Mitsubishi Hitachi Power Systems M501/M701

Heavy Industrial Engines
January 2015

Program Briefing

The Mitsubishi Hitachi Power Systems (MHPS) M501 and M701 are large, heavy duty single-shaft, axial-flow industrial gas turbines based on the Westinghouse 501 (now Siemens SGT6; see report herein).

MHPS is well-positioned to take advantage of the brightening economic picture in Asia, especially China. During the next 10 years we forecast the production of 280 M501 and M701 gas turbines, all for combined cycle plants. We expect annual production levels to be relatively level throughout the forecast period. Total value of the engines (nor including associated plant gear) to be $10.7 billion.

Quick Specs:

Power Class:	185 – 489 MW
Thermal Efficiency:	39.5% (SC) - 58.7% (CC)
Heat rate (@ISO):	1,482 – 2,326 kcal/kWh

Manufacturer

Mitsubishi Power Systems
16-5 Konan 2-chome
Minato-ku
Tokyo 108-8215
Japan
fax:+81-3-6716-3439
website: www.mhi.co.jp/power/e_power/index.html

Technical Description

Components

Layout

Single-shaft, axial-flow, heavy duty industrial gas turbine.

Compressor

Advanced profile airfoils. Bolted rotor construction. Radial pins between discs to assure torque transmission. One variable inlet guide vane to maintain part-load performance. The M701G2 has 14 stages and a 21:1 compression ratio.

Combustor

Can-annular dry low-NOx combustors. Steam-cooled transitions. Bypass valve for part-load stability. Combustor outlet temperature is 1,500°C-class.The M501G has 16 can-annular combustors. The M701G2 has 20 can-annular combustors.

Turbine

Four stages of full 3-D blades and vanes. First three stages are air cooled.

Summary Forecast

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	Total
Units Produced	28	28	28	28	28	28	28	28	28	28	280
Value (2015 $ Millions)	1,070	1,070	1,070	1,070	1,070	1,070	1,070	1,070	1,070	1,070	10,700

Specifications

Simple Cycle Applications

	M501F3	*M701F3*
Power Output :	185 MW	270 MW
Frequency:	60 Hz	50 Hz
Heat Rate-LHV:	2,326 kcal/kWh	2,250 kcal/kWh
Efficiency	n/a	n/a

	M501G	*M701G2*
Power Output :	254 MW	334 MW
Frequency:	60 Hz	50 Hz
Heat Rate-LHV:	n/a	n/a
Efficiency	n/a	39.5%

Combined Cycle (one gas turbine + one steam turbine)

	M501F3	*M701F3*
Power Output:	279 MW	399 MW
Heat Rate-LHV:	1,531 kcal/kWh	1,511kcal/kWh
Efficiency:	n/a	n/a

	M501G	*M701G2*
Power Output:	371 MW	489 MW
Heat Rate-LHV:	1,482 kcal/kWh	1,482 kcal/kWh
Efficiency:	n/a	58.7%

Marketing Data

Costs

Our estimated value for the Mitsubishi M501F is $34.9 million, for the M701F is $49.1 million, for the M501G is $47 million, and for the M701G is $60.1 million.

Recent Orders

June 2008—MHI received consecutive orders for blast-furnace-gas (BFG) fired gas turbine combined-cycle (GTCC) power generation plants from China and Korea. The equipment for a 150-MW BFG-GTCC power plant for Qian'an Iron and Steel Works, part of the Shougang Group, a major Chinese steelmaker, is slated for delivery in May 2009.

The equipment for two 142 MW plants of the same kind, 284 MW in total, are for POSCO Power Corporation, the largest IPP (independent power producer) in Korea and are scheduled for delivery in 2009 and 2010, respectively. POSCO Power is building the power plants at Gwangyang Works of POSCO, the Korea's largest steel company headquartered in Pohang. Mitsubishi Corporation will handle the trade particulars for both orders.

