GE Energy

GE's LM2500+G4 Aeroderivative Gas Turbine for Marine and Industrial Applications

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Industrial AeroDerivative Gas Turbines

imagination at work

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Abstract

GE Infrastructure's Energy and Aircraft Engines businesses, continuing to improve the most experienced and technologically advanced aeroderivative gas turbine, the LM2500®, is now pleased to announce its fourth generation upgrade, the LM2500+G4.

GE has developed the most powerful gas turbine with the highest efficiency of any engine rated between 20 and 35MW. This translates into operational savings and increased revenue potential for the customer's operation.

Aeroderivative gas turbines possess certain technical features inherent in their design heritage, offering significant operational and economic advantages to the end user.

This paper presents an overall description of GE's latest LM2500 series aeroderivative gas turbine, with rated ISO shaft power output of 34.3 megawatts and 41.3% efficiency. It presents the value added to customers based on demonstrated high reliability and availability of the LM2500/+ gas turbine heritage.

The LM2500+G4 shares in Aircraft Engines' research and development funding, which has surpassed one billion dollars each year for the past ten years. Today, GE Energy's entire gas turbine product line continues to benefit from this constant infusion of research and development funding. Advances are constantly being incorporated to improve the benefits of GE's gas turbines to the customer.

Introduction

Headquartered in Cincinnati, Ohio, GE's industrial aeroderivative gas turbines division manufactures aeroderivative gas turbines for industrial and marine applications. GE's Energy and Oil & Gas divisions sell and service LM™ gas turbine products, which include the LM1600®, LM2000, LM2500®, LM2500+, LM6000™ and LMS100®.

These gas turbines are utilized in simple cycle, or integrated into cogeneration or combined cycle arrangements or mechanical drive applications as shown in Figure 1.

Configurations

GE's aeroderivative LM2500 industrial products are produced in two configurations:

- Gas Turbine, made up of Aircraft Engines supplied gas generator and power turbine as shown in Figure 2
- Gas Generator, which may be matched to an OEM-supplied power turbine

The LM2500+G4 is offered by GE with two types of power turbines: a six-stage, low-speed model, with a nominal speed of 3600 rpm; or a two-stage high-speed power turbine (HSPT). The HSPT has a design speed of 6100 rpm, with an operating speed range of 3050 to 6400 rpm. It is sold for mechanical drive and other applications where continuous shaft output speeds of 6400 rpm are desirable. Both the six-stage and two-

Figure 1. Industrial Aeroderivative Applications

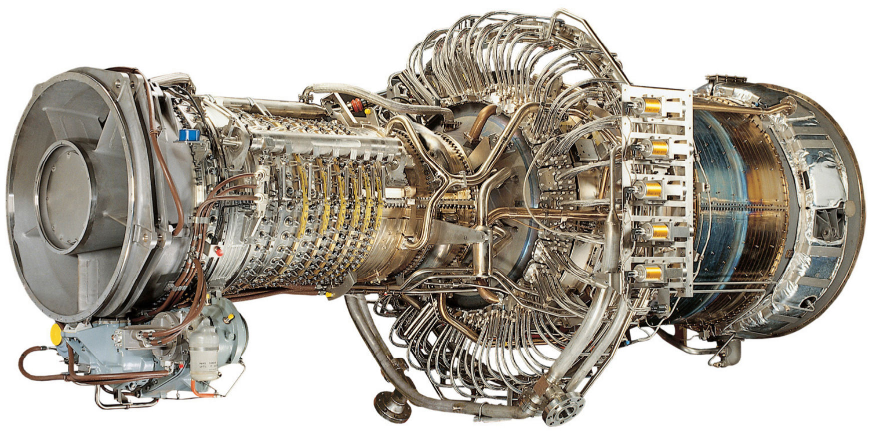

Figure 2. LM2500+ DLE Gas Turbine w/6-stage power turbine

stage power turbine options can be operated over a cubic load curve for mechanical drive applications.

GE also produces a variety of on-engine, emissions-control technologies:

- Single annular combustor (SAC) w/water injection
- SAC w/steam injection
- Dry Low Emissions (DLE) combustor

Heritage of the LM2500+G4 Gas Turbine

The 35-year chronology of the LM2500/+ and now the LM2500+G4 engine program is reflected in Figure 3. No other aeroderivative gas turbine in the 20-35MW range has such credentials with a combined total of 329 million hours and yet continues to grow in the industry segment as a formidable leader.

The operating experience accrued by the parent engine in flight applications and its derivative engine in industrial and marine service is reflected in Figure 4.

