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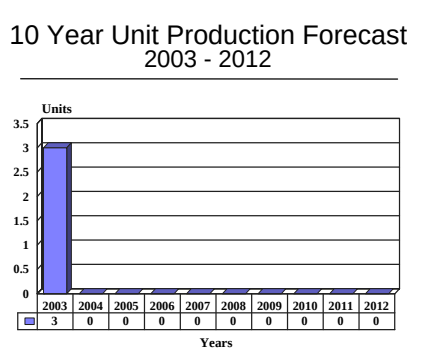
GE LM500 - Archived 2/2004

Outlook

- Ongoing interest in machines of the LM500's output for marine drive for very fast smaller vessels
- No production projected for electrical generation or mechanical load drive applications
- Production after 2003 will likely be done solely by IHI in Japan



Orientation

Description. The LM500 is a simple-cycle, two-shaft, axial-flow aeroderivative industrial and marine gas turbine in the 4-5 MW class.

Sponsor. The LM500 was privately developed by GE. The US Department of Defense, through the US Army and US Navy, sponsored work on the GE TF34 (from which the LM500 was derived) for use in the A-10A and S-3A aircraft models.

Contractors. The prime manufacturer is the General Electric Company (USA), GE Aircraft Engines, Marine Engines unit; Evendale, OH, USA. The turbine machine is manufactured in Evendale, Ohio.

Licensees. The following firms are or have been affiliated with GE on the LM500:

- Ishikawajima-Harima Heavy Industries Company Limited; Tokyo, Japan.
- Kvaerner Energie a.s., Thermal Power Division; Oslo, Norway (now a part of GEPS).
- Turbosystems International (TSI); Latham, NY, USA.
- Hitachi Limited; Tokyo, Japan (no longer active).

Power Class. The approximate power output of the GE LM500 machine in a marine propulsion role is 6,000 shp (4,474 kW).

Status. The LM500 is in production for the JMSDF Hayabusa class vessels.

Total Produced. At the start of 2003, an estimated 55 LM500s had been built.

Application. The main application of the LM500 is military and commercial marine propulsion. At least 15 machines have gone into industrial applications (10 for use as mechanical load drivers and five for electrical generation).

Price Range. Estimated in 2003 US dollars at $1.85-$2.25 million for an LM500 marine engine.

Competition. In the marine propulsion arena outside the Russian Federation and Ukraine, the LM500's main competition comes from the Rolls-Royce 501-KF5 and 501-KF7, UTC Pratt & Whitney Power Systems (PWPS) ST40, and the Vericor TF50A.

Technical Data

Design Features. Among the design features of the GE LM500 are the following:

Inlet Section. Inlet duct provides the structural connection for the forward engine mounts as well as guiding the inlet air from the ducting into the engine.

Compressor. Consists of the front frame, accessory drive assembly, compressor rotor and case/vane assembly. The front frame, a four-strut aluminum casting, provides the forward structural support and the compressor inlet flowpath. Compressor design speed is 16,500 rpm; maximum speed is 17,200 rpm.

The compressor is a single-rotor, variable stator, 14-stage axial flow type with a pressure ratio of 15:1 and an exhaust gas flow of 35.9 lb/sec (16.3 kg/sec). The compressor rotor and stator are fabricated from titanium and nickel-base alloys. The compressor rotor consists of three discs and two drums. The stator case is split horizontally and consists of two sections manufactured of M152 coated steel. Inlet guide vanes (IGVs) and stator vanes, Stages 1-5, are variable and are positioned as a function of compressor-corrected speed. All blades are removable and replaceable individually; IGVs and Stages 1-8 are removable and replaceable individually, while Stage 9-14 vanes can be removed and replaced in sectors with the compressor casing off. Forward blades are titanium, while aft blades are A286 alloy.

Combustor. Annular through-flow combustor designed for uniform temperatures and virtually smoke-free operation. Features machined ring liner construction for long life. Fuel is distributed by 18 individually replaceable injectors. Air is introduced around the individual injectors through counter-rotational swirlers mounted in the combustor dome entrance. Liner material is Hastelloy X.

High-Pressure Turbine. A two-stage, air-cooled design. The turbine rotor consists of IN718 Stage 1-2 discs which are joined together by torque couplings and drive the compressor through a splined conical shaft. Stage 1-2 blades are made of directionally solidified (DS) Rene 80 + RT 22 coating, and are both internally air-cooled. Turbine stator vanes are of X40 + CODEP coating for Stage 1 and Rene 80 + CODEP for Stage 2. Both stages are internally air-cooled, with their stationary tip shrouds being Bradalloy-filled honey-comb. IN706 and IN718 casing materials.