July 2008—MHI boosted its cumulative orders for gas turbines from the Middle East to 80 units with the receipt of two new orders: one for eight units for a large-scale power generation and desalination project by the Ras Laffan C independent water and power producer (IWPP) in Ras Laffan Industrial City, Qatar, and the other for one unit for a electricity and steam cogeneration project at the Karan Gas Facilities of Saudi Arabian Oil Company (Saudi Aramco), the state-owned national oil company of Saudi Arabia.

November 2008—MHI signed a contract with Dongfang Turbine for supply of major components for gas turbine combined cycle power generating facility. MHI is to supply some of the gas turbine high temperature parts, control modules, and steam turbine blades to Dongfang Turbine, and Dongfang will manufacture and assemble the gas turbine and steam turbine, and deliver them to Belarus-Minsk-Power Plant 5 (the final customer).

This is a 40-MW gas turbine combined cycle power plant with one gas turbine (701F type) and one steam turbine. Start of operations is planned for the end of October 2011, and is expected to contribute to stable power supply in the Minsk region.

This project is the first time that Dongfang Turbine has used MHI licensed equipment in another country, and is expected to deepen cooperative relations between the companies.

November 2008—MHI received an order from Técnicas Reunidas, SA, and a Spanish engineering company, for two sets of its natural gas-fired 150-MW M501F generators for a large-scale oil and gas production/processing project of Saudi Arabian Oil Company (Saudi Aramco), Saudi Arabia's state-owned oil firm. The latest order brings the cumulative number of gas turbines ordered for Saudi Aramco to seven units.

January 2009—MHI received an order for an 800-MW natural gas-fired GTCC power generation system from ENMAX Green Power Inc., a subsidiary of ENMAX Corporation, a Canadian electricity provider. The system is destined for the Shepard Energy Centre to be newly built near Calgary, Alberta, and slated to be online to serve the winter load of 2012.

January 2009—MHI received a full-turnkey order for a 750-MW natural gas-fired GTCC power plant from PT. PLN (Persero), Indonesia's state-owned electricity company. The project is to construct a new GTCC power plant on the premises of existing Tanjung Priok Power Plant, located approximately 10 km northeast of the central part of Jakarta. The plant is slated to go on-stream in November 2011.

June 2010—MHI received an order for major components of natural gas-fired GTCC power generation systems with heat supply capability, to be installed in a cogeneration facility built by Huaneng Power International, Inc., one of the major electricity providers in China. The order was placed through Dongfang Turbine Co., Ltd., a major power generation equipment manufacturer in China to which MHI has licensed its gas turbine technology. MHI is to provide two M701F gas turbines as well as major components of a steam turbine. Delivery of the gas turbines in February and March of 2011.

Installations (not comprehensive)

Location	***Equipment***	***Total power***	***Start-up***	***Note***
Tohoku Electric Higashi Niigata No. 3 unit	6xM701D	1,090 MW	1984	combined cycle
Turkish Electricity Generation & Transmission Co., Bursa, Turkey	4xM701F	1,400 MW	12/1999	2 x 2-on-1 combined cycle
Altamira-II Combined Cycle Power Plant, Mexico	2xM501F	495 MW	5/1/2001	combined cycle
CFE, Chihauhua Combined Cycle Plant, Mexico	2xM501F	434.65 MW	5/8/2001	2-on-1 combined cycle
Electricidad Aguila de Tuxpan S de RL de CV, Tuxpan-II Combined Cycle Power Plant, Mexico	2xM501D	495 MW	12/12/2001	combined cycle; dual fuel
Gas & Power Co., Ltd., Japan	1xM501DA	149.9 MW	4/1/2002	combined cycle
AES Parana, Costanera Power Plant, Argentina	2xM701F	830 MW	5/2002	combined cycle
KEPCO Ilijan Corp., Ilijan, Batangas, Philippines	4xM501G	1,251 MW	5/31/2002	combined cycle
Syria Electric Power Authority, Jandaar Combined Cycle Plant		4xM701D	n/a	2003 combined cycle
Tuxpan #3 & #4, Mexico	4xM510F	1,000 MW	May 27, 2003	combined cycle
Covert Generating Project, Covert, MI	3xM501G	1,082 MW	Summer 2003	combined cycle
Mystic power plant, Boston MA		4xM501G	1,688 MW	June 2003 2 x 2-on-1 combined cycle
Nanpu No.4, Kaohsiung, Taiwan		1xM501F	248 MW	June 30, 2003 1-on-1 combined cycle