CF6 Aircraft Engine Family		LM2500/+ Aeroderivative	
Quantity	Operating Hours	Quantity	Operating Hours
6556	278,000,000	2000	51,000,000

Figure 4. Engine Operating experience as of Feb 2005

Figure 3. LM2500+G4 Gas Turbine Heritage

Description of Engine Design Changes

The LM2500+G4 is essentially an LM2500+ with increased flow capacity in the high- pressure (HP) compressor, HP turbine and in the low-pressure turbine. Pressure ratio increases from 23.6 for the LM2500+ to 24.2 for the LM2500+G4. The extent of design changes is limited to minor blade and stationary vane airfoil adjustments that provide the required mass flow increase. The HPT modifications include minor blade-cooling improvement and proven material upgrades from recent aircraft technologies that provide improved higher temperature capability, translating to higher customer savings. The effective area of the compressor discharge pressure seal was adjusted in order to maintain the optimum rotor thrust balance.

Structurally, all frames, such as front, compressor rear, turbine mid and turbine rear frames, remain unchanged. Likewise, HP compressor front and aft cases remain unchanged. Sump hardware and the number of main shaft bearings remain unchanged. These all share the successful experience of the LM2500+.

On DLE applications the combustor is upgraded by providing B ring wingless heat shields, cut back A and C ring heat shields and bolt in heat shields that will allow field replacement, and hence project a reduction in overall combustor maintenance cycle.

With these very limited changes, the LM2500+G4 will provide the same efficiency, reliability, availability, emissions and maintenance intervals as demonstrated successfully by the LM2500+ fleet.

Reliability, Availability and Maintainability Trends Analysis

The LM2500+G4 builds on the LM2500/+ heritage and demonstrated reliability. The LM2500+G4 incorporates proven technology advancements and a large percentage of parts commonality to deliver this same outstanding reliability. The RAM trends of the LM2500/+ family have continued to improve and have surpassed the non-GE aeroderivative industry (20-40 MW range) per Figure 5. GE continues to implement corrective measures that yield a reduction in unnecessary engine trip commands.

Reliability & Availability Simple Cycle Plant for Base Load/Continuous Duty*			
	Average Reliability %	Average Availability %	# of engines reporting
LM2500/+ Family	98.62	95.84	69
Non-GE Industry 20-40 MW	95.13	92.44	33

Figure 5. Reliability and Availability Simple Cycle Plant
*"Source: ORAP®; All rights to Underlying Data Reserved: SPS®, Modified by GE. Data captured at the end of March, 2005."

Emissions Technology

The LM2500+G4 will have the same emissions capability as the current LM2500+ product line, including:

- SAC Dry gas or liquid w/no NOx abatement
- SAC gas w/water or steam down to 25ppmv NOx at 15% O_2
- SAC liquid w/water or steam down to 42ppmv NOx at 15% O_2
- DLE gas only down to 25 ppmv NOx at 15% O_2
- Dual Fuel (DF) DLE NOx down to 100ppmv and 25ppmv on liquid and gas fuel respectively at 15% O_2
- Proven DLE capability for extreme hot and cold ambient condition (running data to -50 deg F and start data to –40 deg F)
- Full load drop/accept capability (SAC and DLE)
- SAC and DLE Fuel property change flexibility
- Dry low emissions via lean, premixed and staged combustion for full power range from start to max power

Note that LM2500 DF DLE technology has already been released to a launch customer with a program schedule set for commissioning two units by mid-2006. The first unit just completed its production tests, and has successfully demonstrated power, heat rate, emissions and fuel transfers.

Fuel & Combustion Flexibility

The LM2500+G4 builds on aircraft engine, LM6000 at 15 ppmv NOx and LM2500+ technologies. The LM2500+G4 with a single annular combustor will have the same fuel flexibility as the LM2500+, and will be capable of operating with a variety of fuels such as:

- Natural Gas fuel
- Syngas & medium BTU gas
- Liquid fuel
- Dual fuel (natural gas or liquid fuel)
- Bi Fuel (natural gas and liquid fuel)
- Water or steam injection for NOx abatement

DLE applications include:

- Gas only DLE
- Dual fuel DLE

Performance

Improvements in base load power comparison relative to LM2500+ were focused across a wide range of ambient conditions. Specifically during off-ISO conditions, as in cold day /hot day, the LM2500+G4 provides an 11 and 12% power increase respectively, as shown in Figure 6. Likewise, in combined cycle mode, the LM2500+G4 is expected to have an 8.5% power and 0.75% heat rate advantage.

Performance characteristics of the LM2500+G4 configured with either six-stage or two-stage power turbine is reflected in Figure 7, while Figure 8 represents the heat rate characteristic. Exhaust flow and temperature characteristics are reflected in Figures 9 and 10 respectively.

