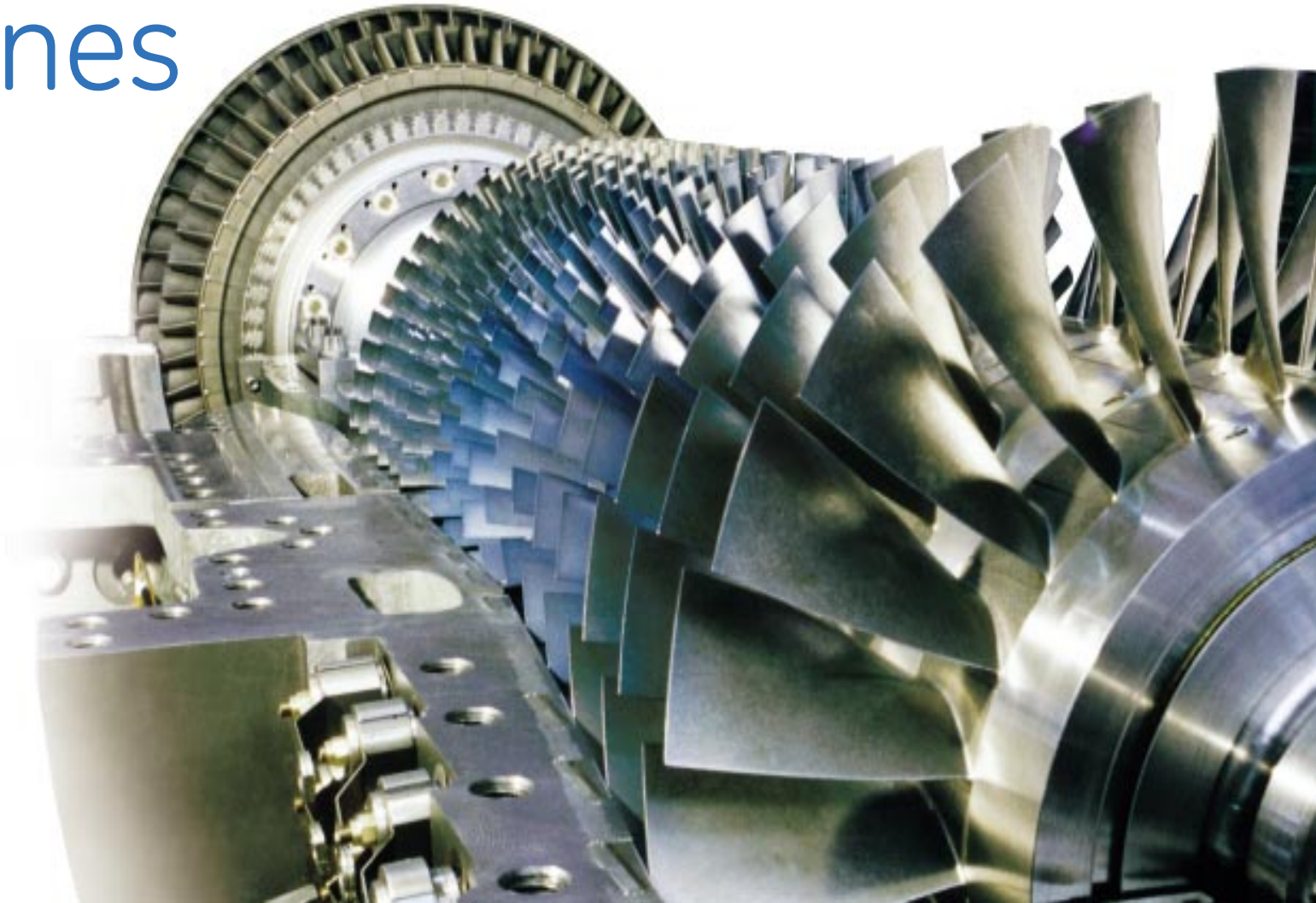
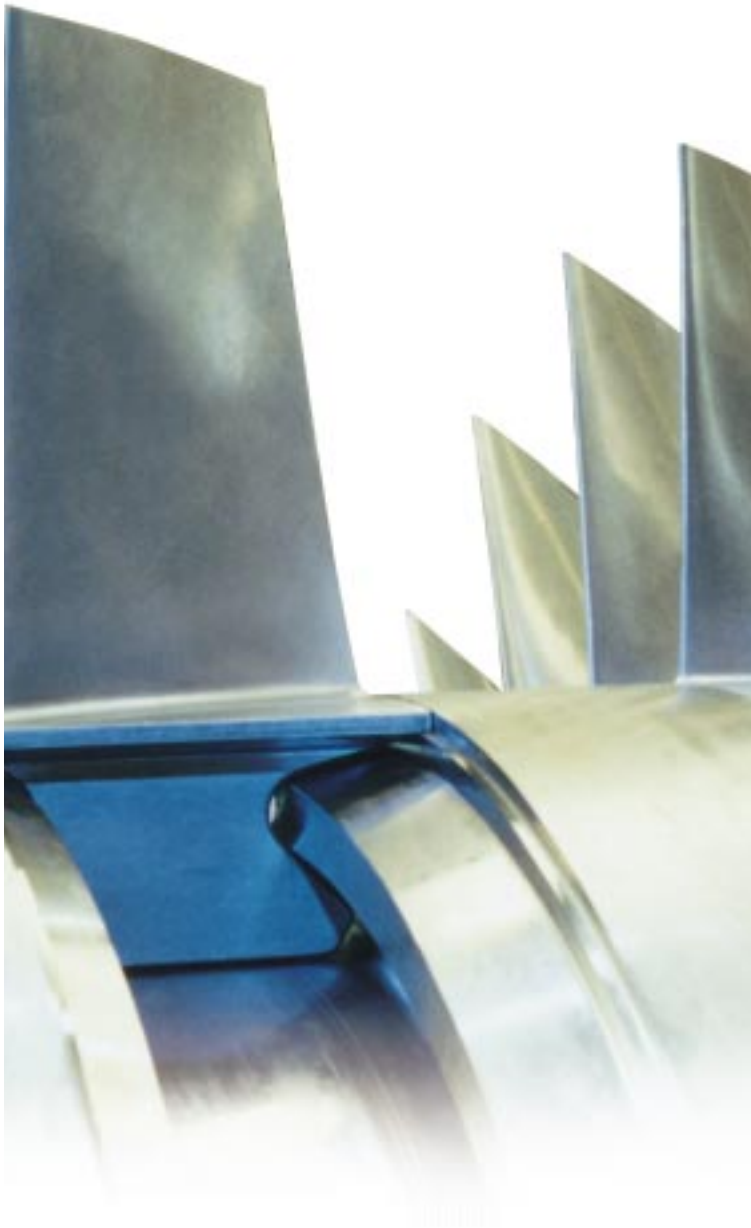
GE
Oil & Gas

# Gas Turbines



# Contents

GE manufactures a complete line of gas turbines for all major Oil & Gas Industry applications. They are installed in natural gas plants, gas compression stations, oil booster stations, petrochemical plants and power generation and cogeneration plants worldwide. GE's Oil & Gas business has long-standing experience in manufacturing gas turbines dating back to 1961 when a manufacturing agreement was established with GE (U.S.A.) to complement the existing portfolio of products for the petroleum and petrochemical industries (reciprocating and centrifugal compressors, gas engines, pumps, valves, etc.). A proven combination of sound design and quality assurance techniques places these gas turbines among the world's most reliable. Basic models produced by GE cover the 12,000 to 124,000 kW power range. They can be provided in simple or regenerative cycles for mechanical drive or generator drive applications. Extensive research and development, advanced design procedures, modern manufacturing technology and on-site experience are behind the success achieved by GE gas turbines.



# **GE10** Gas Turbines

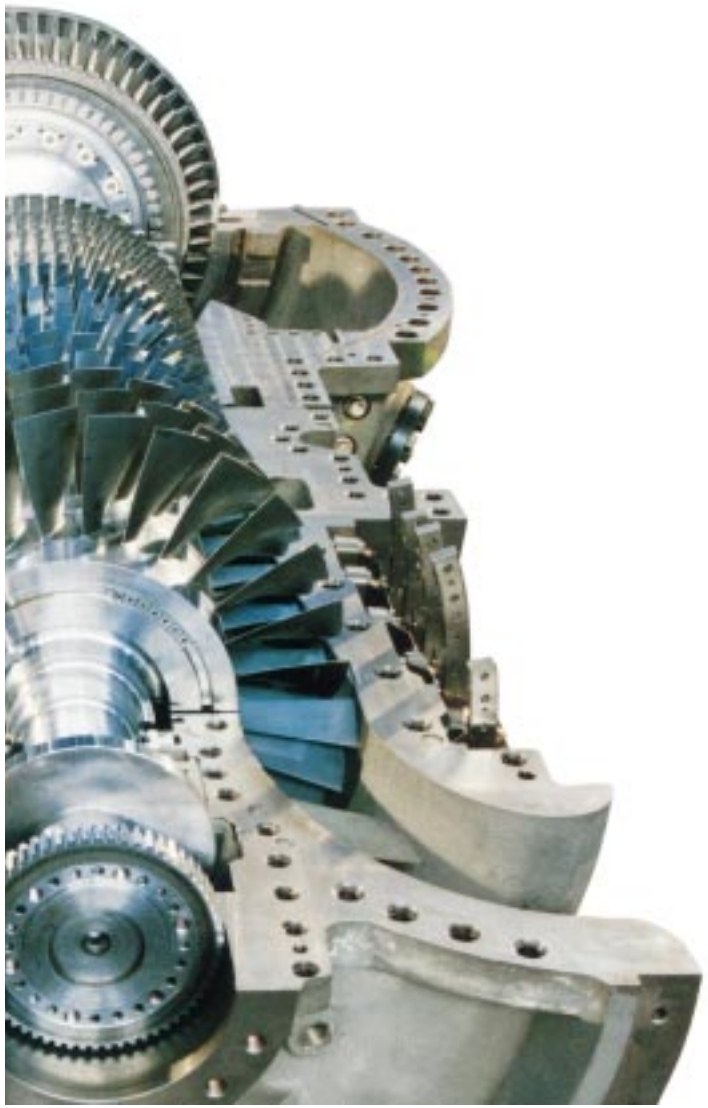
The GE10 is a heavy-duty gas turbine in the 12MW range, available in either a single or a two-shaft configuration.
It is the evolution of the field proven PGT10 and incorporates the latest in aerodynamic design, and compact and versatile package arrangements for both Power Generation and Mechanical Drive applications.
The cases are horizontally split and the rotor has a disk architecture. The combustion system consists of a horizontally positioned single can.
The GE10 is available in both diffusion combustion system and DLN (Dry Low NOx) versions (15/25 ppmvd NOx) and is able to burn a wide range of liquid and gaseous fuels, including Low BTU gas and hydrogen. The GE10 engine design has been highly refined based on the extensive experience gained in operating in all types of environments.
There are over two hundred PGT10/GE10 units running under conditions ranging from the cold of Alaska and Siberia to the heat of the desert and the humidity of the tropics.
Its efficiency and operational flexibility make the GE10 a cost-effective choice for all applications.