Tenaga National, Kuala Lumpur, Indonesia	2xM701D	750 MW	2004	combined cycle
Star Energy Power Corp., Chang Bin Power Station, Taiwan	2xM501F	490 MW	September 2004	2-on-1 combined cycle
Sun Ba Power Corp., Fong Der Power Station, Taiwan	4xM501F	980 MW	September 2004	2 x 2-on-1 combined cycle
Tenga Nasional Berhad, Port Dickson, Malaysia	2xM701F	714.6 MW	June 13, 2005	2-on-1 combined cycle

Milestones

Date	***Milestone***
1989	Full-load shop test of M501F
1997	Commercial operation of M501G
1992	Commercial operation of M701F/M501F
1999	Original M701G enters service
2002	Mitsubishi completes the M701G2 gas turbine shop load test
2004	Mexico orders two M501F gas turbines, two heat recovery steam generators, and one steam turbine for a 495 MW gas turbine combined cycle power plant.
2004	MHI completed delivery of three M501G gas turbines and three steam turbines for the Covert Generating Project located in Covert, Michigan.
2004	New Zealand orders one MHI M701F gas turbine for power plant
Jul. 13, 2009	MHI ships its 500th industrial turbine
Mar. 31, 2010	First M701F4 begins trial operation in Sendai No.4, Japan

Program Overview

Background

Early Development

Takasago Machinery Works was established in 1962 as a dedicated turbine manufacturing plant of MHI's Kobe Machinery Works; it became independent in 1964. Manufacture of industrial-use gas turbines was launched in 1963, and its first unit, an MW171 gas turbine with inlet temperature of 732 degrees Celsius (about 1,350 degrees Fahrenheit), was delivered to the Chiba Plant of Asahi Glass Co., Ltd.

MHI continued to focus on increasing turbine inlet temperatures as a means to improve overall efficiency. In 1989 the company commercialized the 1,350 degrees C-class M701F and in 1996 developed the 1,500 degrees C-class G-Series.

G Series Development

On April 7, 1997, the first 501G gas turbine achieved full-load operation at MHI's Takasago Combined Cycle Power Plant. The plant features a multi-shaft design with a rated 330 MW base load operating on LNG fuel. A natural circulation heat recovery steam generator operates at triple pressure without reheating, supplying steam to a steam turbine featuring a fully air-cooled steam condenser and dry cooling tower.

DLE Combustion System Developed

Beginning in 1980, MHI embarked on development of a dry low emission combustion system at the behest of the Japanese utility Tohoku Electric Higashi Niigata. In an effort to lower NOx emissions without the need for water- or steam-injection, MHI tried various schemes finally settling on the installation of a pilot burner and the application of an air bypass system. The DLE method initially lowered NOx emissions to 75ppm, but subsequent developments have lowered that number to 25ppm.

The first DLE system went into operation in 1984 when MHI delivered six M701Ds to Tohoku Electric Higashi Niigata No. 3 unit.

M501H

In March 2001, Mitsubishi successfully finished the load test, including closed-loop steam cooling in the combined cycle system of the new steam-cooled M501H.

M701G2

The M701G2 gas turbine melds the proven performance of the M701G and an advanced compressor

from MHI's M501H gas turbine activity. The original M701G went into commercial operation in 1999.