Power Turbine. A four-stage, uncooled design. IN718 is used in the rotor, casing, and frames. The four discs carry tip-shrouded turbine blades made of Rene 77, with the first stage CODEP-coated. The power turbine speed is 7,000 rpm.

Bearings. The gas generator rotor is supported by a single front-mounted ball bearing for thrust loads and two roller bearings; the power turbine is supported by two roller bearings. The output shaft is supported by a ball bearing and a roller bearing and connects to the power turbine through the center shaft. Bearings of M50 steel.

Ignition System. Consists of an ignition excitor and two integral igniter-plug lead assemblies.

Fuel System. Operates on natural gas, marine diesel, diesel, and JP fuels.

Dimensions. Approximate dimensions and weight of the LM500 for marine propulsion duty are as follows:

	Metric Units	**English Units**
Length:	2.96 meters (2,96 m)	9.7 feet
Height:	0.91 meters (0,91 m)	3.0 feet
Weight:	905 kilograms (905 kg)	1,990 pounds

Performance. Performance parameters of the LM500 for marine propulsion duty are as follows (60 Hz, 59°F/15°C, S/L, 60% RH, no inlet/exhaust losses, liquid fuel, LHV=18,400 Btu/lb):

Application = Marine Propulsion

	Metric Units	**English Units**
Power Output:	4,474 kW (4 474 kW)	6,000 shp
SFC:	0.269 kJ/kWh (0,269 kJ/kWh)	0.443 lb/shp-hr
Thermal Efficiency:	31%	31%
Heat Rate:	11,520 kJ/kWh (11 520 kJ/kWh)	8,140 Btu/shp-hr
Exhaust Gas Flow:	16.28 kg/sec (16,28 kg/s)	35.9 lb/sec
Exhaust Gas Temperature:	565°C	1,049°F
Power Turbine Speed:	7,000 rpm (7 000 rpm)	7,000 rpm

Variants/Upgrades

At the start of 2003, no information was available from which to ascertain whether any variants or upgrades of the GEAE LM500 had been manufactured or were in development.

Program Review

Background. The General Electric (GEAE) LM500 is an industrial and marine gas turbine machine derived from the GE Aircraft Engines TF34 high-bypass-ratio turbofan aircraft engine which was developed for the Lockheed-California/US Navy S-3A Viking ASW aircraft and the Fairchild Republic/US Air Force A-10 Thunderbolt II low-level-attack aircraft, and then used, under the civil designation CF34, in the Canadair Challenger 601 aircraft.

The modular design concept permits the on-site replacement of individual parts without requiring complete engine tear-down. The borescope inspection capability of the compressor, combustor, and high-pressure turbine allows on-condition monitoring. The compressor casing is split, permitting easy access and replacement of individual blades, vanes, and vane sectors. The power turbine casing is also split to provide access to and individual replacement of blades and vanes. A water-wash manifold for compressor cleaning is provided.

Commonality. Derived from the military TF34 and commercial CF34, the LM500 maintains about 90 percent parts interchangeability. This high percentage assures optimum use and a long life for the logistic support system in place for the 3,200+ TF34/CF34/ LM500 engines currently in service.

A multitude of applications are available for the machine: industrial, for gas compression packages, oil and water pump drives, stationary/mobile generator sets and cogeneration applications; and marine, for cruise and sprint engines as well as ship service power generation. Further diversification has been explored with the development of a cool-water-mixture engine for locomotive use. An engine burning that type of fuel could be of great interest to utilities.

GE/Fiat LM500 Developmental Effort. The LM500 was initially designed in 1978 under a cooperative effort between GE and FiatAvio SpA, similar to that signed for the development and production of the LM2500. The design and development of the LM500 culminated in a 200-hour test followed by tear-down inspection in 1980. Fiat also performed the acceptance test of the engine.

As with the LM2500 program, GE builds the basic LM500 engine, while Fiat manufactures the unique parts for conversion of the engine into a marine and industrial turbine.

LM500 Packagers. The LM500 was formerly packaged by Turbosystems International (TSI), Latham, New York (known even earlier as Norwalk Turbo), under a November 1980 agreement (the unit is now known as Sulzer Turbosystems International, and is headquartered in Houston, TX, USA). Although the firm has discontinued packaging aeroderivative gas turbines, the 15 packages (10 for mechanical drive, four for electric power generation, one for the US Army) delivered in the 1981-1989 time period provide reliable service in gas compression and electric power/cogeneration in Australia, Canada, and the US.

The LM500 package has been offered by Kvaerner Eureka (later, Kvaerner Energie), Thermal Power Division, Oslo, Norway, and by IHI in Japan.