## Axial Compressor

The compressor is a high performance, eleven-stage axial flow design with a 15.5:1 pressure ratio derived from GE Aircraft Engine transonic flow aero design technology.
The rotational speed is 11000 rpm with a mass flow of 47 kg/s.
The antisurge margin exceeds 25%. Advanced 3D airfoils are used for vanes and blades, and the first three rows of stator blades are adjustable to optimize operability.
The cold-end drive configuration guarantees reduced flange movement during gas turbine thermal transients. A patented GECC-1 aluminum ceramic coating is provided for application in marine environments.

## Combustion System and Emissions

The combustion system consists of a single, slot-cooled combustion chamber assembly that permits easy maintenance of the hot gas path.
This combustion chamber can burn a wide range of fuels, from liquid distillates to residuals, to all gaseous fuels including low BTU gas. The broad fuel capability of this
combustor is due to the variable geometry design patented by GE. Guaranteed NOx levels of either 15 or 25 ppmvd @ 15% O2 are available over a broad load range. A DLN Dual Fuel version (liquid + gas fuel) is also available.



# **GE10-1** Gas Turbines

## Turbine

The single-shaft version is optimized for power generation applications.
The turbine consists of three reaction stages. In the first two stages the hot gas parts are cooled by air extracted from the axial compressor. The second and third stages have interlocked shrouds to limit tip leakage and blade vibration.

## Power Generation Package Arrangement

The GE10-1 package is designed specifically for power generation applications in both Simple Cycle and CHP Cycle modes.
The single lift architecture (main skid dimension 12.5 m x 2.5 m) minimizes site installation and commissioning lead time (1.5 months). The integrated control cab eliminates the need for control room civil works and related site wiring. An engine exchange maintenance option is available (5 days downtime) to reduce maintenance cost and time.
Each package is performance tested before shipping to ensure product reliability and quality.
The base configuration consists of a complete unit configured for outdoor installation.
The enclosure guarantees a sound pressure level below 85 dBA at 1 m.
The main skid incorporates the Gas Turbine, Electric Generator (11 kV, 4-poles, open air) which also acts as a starting motor, and the Gearbox (Epicyclical).
The Combustion chamber and valve system is able to accommodate different types of gas/liquid fuel compositions and NOx emission requirements.

| GE10-1 (ISO Conditions Standard Combustor) | |
|---|---|
| Electrical Output (kW) | 11250 |
| Electrical Efficiency (%) | 31.4 |
| Exhaust Flow (kg/sec) | 47.5 |
| Exhaust Temperature (°C) | 482 |

## GENERAL SPECIFICATIONS

### Axial Compressor

- 11-Stage Axial Flow
- 15.5:1 Pressure Ratio

### Combustion Chamber

- Single Can Combustor
- Pollution prevention:
  - DLN Gas Fuel at 25 ppmvd NOx
  - DLN Gas Fuel at 15 ppmvd NOx
  - DLN Dual Fuel Gas Fuel at 25 ppmvd NOx
  - DLN Dual Fuel Liquid Fuel at 85 ppmvd NOx

### Turbine

- 3-Stage HP Turbine 11000 rpm

## AVAILABLE OPTIONS

- Dual Fuel DLN version (liquid + gas fuel)
- 6.0kV electric generator
- 80 dBA sound pressure level package
- Indoor version
- $H_2O$ oil cooler system
- Standard exhaust duct (12 m)
- Lubrication stand-by pump
- Control cabinet located alongside the unit
- Additional pre-engineered BN1701 for complete vibration monitoring

# **GE10-2** Gas Turbines

## Turbine

The two-shaft version of the GE10 is optimized for mechanical drive applications.
It consists of two air-cooled high pressure reaction stages and two low pressure reaction stages coupled to the power shaft.
To optimize the behavior at partial speed/load a variable geometry Nozzle Guide Vane (NGV) is installed between the HP and LP sections.

## GENERAL SPECIFICATIONS

### Axial Compressor

- 11-Stage Axial Flow
- 15.5:1 Pressure Ratio

### Combustion Chamber

- Single Can Combustor
- Emission Control:
  - DLN Gas Fuel at 25 ppmvd NOx
  - DLN Gas Fuel at 15 ppmvd NOx
  - DLN Dual Fuel Gas Fuel at 25 ppmvd NOx
  - DLN Dual Fuel Liquid Fuel at 85 ppmvd NOx

### Turbine

- 2-Stage HPT (11000 rpm) + 2-Stage LPT (7900 rpm)

# **GE10-2** Gas Turbines

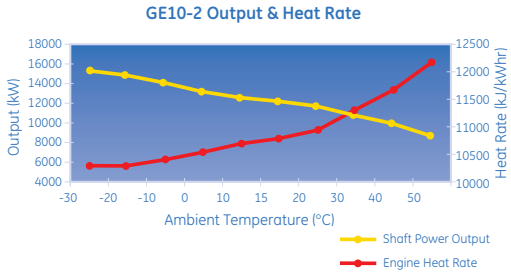
## Mechanical Drive Package Arrangement

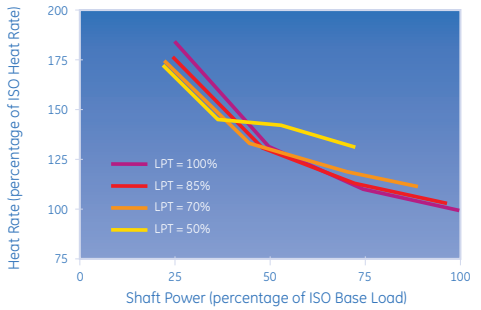
The GE10-2 package is designed for optimum performance in pipeline, re-injection and other oil and gas field applications (on- and off-shore), as a pump drive, and also for power generation applications.
The base configuration consists of a complete unit configured for outdoor installation and has been developed for hazardous area installation in accordance with API standards.
The enclosure guarantees a sound pressure level below 85 dBA at 1 m.
The main skid incorporates the gas turbine, electric starting system, fuel system, and gas detection and firefighting systems ($CO_2$).
The lube oil tank is integral with the gas turbine base plate. The main lube oil pump is mechanical, and is driven by the auxiliary gearbox. The auxiliary oil pump is an AC electric motor-driven pump, and a DC electric motor-driven pump is provided for emergency backup. All control devices are located in a separate control room.
The air filtration system consists of a "self cleaning type" filter house, an inlet duct and a silencer.
The combustion chamber and valve system can accommodate different types of gas/liquid fuel compositions and NOx emission requirements.
An engine exchange maintenance option is available to reduce maintenance cost and time.
The package is mechanically tested prior to delivery.

| GE10-2 (ISO Conditions Standard Combustor) | |
|---|---|
| Electrical Output (kW) | 11982 |
| Electrical Efficiency (%) | 33.3 |
| Exhaust Flow (kg/sec) | 47.0 |
| Exhaust Temperature (°C) | 480 |

## AVAILABLE OPTIONS

- Dual Fuel DLN version (liquid + gas fuel)
- 80 dBA sound pressure level package
- Indoor version
- $H_2O$ type fire fighting system
- Static air filter system
- $H_2O$ oil cooler system
- Gas expansion turbine starting system



# **MS5001** Gas Turbines

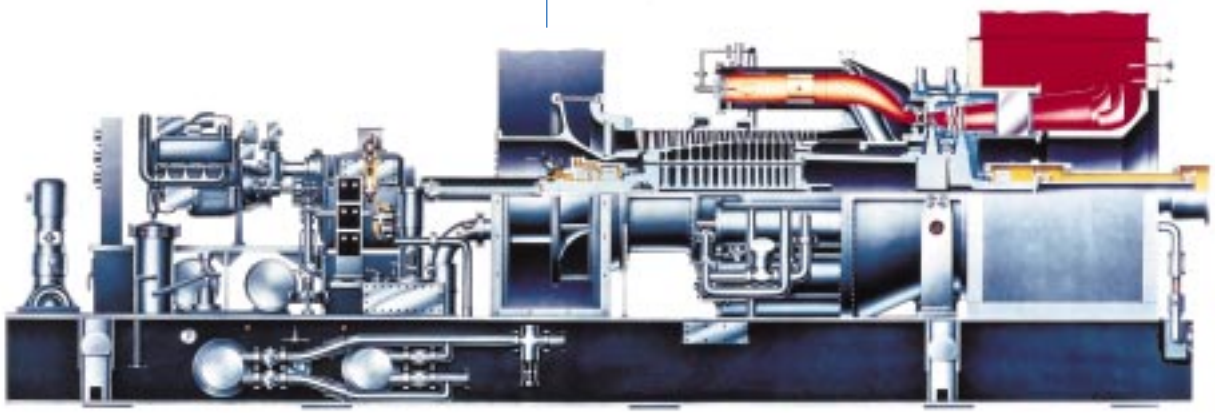
The MS5001 single shaft turbine is a compact heavy-duty prime mover designed for long life and ease of operation and maintenance. The three main features of its simple design are:

- 17-stage, axial compressor
- Combustion system with 10 chambers capable of burning a wide range of fuels including natural gas, light and heavy distillates, and crude and residual oil. A DLN System is also available.
- Two-stage turbine with high energy stage design. The first-stage nozzles are cooled by the axial compressor discharge air.