The M701G2 is presently the most advanced commercial offering from MHI for the 50Hz power generation market, having a 1x1 combined cycle efficiency of 58.7% with output of 489MW, respectively. The primary objective of the M701G2 gas turbine was to marginally introduce H technology without upsetting the proven reliability track record of the original M701G gas turbine. The M701G2 shop load test was successfully completed in May of 2002 at MHI's Takasago factory. The test was up to approximately 40% load due to the factory load absorbing facility limitation.

The M701G2 gas turbine's unit rotor is of bolted construction with a positive torque incorporating such features as radial pins and curvic couplings, respectively. The rotor is supported by two-element tilting pad bearings and an upper-half fixed bearing. The thrust bearing is a double-acting type that uses the leading-edge groove lubrication system. The air inlet system, which contains a silencer, delivers air to the compressor via a plenum bell mouth and houses the inlet, main journal and thrust bearings. There are four stages in the turbine so as to maintain moderate aerodynamic loadings even at the increased firing temperature and pressure ratio, as in the case of all Mitsubishi large frame industrial gas turbines. The combustion system consists of a 20-can annular combustor with almost the same diameter and length as the M501G (the 60 Hz version), which has 16 such combustors. The low NOx hybrid combustor design is an improvement over the current highly successful design that has been in commercial operation in the M501F/M701F fleet for natural gas and liquid fuel firing. The transition piece is cooled by steam through a double-wall structure for more uniform cooling effectiveness. The presence or absence of flame and the uniformity of fuel flow distribution across the combustors are monitored by thermocouples located downstream of the last stage turbine blades. These can also detect combustor malfunctions when at load, while the ultraviolet detectors are used to sense ignition during the initial starting phase.

MRO

MHI Offers LTSAs

MHI offers long-term service agreements (LTSAs) for any of its manufactured gas turbines, as well as for any associated equipment, such as steam turbines, DCS, and generators. Terms of the LSTAs normally are six to 12 years and cover provision of necessary man power, replacement parts, and maintenance engineering support. The main services provided include planning of scheduled inspection and hot parts management; maintenance engineering service; trouble shooting; and Remote Monitoring Service.

MHI also offers long-term parts supply (LTPS) contracts in lieu of an LSTA. Terms are four to six years, during which supply of replacement parts is guaranteed.

November 2001—San Ishidro SA, a Chilean company, and MHI signed an LTSA on November 14, 2001. The LTSA covers four years of maintenance on one M701F Gas Turbine. The LTSA stipulates that MHI will supply new parts, repair parts, and consumables, and will dispatch supervisory and engineering service staff members to conduct inspections and maintenance work.

October 2002—ENDESA Chile signed a contract for the agreement on the LTSA (M701F gas turbine: 1 unit for 4 years) for the San Isidro power plant in Chile, and LTSA (M701F gas turbine: 2 units for 6 years) for Costanera power plant in Argentina.

July 2008—MHI signed a long term parts management (LTPM) contract for Maanshan GTCC plant (150 MW) with Maanshan Iron & Steel Co. in China. The contract was received via Mitsubishi Heavy Industries BFG Gas Turbine Service (Nanjing) Co., Ltd., MHI's blast furnace gas fired gas turbine after service subsidiary in China. This plant is a GTCC power plant consisting of one-on-one-shaft configuration using the M701S(DA) gas turbine. This is a unit price contract over 4 years (2008-2012) for supply of high temperature parts and spares, dispatch of technical adviser, and maintenance.

October 2009—MHI concluded five new LTSAs in Egypt, Turkey, Australia and Argentina. Under the new agreements MHI will provide supply, maintenance and repair services for components that are exposed to very high temperatures as well as expendable parts, and also dispatch engineers to the sites.

The five facilities subject to the newly concluded LTSAs are power generation plants at the Sidi Krir and El Atf Power Stations in Egypt, the Bandirma Power Station in Turkey, the Tamar Valley Power Station in Australia and the Costanera Power Station in Argentina. The plants are either new constructions going on-stream in 2009 or 2010, or existing plants subject to LTSA renewal.