LM2500+G4 boiler steam production capability from an unfired heat recovery steam generator is represented in Figure 11. Steam flow conditions are for SAC/water base load output at 25 ppm NOx, with 4- and 10-inch losses on natural gas fuel.

Mechanical drive part power performance with two-stage power turbine is shown in Figure 12.

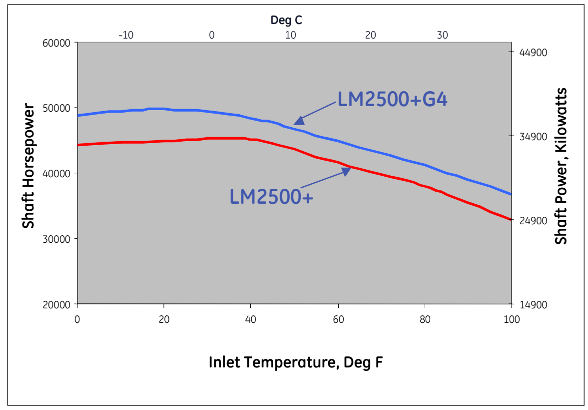

Figure 6. LM2500+ vs. LM2500+G4 Base Load Power Comparison

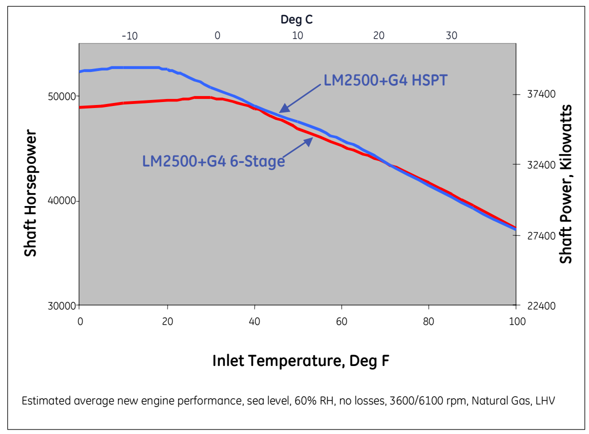

Figure 7. LM2500+G4 SAC Dry Power vs. Inlet Temperature

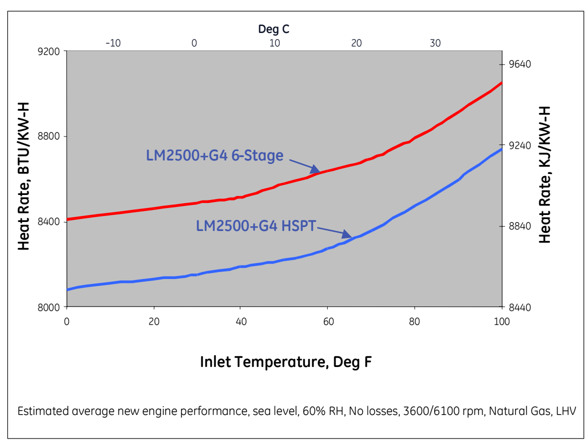

Figure 8. LM2500+G4 SAC Dry Heat Rate vs. Inlet Temperature

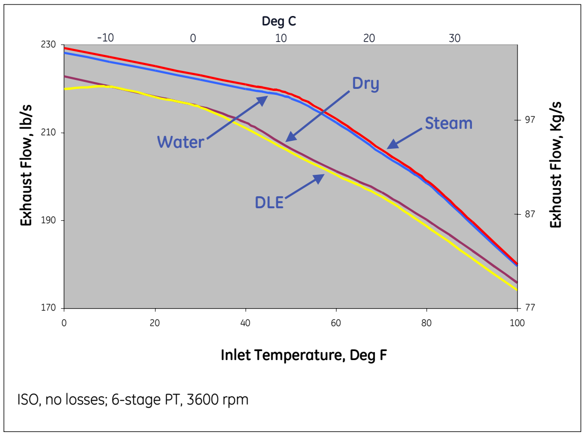

Figure 9. LM2500+G4 Exhaust Flow at Base Load

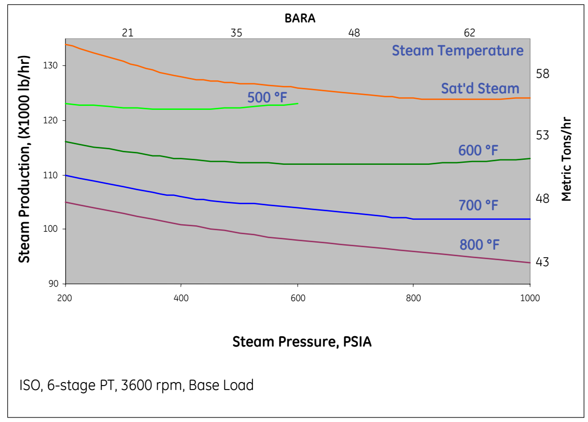

Figure 11. Unfired Heat Recovery Steam Generation

Factory Validation Testing

Plans are in place to fully instrument the first engine during 3Q, 2005 and complete the validation test during 1Q, 2006 in Cincinnati, OH. The test configuration will cover both gas generator and gas turbine with six-stage power turbine. The two-stage HSPT configuration will be tested in GE's Oil & Gas facility in Massa, Italy during 4Q, 2006. Testing will validate that all design requirements are met.