TSI and Hitachi of Japan have included the LM500 in their lines, with Hitachi having become a packager in 1982. TSI units were designated TG-60A and TG-60B, and TM-60A and TM-60B, while Hitachi's units carry the designation GT12.

LM500 Industrial Applications. The LM500 is properly sized for the mechanical compressor drive and power generation markets. Lightweight, compact, and possessing low SFC/heat rate, the design was intended to meet the needs of the 5-7 MW range. Gas compression applications have accounted for the majority of all installed LM500s to date; however, the power generation/cogeneration market was penetrated with the 1985 order for three power generation packages from then-TSI by Hoffman-La Roche. The first of the three gas turbines was delivered in 1987, to Nutley, New Jersey. Activity in the cogeneration market could result in greater sales.

At least five LM500s have been installed for electrical generation duty.

In industrial operation, the LM500 has demonstrated excellent performance and durability, having accumulated over 1 million operating hours, plus more than 4,000 hours for marine military engines and 15,300 hours for marine commercial engines. There are at least 10 LM500 gas turbines used in various industrial applications, including cogeneration and gas compression.

Military R&D. In a unique use of the LM500, the University of Texas Center for Electromagnetics selected the GE gas turbine for use in the US Army's Electromagnetic (EM) Gun Weapon Systems Demonstrator Program. The LM500 powered a compensated pulse alternator designed to store 210 MJ at 8,600 rpm. The EM demonstrator was called a Range Gun; it is a self-contained 90 mm rail gun capable of launching a salvo of nine projectiles with a muzzle velocity energy of 9 MJ at velocities of 8,200-13,120 feet per second (2,500-4,000 meters/sec). The Army has tested EM cannons for potential use in the next generation of main battle tank armament systems.

LM500 Marine Applications. The LM500 was initially designed for marine propulsion applications, in particular for such vessels as coastal patrol craft, minelayers/sweepers, hydrofoils, and surface effect ships. Since the TF34 engine was developed for the S-3A aircraft carrier-based anti-submarine warfare aircraft, little additional work was necessitated to fully marinize the engine for the shipboard environment. For the US Navy, the engine was considered for the LCAC (Landing Craft, Air Cushion) propulsion program and as a generation set for the Ticonderoga class Guided Missile Cruiser and Arleigh Burke class Guided Missile Destroyer programs.

Stanflex 300. The first marine application of the GE LM500 was the Danish Navy's 14 450-ton Stanflex 300 patrol boats built at the Danyard Shipyard's Aalborg Vaerft facility. The vessels have a CODAG system featuring a single LM500 on the centerline shaft and twin 3,840 bhp MTU 16V396 diesels on the outboard shafts; the vessels use fiberglass-reinforced plastic hulls designed for flexibility in all sea conditions. The first LM500 delivery was made in August 1986. The final craft entered service in 1996.

A total of 14 LM500 engines were delivered for this application.

Japanese PG Class Patrol Boats. In April 2000, the LM500 was selected to power two Japan Maritime Self-Defense Force (JMSDF) 200-ton PG class high-speed patrol boats. Each vessel has three LM500s driving waterjets. The vessels are built by Mitsubishi Heavy Industries at its Shimonoseki (Japan) shipyard. The first two vessels, PG 04 and PG 05, were commissioned in March 2002. Information on those vessels indicated that two additional vessels were slated for commissioning in 2003.

It should be noted here that the JMSDF Hayabusa class fast attack craft (FAC) appear to be the same as the PG class. Recent documentation indicates that six Hayabusa class vessels would be built, with vessels Nos. 824 (Hayabusa) and 825 (Wakataka) commissioned in late March 2003. Vessels Nos. 826, 827, 828, and 829 were unnamed as of mid-August 2002; those four vessels are to be completed in 2003-2004.

For the six vessels, a total of 23 engines will have been supplied.

Sparviero Hydrofoils. The LM500 marine application is on board the Italian Sparviero class hydrofoils. The vessels have been offered to Italy and Japan and to several Middle Eastern nations. Fiat in Italy would be the builder of the gas turbines for Italian and Middle Eastern use.

The Japan Maritime Self-Defense Force ordered three high-speed hydrofoil vessels (PG 01, PG 02, and PG 03) that have a single GE/IHI LM500 in a CODOG arrangement; all were commissioned by 1995. The hydrofoils were built in Japan by Sumitomo Shipyard at its Uraga (Japan) shipyard.