Current Developments

MHI Begins Chinese Production

In 2005, Mitsubishi launched local production in China of gas turbine core components under a new joint venture. In July 2004, the Chinese government granted approval for the venture, Mitsubishi Heavy Industries Dongfang Gas Turbine (Guangzhou) Co. Ltd. MHI owns 51% of the company with local Dongfang Steam Turbine Works owning the remainder. MHI is furnishing the required technologies, starting with coating processes for M701F and D-type gas turbines. Eventually, production will expand to rotor blades and stator vanes.

New GE/MHI Steam Turbine

In June 2009, GE Energy and Mitsubishi Heavy Industries announced that they had signed final agreements regarding the co-development of a "next generation" steam turbine (original MoU signed in January 2009). The new unit will be used in cogeneration plants featuring GE's FA series and MHI's G series of gas turbines.

Under terms of the agreement the two companies will jointly develop the steam turbine and then separately market and build the unit for use in their proprietary 50-Hz systems.

New Plant in Savannah

In September 2009, MHI announced a plan to build a gas turbine manufacturing plant in the US, and as the plan's initial phase the company will construct a plant near Savannah, GA, to produce combustors, targeting production launch by the end of 2010. The plan also calls for MHI to develop this initiative further, taking subsequent market conditions into account, toward the establishment of a base in the US to both manufacture and service gas turbines. With the establishment of this base in North America, where significant increase in demand for gas turbine combined cycle power generation systems is expected, MHI aims to enhance its worldwide gas turbine production capacity to 50 units per year.

New J Series

MHI completed development of the J series gas turbine, incorporating in the spring of 2009 and has subsequently worked on its commercialization. The new turbine is able to withstand 100 degrees higher temperature than the 1,500°C-class G-Series gas turbine, the top-of-the-line until now. The 60-Hz W501J gas turbine achieves a rated power output of about 320 MW simple-cycle and 460 MW in combined-cycle applications. MHI says it has achieved over 60% gross thermal efficiency.

MHI says that it plans to commence delivery of the new variant to customers in 2011.

Teal Group Evaluation

MHPS is well-positioned to take advantage of the brightening economic picture in Asia, especially China. During the next 10 years we forecast the production of 280 M501 and M701 gas turbines, all for combined cycle plants. We expect annual production levels to increase slightly each year throughout the forecast period. Total value of the engines (not including associated plant gear) to be $10.7 billion.

Production Forecast

Units	Thru 2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	Total
Power Generation												
earlier models	85	—	—	—	—	—	—	—	—	—	—	85
M501D	20	—	—	—	—	—	—	—	—	—	—	20
M501F	99	—	—	—	—	—	—	—	—	—	—	99
M501G	83	6	6	6	6	6	6	6	6	6	6	143
M501J	21	6	6	6	6	6	6	6	6	6	6	81
M701D	91	—	—	—	—	—	—	—	—	—	—	91
M701F	150	—	—	—	—	—	—	—	—	—	—	150
M701G	74	8	8	8	8	8	8	8	8	8	8	154
M701J	32	8	8	8	8	8	8	8	8	8	8	112
Total	**538**	**28**	**28**	**28**	**28**	**28**	**28**	**28**	**28**	**28**	**28**	**564**

Value (2015 $Millions)	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	Total
Power Generation											
M501G	270	270	270	270	270	270	270	270	270	270	2,700
M501J	360	360	360	360	360	360	360	360	360	360	3,600
M701G	440	440	440	440	440	440	440	440	440	440	4,400
M701J	480	480	480	480	480	480	480	480	480	480	4,800
Total	**1,070**	**1,070**	**1,070**	**1,070**	**1,070**	**1,070**	**1,070**	**1,070**	**1,070**	**1,070**	**10,700**