The MS5001 Gas Turbine is the ideal solution for power generation where low maintenance, reliability and economy of fuel utilization are required. Low operating and investment costs make the MS5001 packaged power plant an economically attractive system for load generation. The MS5001 is also ideally suited for cogeneration achieving a very high fuel utilization index and considerable fuel savings. Typical applications are industrial plants for cogeneration of power and process steam or district heating systems.

As a consequence of the extremely favorable operating, maintenance and economic characteristics of the MS5001 it has been very well accepted in the industry and there are more than 2500 units in operation all over the world.

MS5001 Gas Turbine



# **MS5002C-D** Gas Turbines

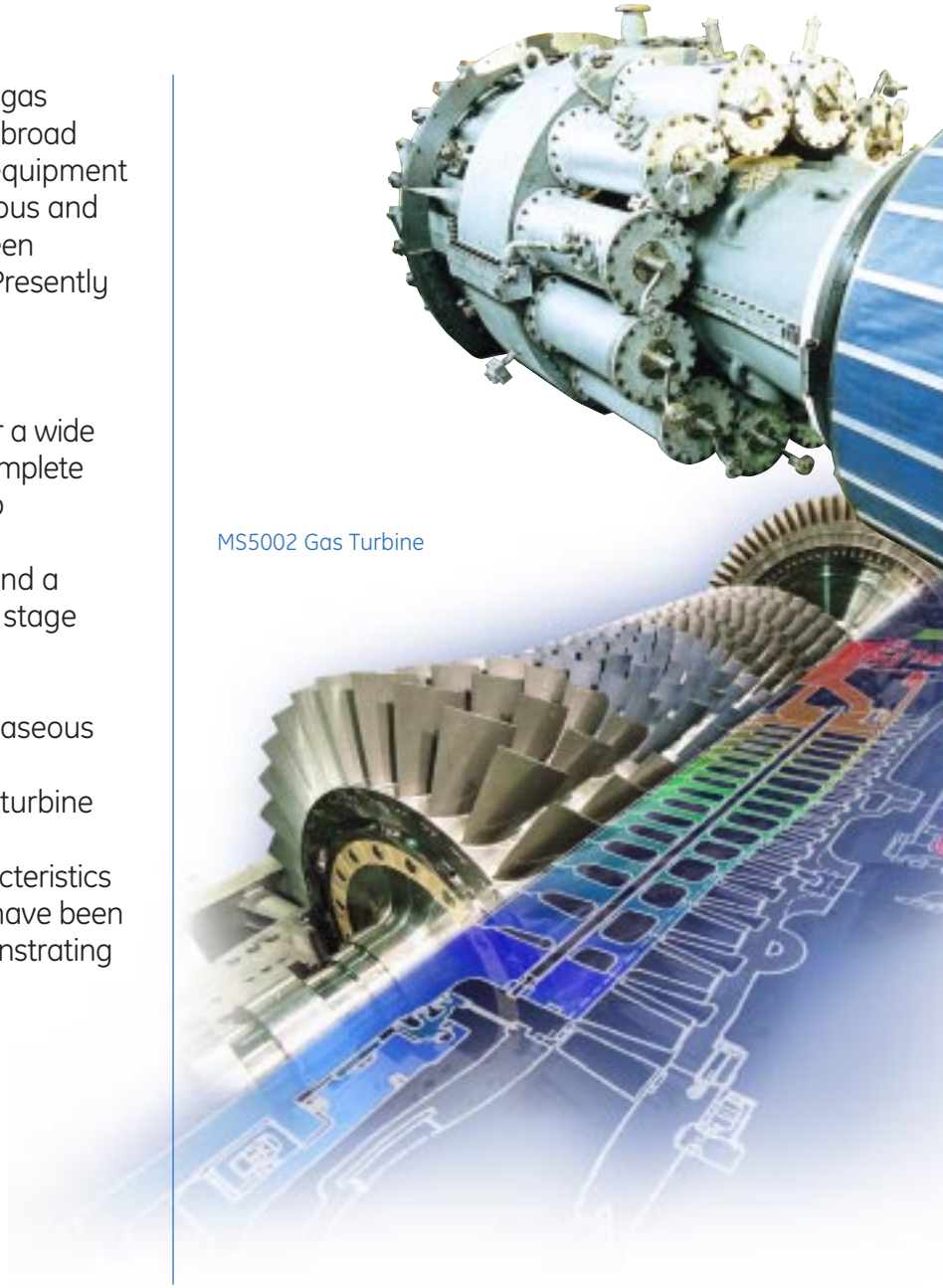
The MS5002 is a gas turbine specifically designed for mechanical drive applications such as gas boosting, gas injection/re-injection, oil & gas pipelines, LNG plants and gas storage. It has a broad operating speed range to meet the operating requirements of the most common driven equipment (centrifugal compressors and pumps) as well as the ability to burn a large variety of gaseous and liquid fuels. The MS5002 gas turbine was introduced in the market in the 1970s and has been updated and up-rated over the years to meet the industry demand for increased output. Presently two versions are available:

- MS5002C
- MS5002D

The MS5002 two-shaft, heavy-duty gas turbine is designed for high operating efficiency over a wide range of speed and load. The simple design and extreme robustness of the MS5002 allow complete maintenance to be performed on site without the need for specialized tooling or service shop assistance. The main features of its design are:

- High pressure shaft consisting of a 16-stage (17 for MS5002D), axial-flow compressor and a single-stage, high energy turbine. The first stage nozzles are air cooled and the second stage nozzles are of the variable angle type.
- Low pressure shaft is a single stage, high energy turbine.
- Twelve combustion chambers are contained within a single wrapper. A wide range of gaseous and liquid fuels can be burned. A DLN Combustion System is also available.
- A centralized lube oil system supplies clean, cooled, pressurized oil to lubricate the gas turbine and the driven equipment including the oil required for any compressor seals.

As a consequence of the extremely favorable operating, maintenance and economic characteristics of the MS5002, nearly 500 units (more than 300 manufactured by GE's Oil & Gas business) have been installed world-wide in all types of environments (arctic, desert, off-shore etc.) always demonstrating ease of operation and very high reliability and availability.



MS5002 Gas Turbine

# **MS5002E** Gas Turbines

The most recent addition to the GE family of gas turbines is the MS5002E which delivers high efficiency, low environmental impact and high reliability. This dual-shaft gas turbine has proven its capability for use in power generation and mechanical drive applications.

The MS5002E uses GE's state-of-the-art combustion technology (DLN2.5H) which has accumulated more than 14 million firing hours in the "F/FA" Class GE Frame gas turbine. This model was designed to maintain or exceed the availability and reliability of previous Frame5 models. To maximize hot parts life duration, the firing temperature was kept approximately 100°C lower than that of the "F/FA" Class.

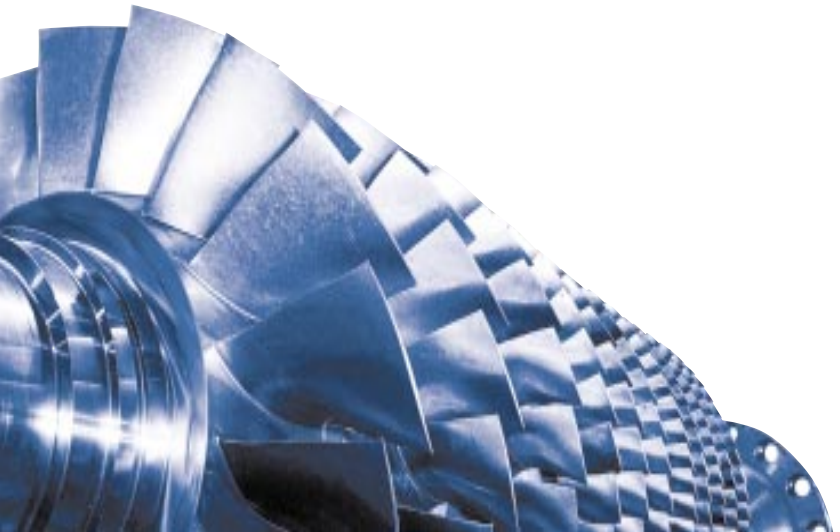
Superior efficiency was achieved through the use of advanced design tools to optimize airfoils (for both axial compressor and turbine sections), clearances, leakages and the distribution of cooling flows.