Customer Benefits

The LM2500+G4 maintains its credentials from the successful LM2500/+ product line. More output, high reliability and lower initial capital investment on a $/kW installed basis are just a few of the benefits contributing to the customer value delivered by the LM2500+G4.

On DLE applications the LM2500+G4 emission levels are maintained at 25 ppm even with increased power capability relative to the LM2500+.

Documented fleet reliability and availability is greater than 3% over other industrial aeroderivatives in the 20-40 MW power range (Figure 5). This incremental availability difference translates into more revenue stream for our customers. Meanwhile, the 10% power increase while maintaining the existing LM2500+ gas turbine footprint and weight could, for example, translate to:

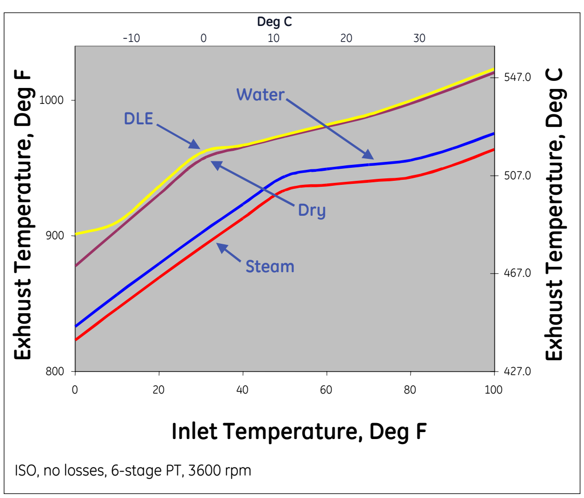

Figure 10. LM2500+G4 Exhaust Temperature at Base Load

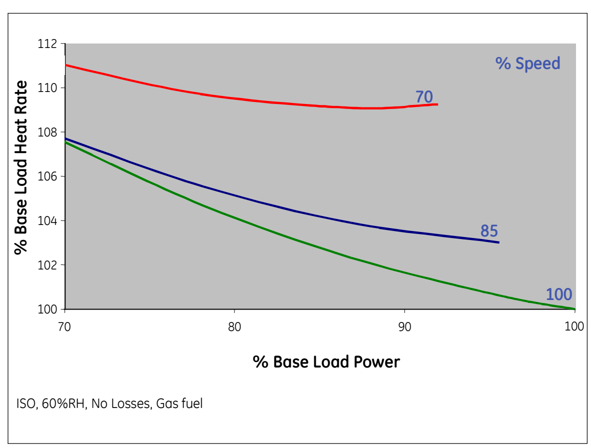

Figure 12. LM2500+G4 SAC HSPT Part Load Performance

- Oil production rates in the oil and gas industry in general are proportional to available horsepower. Hence, for example, an oil field where a 42,000 SHP gas turbine is installed would typically produce 80,000 barrels of oil per day. The LM2500+G4 10% power increase would provide incremental sales revenue of (assuming $50/bbl) $400,000 per day.
- In the power generation industry, the LM2500+G4 3MW increase would generate (assuming a $6/MW-hr profit & 8000hr/year) an additional $144,000/yr profit.
- Steam production rate in cogen application would be 46 metric tons/hr at 600 psig and 750 deg F; this is a 17% increase over the LM2500+.

Summary

GE's continued investment in R&D engine technology enables the LM2500 series of gas turbines to maintain their leadership position in technology, performance, operational flexibility and value to the customer. The LM2500+G4 continues to build on its successful heritage and yet provides the ability to operate with a variety of fuels and emission control technologies that have gained the widest acceptance in the industry, with total operating experience in excess of 51 million hours. This provides very low technology and business risk to our clients.

The LM2500+G4 with six-stage power turbine will be available in early 2006 followed by the two-stage HSPT by 2007.

LM2500/+ engines have been selected for a multitude of applications from power generation to mechanical drive, for exploration, production and transmission of oil and gas, on/off shore and FPSO, as well as marine propulsion systems in military and commercial marine environments.

References

GER-3695E GE Aeroderivative Gas Turbines-Design and Operating Features

Photos courtesy of Bechtel.com, Statoil.com