2002 (1), 2003 (1)	3
Russia	2014	3
Saudi Arabia	1998 (4), 1999 (1), 2000 (4), 2001 (1)	10
Singapore	2007 (1), 2010 (2)	3
Spain	1997 (1), 2003 (1)	2
Sri Lanka	2001	1
Sweden	2009	1
Taiwan	2000 (1), 2002 (2), 2004 (2), 2005 (1)	6
Thailand	2002 (1), 2004 (2), 2011 (1), 2017 (5)	9
Turkey	1999 (1), 2001 (1)	2
UAE	2002 (3), 2007 (2), 2010 (4)	9
U.K.	1998 (1), 2003 (1), 2005 (2), 2007 (1), 2015 (2), 2017 (3)	10
U.S.	1998 (1), 1999 (2), 2001 (1), 2002 (16), 2003 (3), 2007 (1), 2011 (2), 2012 (1), 2013 (2), 2015 (2), 2017 (3)	34
Vietnam	2003 (1), 2005 (1)	2
TOTAL		**209**

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Forecast Rationale

The GE corporate decision to merge GE Oil & Gas with the Baker Hughes division of GE to form BHGE and then to progressively separate GE from BHGE spells doom for what used to be GE Oil & Gas. The future course of action will be sadly familiar to those who have studied corporate finances over the years. The management at Baker Hughes will evaluate which of its activities have substantial commercial value and sell them. Eventually, what is left will be liquidated. This process is already underway with the recent sale of the Natural Gas Solutions division.

In this environment, the main issue for what used to be GE Oil & Gas is that its steam turbine product line has a preponderance of products used for mechanical drive applications. This mechanical drive sector is under serious pressure from gas turbines, especially aeroderivative units, and as well as from gas-powered diesels. Both have superior operating characteristics and make for simpler engineering layouts and installations than steam turbines.

From the steam (and gas) turbine perspective, the sale of the assets once held by GE Oil & Gas appears to mark the end of the group. Many of its products are dated, while others are unsuited to today's evolving environment. All too many fit into both categories. In a market besieged by overcapacity, they offer a quick and easy means of eliminating one contributor to that situation. It appears likely that in a few months, or years at the most, the company and its products will have been liquidated.