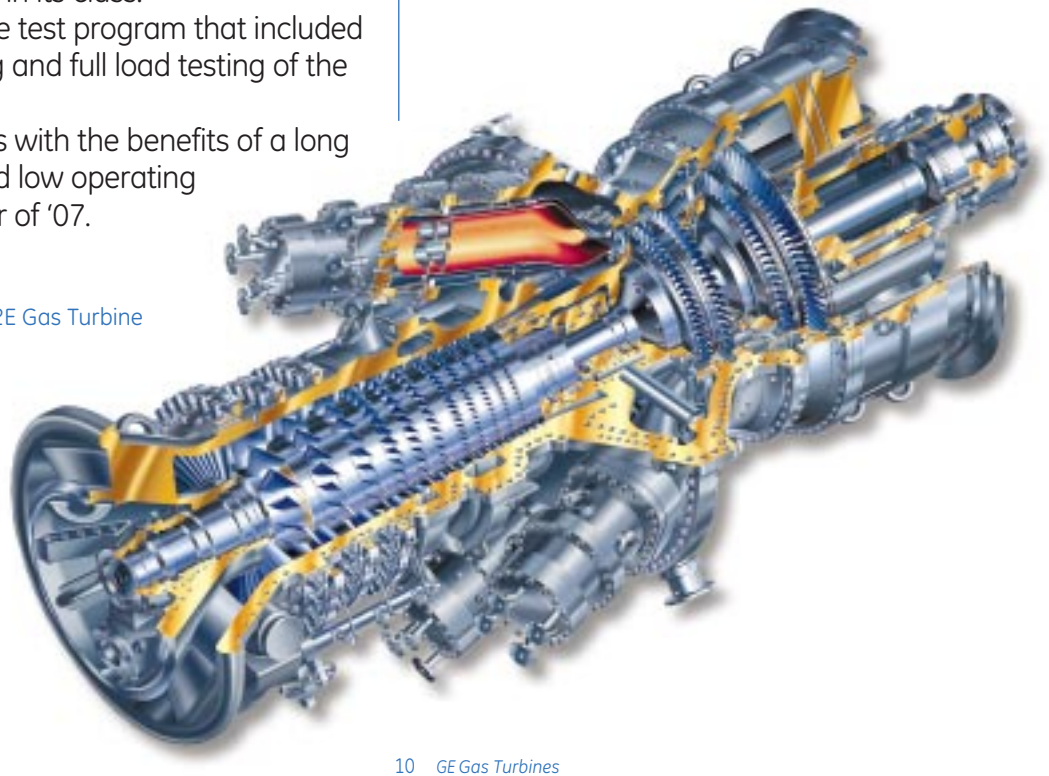
Compared to the MS5002C and D or MS5001, the efficiency gain of the MS5002E results in a reduction in emissions of over 20,000 tons of CO2 per year, equivalent to the amount of C02 absorbed by 20 sq km of forest in a year. In addition, the MS5002E NOx emission level is down to 18 ppm. These achievements make the environmental impact of the MS5002E the lowest in its class.

The design of the MS5002E was thoroughly validated through an extensive test program that included a full scale test of the axial compressor, and full scale rotordynamic testing and full load testing of the gas turbine system in both mechanical and generator string tests.

The MS5002E is ready for the Oil & Gas market and will provide customers with the benefits of a long lasting and reliable machine combined with low environmental impact and low operating costs. The first requisition unit will start at the customer's site in September of '07.

| PERFORMANCE | MS5002E | |
|---|---|---|
| (@ ISO conditions) | Generator Drive | Mechanical Drive |
| Output | 31100 kWe | 32000 kW |
| SC Efficiency (%) | 35.0 | 36.0 |
| Pressure Ratio | 17:1 | 17:1 |
| Heat Rate (kJ/kWh) | 10285 | 10000 |
| NOx (ppm) | 18 | 18 |
| Exh. Gas Flow (kg/s) | 101 | 101 |
| Exh. Gas Temp. (°C) | 510 | 510 |
| Load Rated Speed (rpm) | 3000/3600 (both geared) | 5714 |





MS5002E Gas Turbine

# MS6001B/MS7001EA/MS9001E

## Available for Oil & Gas Applications

### APPLICATIONS

These gas turbines are fuel-flexible, and can operate on natural gas, liquefied natural gas (LNG), distillate and treated residual oil in a variety of applications including:

- mechanical drive for large compressor trains
- simple cycle and combined cycle
- base load and peaking power generation
- industrial and cogeneration

### FEATURES

- 17-stage compressor with stacked disk design
- reverse flow combustion system with an individual nozzle single combustion chamber
- 3-stage turbine with air-cooled, first and second-stage nozzles and buckets
- two or three bearing rotor supports

### MS6001B

The MS6001 is a single-shaft, heavy-duty gas turbine. The high efficiency axial compressor has 17 stages. The combustor has ten combustion chambers with individual fuel nozzles. The machine has a three-stage impulse turbine with air-cooled buckets and stationary nozzles on the first two stages to achieve higher firing temperatures and consequently higher efficiency without compromising hot section component life.

MS6001B Gas Turbine

### MS7001EA

The MS7001EA is a highly reliable, mid-sized packaged power plant developed specifically for 60 Hz applications. With design emphasis placed on energy efficiency, availability, performance and maintainability, the 7EA is a proven technology machine with more than 850 units of its class installed or on order worldwide as of December 2006. The simple, medium-sized design of the 7EA lends itself to flexibility in plant layout and easy, low cost addition of power augmentation when phased capacity expansion is needed. A predecessor of the 7FA, the 7EA is ideal for plants that require high efficiency along with shaft speed for direct coupling to the generator.

MS7001EA Gas Turbine

### MS9001E

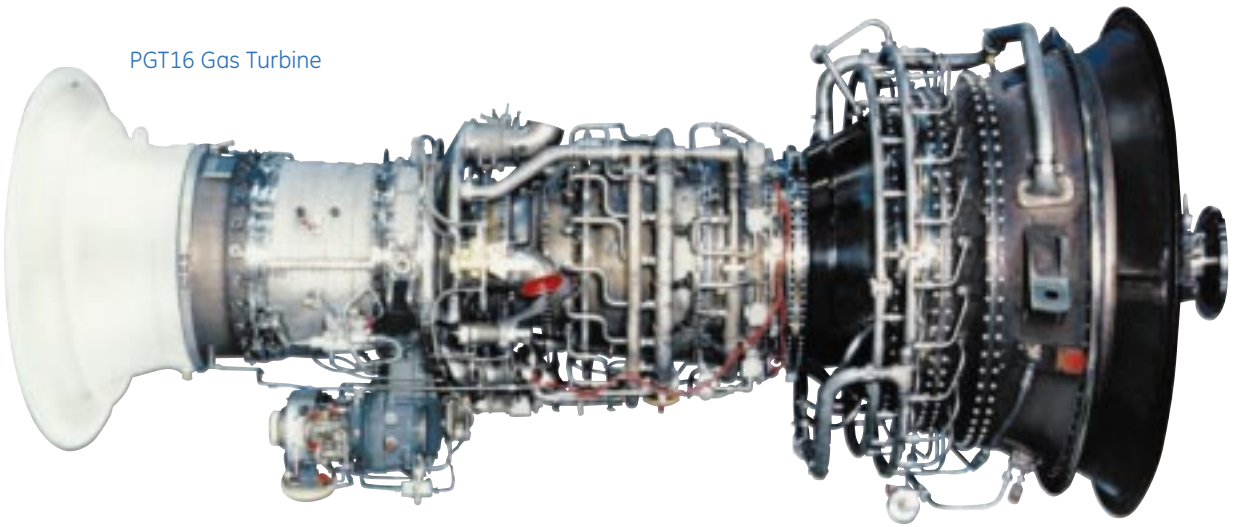
The MS9001 is a single-shaft, heavy-duty gas turbine developed for generator drive service in the 50 Hz market. Its efficiency is approx 33% in simple cycle mode and over 50% when operated as a combined cycle. The MS9001 is designed to burn a variety of liquid and gaseous fuels.

MS9001E Gas Turbine

# **PGT16** Aeroderivative Gas Turbines

The PGT16 gas turbine consists of the twin spool GE Aeroderivative LM1600 Gas Generator coupled with a rugged, industrial power turbine designed by GE's Oil & Gas business. The LM1600 Gas Generator is derived from the F404 turbofan aircraft engine.
The power turbine of the PGT16 gas turbine is identical to that of the PGT10 heavy duty, high efficiency gas turbine which has been in operation for more than half a million hours.
The power turbine shaft speed (7900 RPM) is optimized for direct coupling to pipeline, injection and process centrifugal compressors with a speed range that matches most operating requirements encountered in oil & gas applications. For generator drive applications the PGT16, synchronously coupled to a generator with a speed reduction gear, is a highly flexible turbogenerator which can be operated in simple cycle, combined cycle or cogeneration applications with an electrical efficiency close to 50%.

PGT16 Gas Turbine



## GENERAL SPECIFICATIONS

### Compressor
- Twin spool axial compressor (3 stage LP compressor, 7 stage HP compressor)
- Pressure ratio 20.1:1

### Combustion
- Annular combustion chamber (18 fuel nozzles)

### Turbine
- Twin Spool Gas Generator turbine (1 stage HP turbine, 1 stage LP turbine)
- Two stage Power turbine with variable angle first stage nozzles

### Package
- Completely mounted on a single base plate
- The enclosure is integral with the base plate providing maximum accessibility for maintenance of the gas turbine and auxiliaries

### Emission Control
- Steam or water injection systems for NOx abatement
- Dry Low Emission (DLE) combustion system

# **PGT25** Aeroderivative Gas Turbines

The PGT25 gas turbine consists of an LM2500 GE aeroderivative gas generator coupled with a rugged, industrial power turbine designed by GE's Oil & Gas business.

## GAS GENERATOR

The LM2500 gas generator has already accumulated several million fired hours not only as an aircraft engine (TF39 and CF6-6 engines), but also in the industrial field in many mechanical drive applications (marine, onshore and offshore gas transmission) and for generator drive service.
The LM2500 gas generator incorporates a 16-stage axial-flow compressor capable of reaching an 18:1 pressure ratio. Inlet guide vanes and adjustable stator vanes on the first six compressor stages provide for efficient operation over the entire operating range.

