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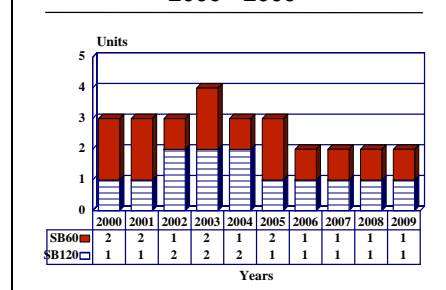
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Mitsui SB60/SB90/SB120 - Archived 4/2001

Outlook

- Capable of burning a wide variety of non-standard fuels such as blast-furnace gas, landfill gas and various industrial waste gases
- Low-calorific-value fuels make it suitable for robust conditions
- Potential sales market arena is still Far East, Asia and Australasia
- Japan of most interest once it shakes current recession
- Sold thus far in India, Bangladesh, Australia and Japan

10 Year Unit Production Forecast
2000 - 2009



Orientation

Description. Single- and twin-shaft, axial-flow industrial gas turbine machines in the 12-23 MW class.

Sponsor. The SB60/SB90/SB120 series was privately developed by the prime manufacturer/contractor.

Contractors/Manufacturers. The prime manufacturer is Mitsui Engineering & Shipbuilding Company Limited, Energy Plant Division, Tokyo, Japan. The US representative for the company is Mitsui Zosen (USA) Inc, New York, New York.

Licensee. John Brown Engineering Limited, Clydebank, Dunbartonshire, Scotland, UK (for uprated Model SB60).

Power Class. The approximate power output (ISO base load, oil fuel) of the Mitsui series is as follows:

Model	Output
SB60-2 ^(a)	12,490 kW
SB60-1 ^(b)	13,570 kW
SB90 ^(c)	16,810 kW
SB120	23,000 kW

^(a)Twin-shaft version.

^(b)Single-shaft version.

^(c)Model withdrawn from the market in 1995.

Status. The SB60-1/-2 and SB120 are in production. The SB90 Model was withdrawn from the market in 1995.

Total Produced. By early 2000, an estimated 11 SB60-1/-2s, six SB90s, and two SB120s had been built.

Application. Generator drive for use in simple-cycle, combined-cycle and cogeneration duty; mechanical load driver for pipeline and process industries.

Only one machine in this series has been installed for mechanical load driver duty.

Price Range. Estimated in 1999 US dollars as follows: SB60 gas turbine generator package, \$5.95-\$6.45 million; SB120 gas turbine generator package, \$9.75-\$10.1 million.

Competition. The chief competition to the in-production machines in this series is as follows:

SB60. Machines that compete most notably against the SB60 include the Mitsubishi MF-111, Nuovo Pignone PGT10 and PGT16, and GE M&I LM1600(PA).

SB120. Machines that compete most notably against the SB120 include the Nuovo Pignone PGT25, GE M&I LM2500(PE), and ABB GT10.

Technical Data

Design Features. Mitsui gas turbines have the following design features: double-shell turbine construction with an outer casing internally lined with insulation and cooled by compressor air, and an inner casing fitted with an insulating liner ring to reduce thermal stress; a center-plane horizontally split casing, allowing ease of inspection and maintenance; and the ability to burn a variety of fuels.

Compressor. Models SB90 and SB120 have 10 axial stages (SB60 has 16 stages) and a single compressor rotor. Blades of 13 percent Cr stainless steel and 17-4PH; stator blades of 13 percent Cr steel.

Combustor. Single-can reverse-flow combustor design, with combustor mounted directly on turbine casing. The primary combustion chamber has three fuel nozzles, each surrounded by a swirler on its head.

Combustor flame tube of Hastelloy X; outer casing of carbon steel and 18 percent Cr 8Ni stainless steel. A series of interchangeable combustors allows the burning of a wide range of low-grade fuels.

Turbine. Four-stage turbine design. Stage 1 blades of U710, Stages 2-3 of IN700, stage 4 of A286. Stage 1-2 nozzles of X40; Stages 3-4 of LCN155. Stage 1 blades are air-cooled.

Bearings. SB60 has four tilting-pad journal bearings and two tilting-pad thrust bearings; SB90 has two tilting-pad journal bearings and one tilting-pad thrust bearing.

Accessories. Diesel electric starter is standard, with electric motor or gas expansion starting optional. Control system is of solid-state design, manufactured by Woodward Governor Company.

Dimensions. Approximate dimensions of the Mitsui gas turbine series are as follows:

	SB60-1	SB60-2	SB90	SB120
Length (mm)	6900	7400	7300	9400
Width (mm)	3300	3300	3200	5200
Height (mm)	4500	4500	5200	6000
Weight, dry (kg)	52,000	54,700	60,000	90,000

Performance. Approximate performance parameters of the Mitsui gas turbine series are as follows (ISO base rating, based on standard liquid fuel):

Model	Output kW	Heat Rate Btu/kWh	Mass Flow kg/sec	EGT °C
SB60 ^(a)	12,490	11,490	55.3	456
SB60 ^(b)	13,570	11,530	59.4	492
SB90 ^(c)	14,100	-	85.8	510
SB120	23,000	11,190	101.0	475

^(a)Two-shaft version.