Kvaerner Fjellstrand Foil-Cats. The LM500 marine gas turbine was contracted as the main propulsion for two 40-meter Foil-Cat class ferry boats, with each vessel using two LM500s. The ferries were constructed by Kvaerner-Fjellstrand A/S shipyard in Omastrand, Norway. In 1994, Far East Hydrofoil Company Limited of Hong Kong placed an order for two of the Foil-Cats. Each is powered by a Kvaerner license-built LM500 rated at 5,900 shp (4,400 kW).

Funding

No recent US or Japanese government funding specifically related to the LM500 has been identified.

Recent Contracts

No major military or commercial contracts pertaining to the LM500 have been received during the past year.

Recent Activity

Historical Sales/Order Book. Five LM500s were sold in 1990, all for marine duty. Two machines were sold in 1991, for non-US marine propulsion duty. Seven were sold in 1992 and four each in 1993 and 1994, all foreign marine applications. No sales of the LM500 were officially reported from 1995 through 1999. In the year 2000, six machines were sold to the JMSDF for two PG class high-speed patrol boats (GEAE Marine Engines to supply the engines to Ishikawajima-Harima Heavy Industries). After 2000, additional LM500s were ordered for the remaining four Hayabusa class FAC.

Timetable

Month	Year	Major Development
Jul	1978	LM500 effort begun
Jan	1980	System verification and endurance testing begun
3Q	1980	Engine tests with 1,560 rpm gearbox initiated
	1981	Testing of marinized components completed; first machine delivered
	1982	Norwalk Turbo introduces TC-60 unit
	1984	LM500 uprated to current rating
Oct	1985	First orders for marine applications received from Denmark
Aug	1986	First marine engines delivered
	1987	First machines for electric drive delivered
Oct	1987	First Standard FLEX300 vessel commissioned
Late	1991	First Foil-Cat begins commercial operation
Late	1991	First marine engines delivered to Japan
	1993	First Japanese Hydrofoils enter service
	1995-1999	No LM500 engines/machines ordered
Apr	2000	Six LM500s ordered for two Japanese PG class patrol boats
Mar	2003	The two JMSDF PG class (Hayabusa) vessels commissioned
Late	2003	Final four Hayabusa class vessels to be completed
Thru	2012	Availability/aftermarket support of LM500 to continue

Worldwide Distribution

At the start of 2003, an estimated 55 LM500 engines had been delivered and installed. The machine has been installed for customers in **Australia**, **Canada**, **China** (Hong Kong), **Denmark**, **Japan**, and the **USA**. Countries having the greatest number of installations include Denmark with 14 and Japan with 20.

Forecast Rationale

The GE LM500 established itself in the marine turbine marketplace following some early mechanical drive and electrical generation installations. The number of turbine-powered ferries continues to grow, and the LM500 can easily handle power requirements in that arena, either in single-unit installations or in pairs.

With the overall commercial ferry market gaining acceptance year by year, and with ongoing interest in the marine military market for gas turbines of the size of the LM500 for patrol boats and small fast attack craft, the LM500 continues to have market potential. It does, however, face stiff competition from the Rolls-Royce 501-KF5 and 501-KF7, the UTC PWPS ST40 and the Vericor TF50A, and from engines made in the Russian Federation and Ukraine.

Despite a large installed base of the CF34 and TF34 aeroengines, GE has not effectively marketed the machine through its packagers and business associates/licensees. GE and IHI are expected, however, to continue to promote the LM500 to potential marine customers.

The potential exists for sales of this gas turbine machine for electrical generation and various mechanical load drives, but with no orders having been garnered in the

recent past, we are not forecasting production of the LM500 in any specific year for either marketplace.

Japan's order for its final four JMSDF Hayabusa class vessels resulted in the production of nine machines in 2002. An additional three machines will be built in 2003. After 2003, any production of the LM500 for marine power will likely be done in Japan by IHI.

Ten-Year Outlook

ESTIMATED CALENDAR YEAR PRODUCTION

			High Confidence Level			Good Confidence Level				Speculative			
Engine/Machine	**Application**	**thru 2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**Total 2003-2012**
GEAE, MARINE UNIT													
LM 500	GENERATION	5			No production likely during forecast period.								–
LM 500	MARINE POWER	14			No production likely during forecast period.								–
LM 500	MECHANICAL DRIVE	10			No production likely during forecast period.								–
Subtotal - GE (a)		29	–	–	–	–	–	–	–	–	–	–	–
ISHIKAWAJIMA-HARIMA, L & M (Licensee)													
LM 500	MARINE POWER	20	3	0	0	0	0	0	0	0	0	0	3
KVAERNER ENERGIE (Licensee)													
LM 500	MARINE POWER	6			No production likely during forecast period.								–
TOTAL PRODUCTION		55	3	0	0	0	0	0	0	0	0	0	3

(a) Total includes units shipped to packagers.