## POWER TURBINE

The PGT25 power turbine components were designed taking into account many years of experience gained in the field by heavy duty gas turbines and axial/centrifugal compressors. The aerodynamic blading was designed with the main objective of obtaining very high efficiency at both design and reduced speeds.
The 6500 RPM design speed means the turbine can have two stages with a moderate aerodynamic load and a high expansion efficiency. The two expansion stages are of the high energy, three-dimensional design type.
The investment casting superalloy selected for the blading assembly has a cobalt base for the nozzles and a nickel base for the rotor blading (i.e., the same materials used on heavy-duty gas turbines). A large creep and fatigue (LCF-HCF) safety margin on blade life is ensured by a moderate gas temperature at the power turbine inlet. The two-stage rotor is overhung and the shaft is supported by two tilting pad bearings contained in a cylindrical cartridge. The system can be easily dismantled with a simple translation of the gas generator within the package space thus reducing the time required for a major overhaul of the power turbine to a few days. Engineering simplicity and advanced materials yield long time between overhauls and reduced maintenance costs.
The turbine is assembled on a light but rigid base plate with extensive use of prefabricated standard components preassembled and tested in the shop to minimize on-site assembly time.

## GENERAL SPECIFICATIONS

### Compressor

- Sixteen stage axial compressor
- Pressure ratio 18:1

### Combustion

- Annular combustion chamber (30 fuel nozzles)

### Turbine

- Two stage Gas Generator turbine
- Two stage Power turbine (6500 RPM).

### Package

- Completely mounted on a single base plate
- The enclosure is integral with the base plate providing maximum accessibility for maintenance of the gas turbine and auxiliaries

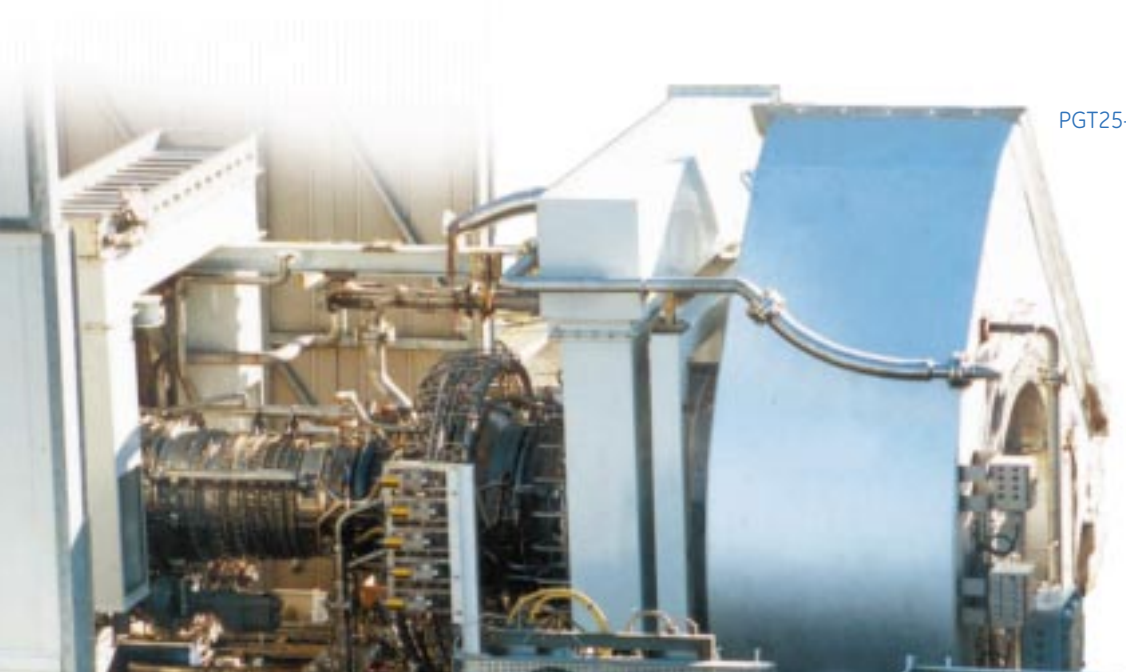
### Emission Control

- Steam or water injection systems for NOx abatement
- Dry Low Emission (DLE) combustion system

PGT25 Gas Turbine

# **PGT25+** Aeroderivative Gas Turbines

The PGT25+ gas turbine was developed for 30 MW ISO shaft power service with the highest thermal efficiency level (approx. 41%). The PGT25+ gas turbine consists of the GE Aeroderivative LM2500+ Gas Generator (updated version of the LM2500 gas generator with the addition of a zero stage to the axial compressor) coupled with a 6100 RPM, 2 stage Power Turbine (High Speed Power Turbine - HSPT). Built on the LM2500 heritage and demonstrated 99.6% reliability, the LM2500+ incorporates technology improvements, while maintaining a large percentage of parts in common with the LM2500 to deliver the same outstanding level of reliability. Designed for ease of maintenance, the LM2500+ also provides a high level of availability. High efficiency and reliability are among the large number of benefits contributing to PGT25+ customer value. Specialized aeroderivative annular combustion chamber fuel nozzles make the PGT25+ ideal for a wide range of mechanical drive (gas pipeline, etc.), power generation, industrial cogeneration, and offshore platform uses in any environment.
Engineering simplicity and advanced materials yields long time between overhauls and reduced maintenance costs.



PGT25+ Gas Turbine

## GENERAL SPECIFICATIONS

### Compressor
- Seventeen stage axial compressor
- Pressure ratio 23:1

### Combustion
- Annular combustion chamber (30 fuel nozzles)

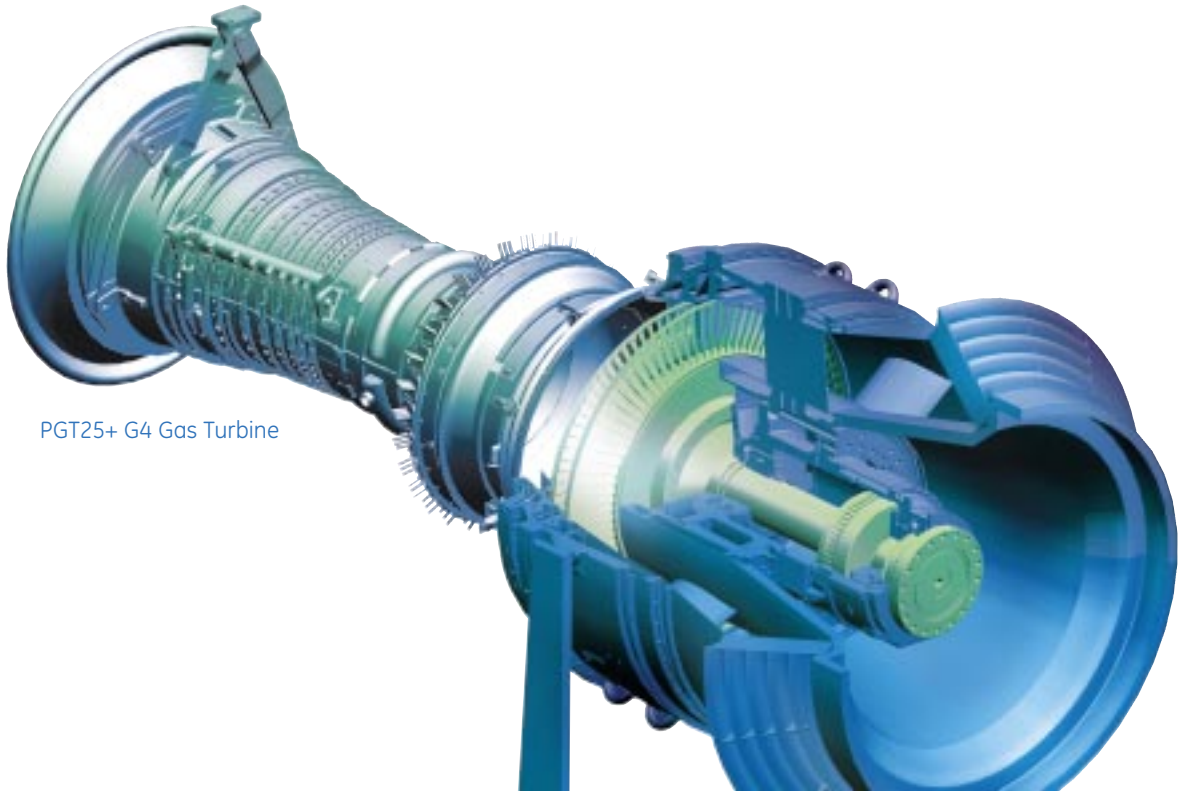
### Turbine
- Two stage Gas Generator turbine
- Two stage Power turbine (6100 RPM).

### Package
- Gas Generator, Power Turbine and auxiliary systems mounted on a single base plate
- The enclosure is integral with the base plate providing maximum accessibility for maintenance of the gas turbine and auxiliaries

### Emission Control
- Steam or water injection systems for NOx abatement
- Dry Low Emission (DLE) combustion system

# **PGT25+G4** Aeroderivative Gas Turbines

The PGT25+G4 is a 34MW gas turbine consisting of an enhanced LM2500+ G4 Gas Generator coupled with a 2-stage High Speed Power Turbine Module with increased flow capacity. High efficiency and reliability together with fuel flexibility and low emissions are just some of the many features that make this product the ideal choice for both mechanical drive and power generation in pipeline and E&P applications both onshore and offshore. Upgrade kits for the installed base of PGT25+ units are available to increase output power by 10%.
The gas generator of the PGT25+G4 is that of the PGT25+ upgraded for increased flow capacity of the high pressure (HP) compressor and turbine.
The power turbine  for the PGT25+G4 was developed based on GE's extensive experience with heavy duty gas turbines. The aerodynamic blading design provides high efficiency at both the design point and at reduced speed.