^(b)Single-shaft version.

^(c)Version no longer offered.

Variants/Upgrades

Among the major variants in the Mitsui SB60/SB90/SB120 series are the following:

SB60. The standard SB60 is a twin-shaft machine, featuring a 16-stage compressor, two-stage compressor turbine and two-stage power turbine. Six variable vane stages are standard. Pressure ratio is approximately 13.2:1 for the two-shaft version and 12.1:1 for the single-shaft version. Compressor design speed is 6,780 rpm, with a speed range of 5,760-7,120 rpm. Power

turbine design speed is 5,680 rpm, with speed range of 3,400-8,520 rpm. Air flow rate is 131 lb/sec (59.4 kg/s) at base load. The normal SB60 drives from the cold end, although for CHP applications the annular exhaust can be configured to discharge to the side.

Development of a single-shaft SB60 was begun in 1986, and the first single-shaft machine was installed in Chiba, Japan, for Mitsui Petrochemical Industries for generator drive in a cogeneration plant operation. John

Brown Engineering (JBE) developed an uprated SB60, which was ready in early 1989. The first twin-shaft SB60-2 became available in 1991.

SB90. The SB90 was an axial-design unit featuring 10 rotor stages and 12 vane stages. Pressure ratio was rated at approximately 6.2:1. Compressor and turbine design speed of this machine was 5,475 rpm, with a compressor speed range of 5,200-5,749 rpm. Air flow was rated at 171 lb/sec (77.56 kg/s) at base load.

After a 30-year run, this machine was pulled from the company's product offering in 1995.

SB120. The SB120 is an axial design unit featuring 10 rotor stages, having a power output of 23,000 kW. Pressure ratio is approximately 11.7:1. Power turbine speed is 5,070 rpm. Air flow is 225 lb/sec (102 kg/s) at base load. Exhaust temperature is 475°C (887°F). One unit has been built, for the Showa Yokkaichi Sekiyu Company for its petroleum refinery in Yokkaichi, Japan; the machine was installed in 1986. The facility includes steam injection to reduce NOx emissions, and the gas turbine unit is connected to a waste heat boiler to generate approximately 50 tons/hr (45.4 tonnes/hr) of steam at 320°C.

Program Review

Background. Mitsui Engineering & Shipbuilding entered the gas turbine marketplace in 1949 with a gas turbine machine of its own design. In 1963, after several years of internal development and redesign, the firm began designing a prototype open-cycle gas turbine machine for industrial use. The early model, Model SB15, ran at 1,350 kW and was completed in 1965.

Although work had concentrated on machines of lower power output, in 1967, an order placed with Mitsui for two 8,000 kW machines from the Toyo Engineering Corporation spurred the development of machines of higher power outputs. The machines, designated SB90, were quickly developed, with the Toyo units installed at a fertilizer plant in Bangladesh (then East Pakistan). In 1979, the latest model in the 10,000+ kW series, the SB60, was introduced: that is the only twin-shaft model in the Mitsui series. In 1982, Mitsui completed the development of the SB120, an enlarged SB60, with modification of the design from the two-shaft to a single-shaft arrangement. One SB120 was fabricated, and was installed for generator drive in early 1986.

Despite their long history of activity in the industrial gas turbine market, Mitsui Engineering & Shipbuilding's SB Series' delivery total amounted to just 80 machines as of spring 1997. A total of 16 machines in the SB60/SB90/SB120 class had been delivered as of that time. Of these, only a few SB90 and the sole SB120 machines have found users requiring their power and fuel-type flexibility. That total is quite surprising, as the firm's market niche is its

ability to burn a wide variety of non-standard fuels such as blast-furnace gas, landfill gas and various industrial waste gases, all of which are characterized by low calorific value – an aspect that should be appealing to a wide geographic area.

It may have been that very aspect that caused John Brown to market the SB60. This multi-fuel capability will probably remain a key sales tool of the Mitsui machines in simple-cycle and mechanical drive configurations for the fast-developing Golden Triangle nations of Southeast Asia. No doubt, this region has diverse fuel resources upon which to draw power from, and Mitsui would appear to have the machines with the capability to harness that diversity.

Mitsui SB Series in Combined-Cycle Plants. Mitsui also manufactures heat recovery boilers and steam turbines. Gas turbine exhaust gas can be utilized as a heat source of steam generation or as additional electricity. Fuel can be more efficiently utilized by adding a waste heat recovery boiler and turbine system to a Mitsui gas turbine plant to generate process steam or to drive a steam turbine.