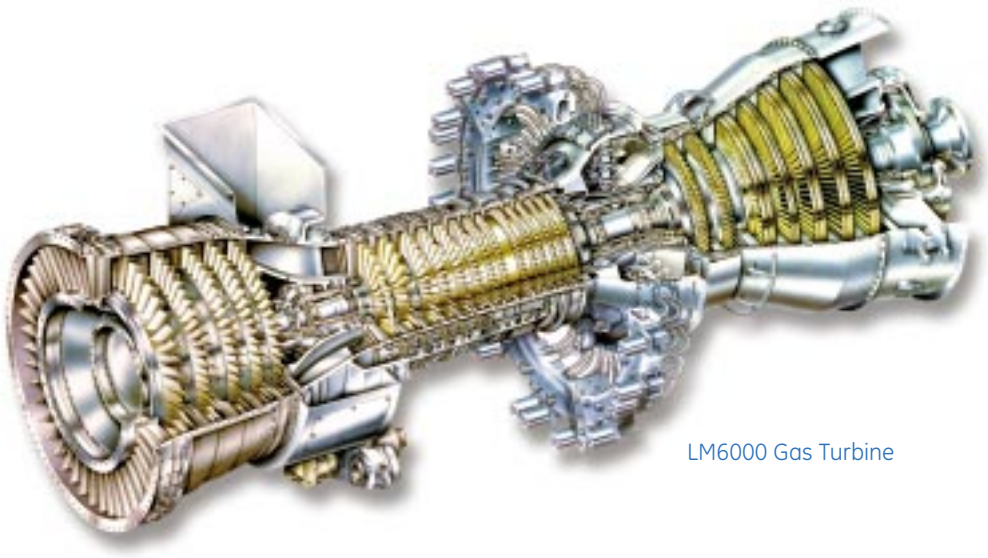
PGT25+ G4 Gas Turbine

## GENERAL SPECIFICATIONS

- Output Power 34 MW
- Heat Rate 8700 kJ/kWh
- Exhaust Temperature 510 °C
- Exhaust Flow 89 kg/s
- Pressure ratio 24:1
- DLE Combustor
- Standard Natural Gas
- 100% Power Turbine Speed
- ISO conditions 60% Relative Humidity
- Sea Level
- Cycle Deck Limits Applied
- Tamb °C 15

# **LM6000** Aeroderivative Gas Turbines

The LM6000 is a simple-cycle, two-shaft, high performance gas turbine derived from the GE CF6-80C2 high bypass turbofan aircraft engine, the industry standard for high-thrust engines. The LM6000 delivers more than 44.8 MW at over 42.7% thermal efficiency. Direct drive provides 60,000 shaft horsepower from either end of the low pressure rotor for a wide range of electric power generation and mechanical drive applications in any environment.
High thermal efficiency, low cost, and installation flexibility make the LM6000 the ideal choice as a prime driver for utility peaking, mid-range, and base load operations, as well as for industrial cogeneration.
The LM6000's design allows full speed range capability from 50-105% of the rated speed of 3600 RPM. Continuing the tradition of the established record of GE's LM2500, the LM6000 is ideal as a source of drive-power for pipeline compression, offshore platform and gas re-injection, as well as for LNG compressors. The LM6000 was GE's first aeroderivative gas turbine to employ the new Dry Low Emissions (DLE) premixed combustion system. DLE dual fuel, water or steam injection can also be used to achieve low NOx emissions.



LM6000 Gas Turbine

## GENERAL SPECIFICATIONS

### Compressor
- Two axial compressors (LPC, HPC)
  - 5 stage LPC
  - 14 stage HPC
- Pressure ratio 28.5:1

### Combustion
- Annular combustion chamber (30 fuel nozzles)

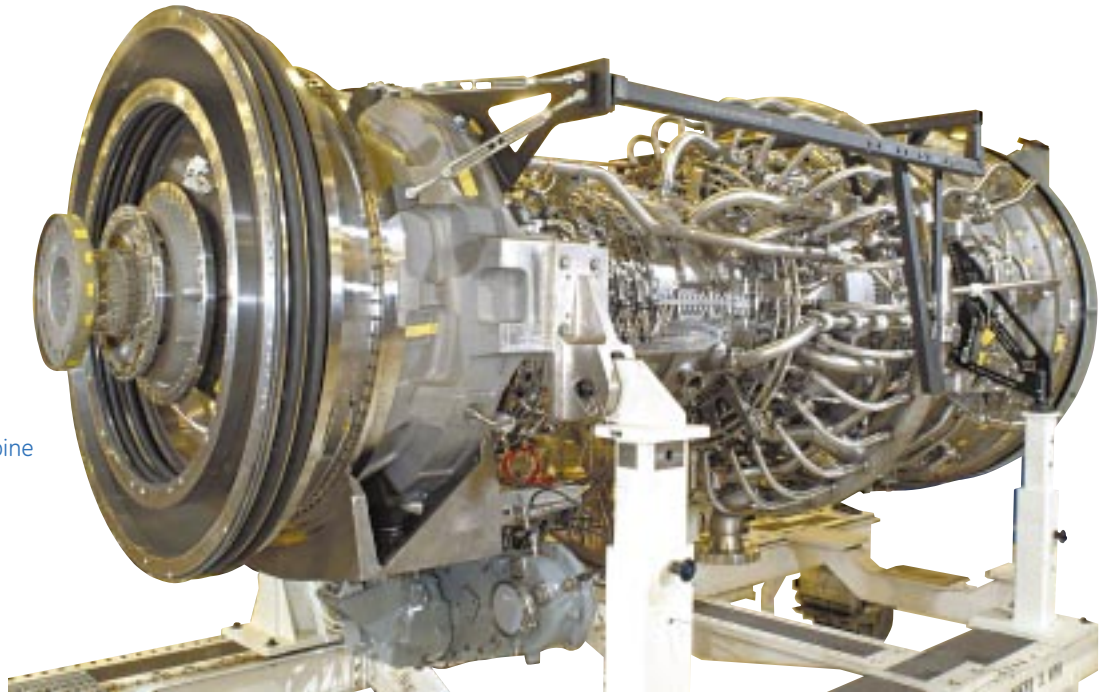
### Turbine
- Two stage HPT
- Six stage LPT (3600 RPM)

### Package
- Gas generator, power turbine and auxiliary systems mounted on a single base plate
- The enclosure is integral with the base plate providing maximum accessibility for maintenance of the gas turbine and auxiliaries

### Emission Control
- Steam or water injection systems for NOx abatement
- Dry Low Emission (DLE) combustion system

# **LMS100** Aeroderivative Gas Turbines

The LMS100, is a simple-cycle, three-shaft gas turbine that uses intercooling technology to increase power and efficiency. At more than 100MW, or 134,000 shaft horsepower and 46% efficiency, the LMS100 provides the highest level of performance of any aeroderivative gas turbine today. Combining GE Aviation's highly successful CF6-80C2/80E high bypass turbofan engine and GE Energy's Frame 6FA+e gas turbine, this powerful machine represents the most extensive collaboration of design and manufacturing expertise in the history of GE.
The LMS100's aeroderivative core and free power turbine allows operating flexibility not seen in any other gas turbine of its size. The free power turbine is ideal for mechanical drive applications due to the simple change-out of the first stage Power Turbine nozzle to optimize performance for 3,000 or 3,600 rpm drive shaft speeds. The part power efficiency of the LMS100 is greater than other gas turbines at maximum power. The modular design and ability to change-out the supercore (core + intermediate pressure turbine assembly) engine in 24 hours, provides increased availability. The LMS100 utilizes a single design for 50Hz, 60Hz and mechanical drive with one common gas turbine, improving fleet reliability.



LMS100 Gas Turbine

## GENERAL SPECIFICATIONS

### Compressors

- Two axial compressors (LPC, HPC)
  - LPC first 6 stages from GE MS60001FA+e
  - HPC 14 stage from CF6-80C2/LM6000
- Pressure ratio 42:1

### Combustion and Emissions Control

- Annular combustion chamber (30 fuel nozzles)
- Dry Low Emissions (DLE) available 2009 (15 premixers)
- Water or steam injection for NOx abatement
- DLE available in 2009

### Turbines

- Three turbine sections (HPT, IPT, PT)
  - HPT 2 stage air-cooled
  - IPT 2 stage
  - PT 5 stage (variable speed)

### Package

- Gas turbine driver package with enclosure
- Auxiliary skid mounted in front of the package for short easy connections
- Package factory wired to I/O packs in terminal box for increased reliability – Fiber optic cable to control system

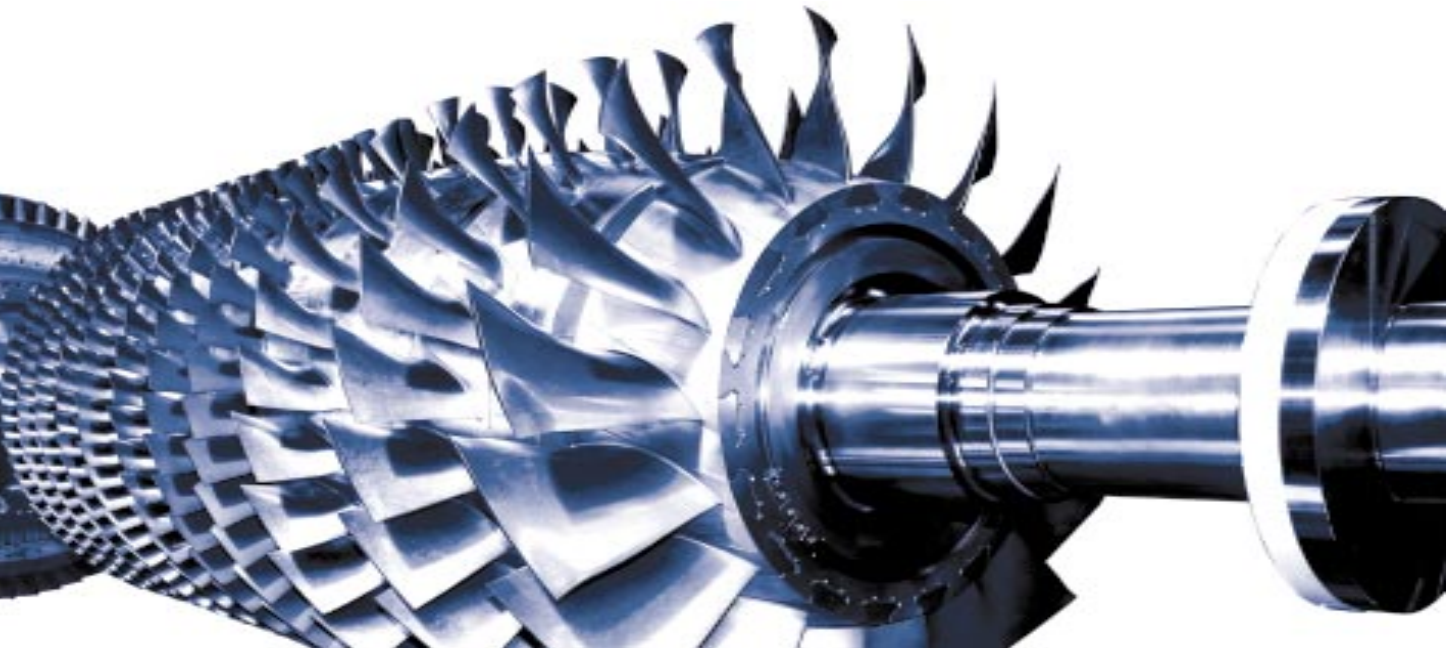
### Emissions Control

- Water or steam injection for NOx abatement
- DLE available in 2009

# Main Components

## Heavy Duty Axial Compressor

The compressor rotor is made of separately forged wheels (all models except part of the GE10 which has a solid forged rotor). Each individual wheel undergoes inspection and is X-rayed for material flaws. In addition, each wheel is balanced individually and the rotor is balanced on three planes. Rabbet fits are used to ensure concentricity and multiple through-bolts secure the wheels to form a correctly pre-stressed assembly. The blades are held in the compressor rotor and stator rings by dovetail platforms. The stainless steel blades provide excellent corrosion resistance and good internal damping characteristics. The large chord, broad-blade compressor blades have low stresses and the unique ability to withstand damage by small foreign objects as well as to maintain high performance in spite of normal wear and contamination. The stator casing is horizontally split for ease of assembly, maintenance and inspection. Iron castings give dimensional and thermal stability to maintain good radial tip clearances for maximum power and efficiency. Several compressor designs are available covering pressure ratios from 8:1 to 17:1 and air flows from 20 to 400 Kg/sec with 11-17 stage configurations. The GE10 and MS5002E compressors have variable geometry, implemented by means of adjustable vanes (inlet guide vanes and first stage stator vanes), in order to provide flow control within the operating range.



## Heavy Duty Turbine First Stage Nozzle

The complete first stage nozzle assembly consists of airfoil-shaped vanes which are contained between an inner and an outer sidewall. The design of the nozzle assembly and the arrangement for its support within the turbine shell accommodate the effects of thermal expansion caused by the hot gases and keep the assembly properly aligned in the gas path. Seals in the turbine shell prevent leakage of combustion gases around the nozzle from the inlet to the exhaust. Compressor discharge air is fed to these sealing rings through orifices in the shell. A key feature of the first-stage nozzle is the air-cooled partition which increases nozzle life substantially. Cooling air from the compressor discharge is directed through the body of the individual nozzle partitions, exiting through holes near the trailing edge. This not only cools the metal, but blankets the trailing edge with a film of air. Additionally, relatively thick nozzle partition trailing edges provide increased strength and oxidation resistance, again providing longer nozzle life.

## Heavy Duty Turbine Buckets and Wheels

The long shank bucket design lowers the turbine wheel rim a substantial distance below the hot gas path. The high thermal resistance of the shank results in a considerable temperature drop between the hot bucket vane and the wheel dovetail slot, thus reducing temperature levels and gradients in the turbine wheel and the dovetail area where rotating stresses are high. Further wheel protection is provided by radial seals on the first-stage bucket shanks that restrict hot gas leaks into the wheel cavities. Compressor bleed air is used to cool the wheels and maintain relatively low temperature levels.

# Gas Turbine Operability

## Large Operability Window

A variety of innovative design solutions are offered to maximize the operability window of the Oil & Gas heavy duty gas turbine fleet. In addition to variable stator vanes and blow-off valves, the design solutions include:

- variable turbine nozzle guide vanes
- a variable bypass combustion chamber
- a high turn-down capability combustion chamber
- corrected parameter control logic

The various combinations of design solutions are specifically adapted to the demands of the marketplace for each gas turbine model.

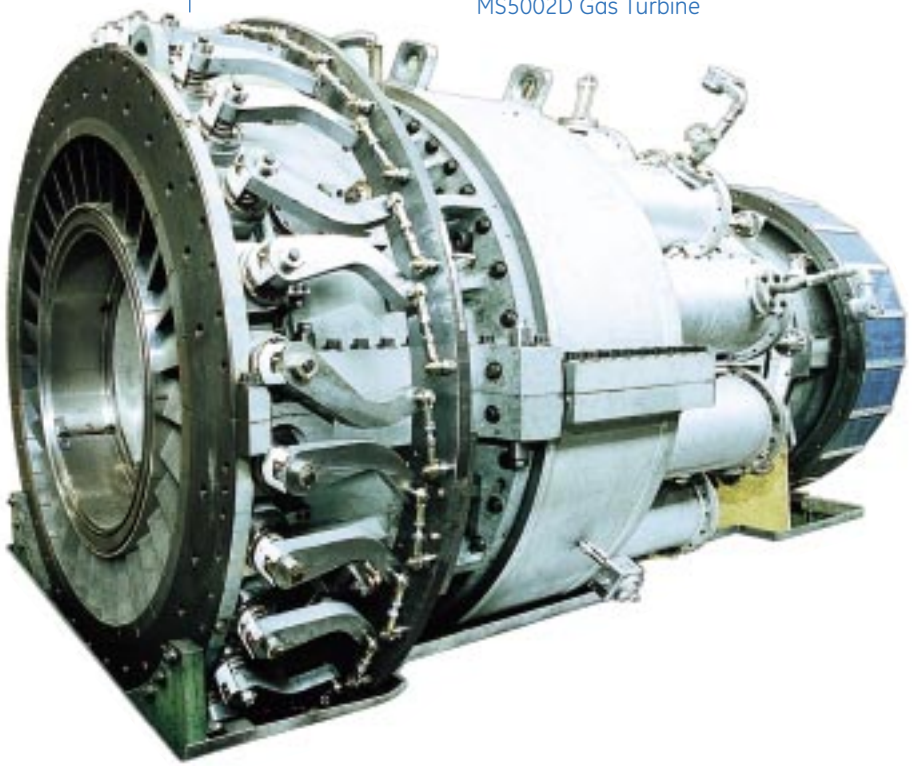
For example: The GE10-2 DLN (Dry Low NOx) model utilizes a variable bypass combustion chamber to maintain the optimum flame temperature for low emissions all the way down to 50% load, and the variable nozzle guide vanes of the free power turbine to ensure that the gas generator shaft speed is always at the design value, thereby ensuring maximum output.

The MS5002D instead uses variable nozzle guide vanes to maintain maximum output on the standard model, and to maintain the optimum flame temperature for low emissions down to 50% load on the DLN model. They are also used in regenerative cycle applications to maximize the efficiency of the regenerator and hence, to maximize fuel economy.

The MS5002E makes use of the DLN2 combustion design used in GE's F-Class machines to ensure low emissions over a range of flame temperatures, thereby delaying the opening of the bleed valves at part load while maintaining the highest possible efficiency at base-load.

Note that the flexibility given by each of these solutions delivers a further performance advantage on cold days with respect to other engines that are forced to open bleed valves (to meet environmental emissions laws) even at base-load.

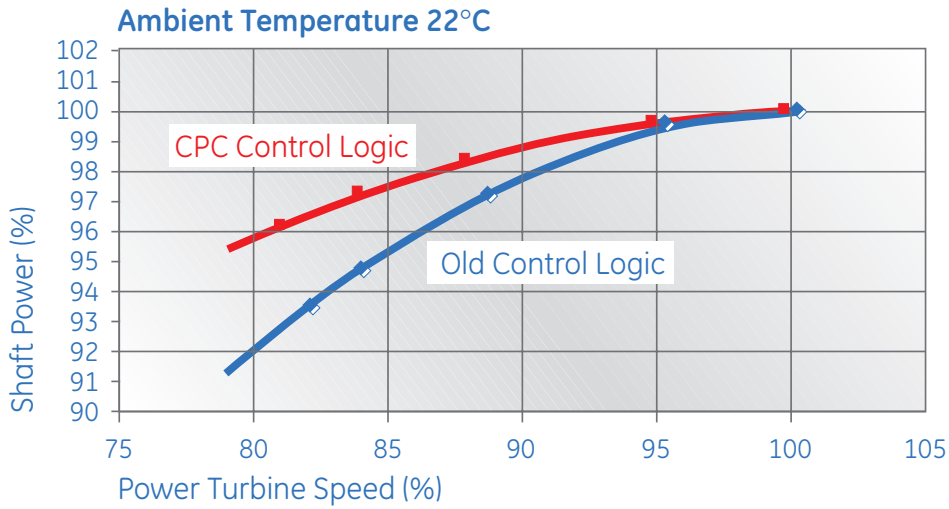
MS5002D Gas Turbine



## CPC Logic

One of the enhancements recently introduced is the Corrected Parameter Control logic (CPC). This type of control philosophy applies principally to mechanical drive units, and consists of an exhaust temperature control curve that self adjusts according to the condition of the inlet filters and actual power turbine speed. This allows the engine to be operated at optimum conditions not only at the nominal point, but over the entire operating envelop of inlet conditions and power turbine speeds. The results of this improvement have already been proven in the field, and are shown in the following figure (relating to the test of a GE10-2 unit at various free power turbine speeds). Through the application of CPC logic it has been possible to significantly increase the maximum output without compromising the safe operation of the unit by simply optimizing its operation in real-time.