The Mitsui SB series machines are available in combined-cycle arrangements, including a generator, steam turbine, electric and ancillary controls, a de-aerator, and a waste heat boiler. Total generated output (gas turbine output + steam turbine output) is as follows (at ambient temperature of 15°C):

<u>Parameter</u>	<u>SB60</u>	<u>SB90</u>	<u>SB120</u>
Total Output (kW)	20,800	24,200	32,810
Heat Rate (kJ/kWh)	8681	9183	8488
Heat Rate (kcal/kWh)	2074	2194	2028

Mitsui/John Brown Engineering Agreement. In 1986, Mitsui and John Brown Engineering (JBE) signed an agreement that allowed JBE to manufacture and

market an uprated and improved version of the SB60. The uprated JBE SB60 has a pressure ratio of 13.7:1, up from 12.4:1, and a 100°C higher turbine inlet

temperature, all without a major increase in mass flow. The overall efficiency is approximately 31.5 percent at the output shaft coupling. Under the agreement, Mitsui supplies rotors and stationary blading. JBE then manufactures casings and other parts, although it has latitude in the design of the overall package and specification of auxiliary equipment. While various Mitsui combustor designs are available to JBE for the SB60, combustors are not included with the equipment supplied from Japan, thereby giving JBE the ability to

buy from Mitsui, to build its own, or to buy from other suppliers in Europe. Much of the overall SB60 package is sourced in Europe.

Agreement with Solar. In 1996, Mitsui signed a packaging agreement with Solar Turbines for the Solar Centaur 40 and 50, Taurus 60 and 70, and Mars 90 and 100. Mitsui's SB series is specialized for the market in fuels that the Solar machines do not burn, with the exception of the Mitsui SB5, which does not compete against any Solar machine.

Funding

Government funding specifically pertaining to this Mitsui series has not been identified.

Recent Contracts

No major identifiable commercial or military contracts pertaining to this Mitsui series have been announced.

Timetable

Among the major events in this Mitsui series are the following:

<u>Month</u>	<u>Year</u>	<u>Major Development</u>
	1967	First order for SB90 placed
Jul	1968	First SB90 start-up attained
	1979	SB60 introduced
Oct	1980	First SB60 start-up attained
	1982	Development completed on SB120
Feb	1986	First start-up of SB120 attained
Mid	1986	Mitsui/John Brown Engineering agreement concluded
Apr	1987	Start-up of first single-shaft SB60 attained
	1995	SB90 machine model withdrawn from the market
Thru	2009	Continued production and/or availability of SB60 and SB120 projected

Worldwide Distribution

By the year 2000, an estimated 19 machines in the SB60/SB90/SB120 series had been built and shipped (including one SB120). Among the major customer nations are **Australia, Bangladesh, India and Japan.**

Forecast Rationale

The Mitsui SB60 and SB120 are expected to be available to meet the growing power demands of the East Asian nations, once the '97 economic crash eases its grip on the key players. The SB60 is projected to have slightly higher sales than the SB120, since it is available in both single- and twin-shaft configurations.

In Europe, however, John Brown Engineering will likely find sales of the SB60 very tough going due to the availability of numerous gas turbine machine models in that power class, particularly from Rolls-Royce, as well as GE and its licensees. These

competitors should really have an edge in the European market with their heavy market penetration there and the strong support structure. Besides those players, Europe is, of course, the stomping ground of ABB Alstom Power, Siemens and other well-established families.

On the other hand, the multi-fuel capability of Mitsui machines makes them ideal for conditions where prime-quality natural gas or kerosene is not available. Considering that power consumption worldwide will grow significantly over the next several years, these

machines could present a suitable solution for operators in harsh climatic conditions, such as in the tropics, and in circumstances where fuels of low-calorific value are easily obtainable in large quantities.

The anticipated rise in crude prices also might boost the use of these machines in the oil industry as pumps and

compressor drivers. In the decade extending through the year 2009, we project that an estimated 27 machines in this part of the Mitsui gas turbine product line will be built, of which perhaps 14 are SB60 models. Some of the machines built are expected to be part of power plant installations, in which Mitsui is installing much larger gas turbine machines as the main power source.

Ten-Year Outlook

ESTIMATED CALENDAR YEAR PRODUCTION

Engine	(Application)	thru 99	High Confidence Level				Good Confidence Level			Speculative			Total 00-09
			00	01	02	03	04	05	06	07	08	09	
MITSUI ENGINEERING & SHIPBLDNG													
SB120	GENERATION	2	1	1	2	2	2	1	1	1	1	1	13
SB60 (a)	GENERATION	11	2	2	1	2	1	2	1	1	1	1	14
SB90 (b)	GENERATION	6	0	0	0	0	0	0	0	0	0	0	0
Total Production		19	3	3	3	4	3	3	2	2	2	2	27

(a) Production includes licensed production by John Brown Engineering.
 (b) Model was withdrawn from the marketplace in 1995.