The variable free power turbine speed element of the CPC logic is a standard feature of MS5002D DLN and MS5002E models, and all new GE10-2 units. The retrofit of existing gas turbine models with this solution is also offered.



# LNG, Exploration and Production, Floating Production Units

## Gas, Water Injection & Gas Storage Units

Gas compression is a critical operation in the Oil & Gas production chain. Therefore, reliability is a key factor in the design of our natural gas compressors.
We have delivered over 200 compressor trains for gas re-injection and gas storage applications. Of the more than 380 casings supplied, 105 have a design pressure higher than 7,200 psia (500 bar a). Our many years of experience in designing, manufacturing, installing and servicing these machines has validated GE designs and production processes. Reliability of this rotating equipment is directly related to rotor stability and impeller integrity throughout the entire envelope of operating conditions and our machinery has been successfully proven by long years of service under the challenging conditions found in the Oil & Gas Industry.
The high level of power involved in these compression applications requires gas turbines as drivers. GE provides a complete range of mechanical drive gas turbines that are ideally matched to Oil & Gas applications. The extensive use of the GE MS6001 and MS7001EA single shaft gas turbine technology for LNG mechanical drive applications is a result of our plant integration services and the ability to optimize the design of both the gas turbine and the compressor for these applications. The result is flawless performance of turbocompressors that have accumulated more than 100,000 hours of operation in the largest LNG plants in the world.
Our ability to integrate, test and deliver the entire turbocompressor train is a great advantage to the Customer in terms of the optimization of system performance and delivery time, as well as the efficiency of working with a single supplier.

Ras Laffan
Mesaieed - Qatar
MS5002 Turbo units for
LNG and Ammonia
Synthesis

Bongkot Field - Thailand
Single lift module for
offshore application
PGT25 Gas Turbines

Woodside - Australia
MS5002C LNG main refrigerant
compressor drive

Hassi R' Mel - Algeria
Natural Gas Re-injection plant
36 MS5002 Gas Turbines

# Pipeline Transportation

## Pipeline Standard Units/Packages

The gas turbines manufactured by GE's Oil & Gas business have features that make them particularly suitable for pipeline compressor applications. GE's pipeline centrifugal compressor line complements its gas turbine line to optimize matching with the gas turbine driver, resulting in perfectly integrated turbocompressor units.
Specific pipeline service requirements, flexibility in meeting varying operating conditions, reliability, availability and unattended remote control are fully satisfied by these gas turbine and pipeline compressor lines. Direct compressor turbine couplings improve the reliability and efficiency of the turbocompressor units reducing the spares inventory. Compact integrated turbocompressor units make for easy transportation and rapid on-site commissioning. All units are on structural steel base plates, completely shop piped, wired, instrumented, tested and ready to be shipped to the site, minimizing commissioning time.

Blue Stream
Pipeline Project from
Turkey to Russia
PGT25 - BCL406/b

Sbikha - Tunisia
PGT 25 - PCL603
Pipeline Compressors

Feriana - Tunisia
PGT25 - PCL600

Biskra - Algeria
OK1 - SP3bis Station
GE10-2

Cape Bon - Tunisia
Trans-Med Pipeline Cape Bon to Sicily
Head Station 25 MW Gas Turbine
Driven Booster Compressors.
MS5002 - BCL404/a

# Refinery and Petrochemicals

## Downstream Plants

Gas turbine-driven centrifugal compressors are also used in downstream process industries such as refineries and petrochemical and fertilizer plants that need flexible and reliable compression trains.

Our turbocompressors are individually tailored to meet the customer's performance requirements. They combine in a packaged unit the extensive experience gained by our company on both types of machines and the advantages of a single source of supply--fully integrated auxiliary systems and high operational flexibility and reliability.

Typical applications include:

- Process air centrifugal compressor drive in ammonia synthesis plants
- High power centrifugal or axial compressor drive in Gas to Liquids plants
- Production of compressed air from the turbine axial compressor section and compressor drive in air fractionating processes.

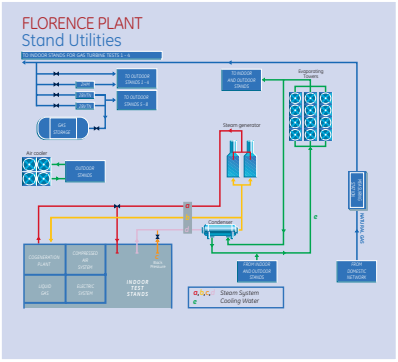
Livorno - Italy
MS9001 Turbogenerator units
for Refinery plant

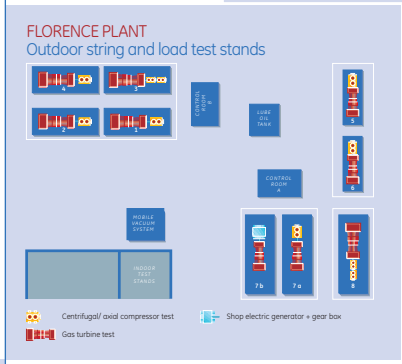
Mesaieed - Qatar
MS5001 Turbogenerator units
for Fertilizer plant

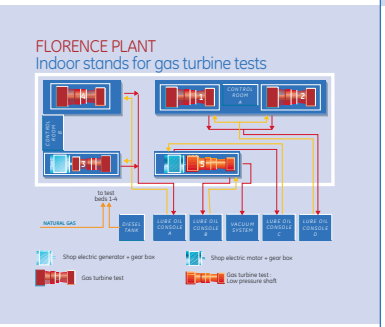
Rhourde Nouss - Algeria
MS5001 - MS3001 Gas Turbines and
2BCL 406B Compressors

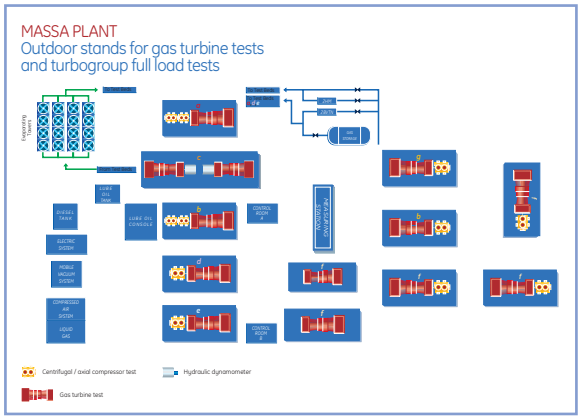
# Test Facilities

Mechanical tests are carried out on all of our gas turbines. Complete turbocompressors and turbogenerators, including all auxiliary equipment, can be full speed, full-load tested in outdoor test beds complying with API, ASME, VDI and ISO international standards at the Florence or Massa plants. Even complete modules can be tested at the Massa plant and than shipped without being disassembled because of its proximity to the Massa harbor. The test beds are equipped with computer Data Acquisition Systems capable of collecting thermodynamic and mechanical data and computing in real time. Test facilities include a high pressure feed system for gas mixtures (inert and flammable gases), a gas chromatograph for gas analysis, a 60 Hz generator, low and high pressure gas coolers, and steam and lube oil supply. The cooling towers allow closed-loop test up to 130 MW. We also test complete plants on site on customer request.



# Service

GE's Oil & Gas business provides a complete set of services to support the entire gas turbine product line. We offer an extensive portfolio of proactive and interactive service products such as condition-based maintenance and long term service agreements complementing the traditional service offerings of OEM spare parts, repairs, and field services.
Our innovations are not limited to mechanical engineering. We have developed business solutions such as remote monitoring & diagnostics to help drive customer value by providing higher equipment reliability, availability, and productivity at a predictable cost.
Other advanced information-based developments include electronic parts catalogs, and e-commerce solutions.
Global Services engineers are backed up by our new product design engineering groups and by the GE Global Research Center -- hundreds of creative minds working to provide the high-tech products and business solutions for the 21st century.

# Training

GE's Oil & Gas business offers training for the operation and maintenance of our complete line of machinery and equipment.
This training can be provided either at the client's site or at the Learning Center located at the GE Infrastructure Oil & Gas headquarters in Florence, Italy. Instructors are field-seasoned experts who combine their understanding of theory with practical experience.
The quality training that they provide is a prerequisite for improving the skills of operations and maintenance personnel, to ensure safety, and superior equipment efficiency and availability.
Courses and and documentation are designed to meet customer needs, focusing on the GE Energy machinery and equipment actually installed at their sites.
Traditional training tools are augmented with computer-based training and interactive multimedia technology. Courses and technical literature can be provided in a variety of languages.

## CENTER OF EXCELLENCE FOR TRAINING

### Florence Learning Center Facilities:

- 5600 $m^2$ of space
- More than 20 training rooms
- Speedtronic Mark V & Mark VI
- Bently Nevada simulators
- Laboratories
- Multimedia rooms
- Conference center
- Auditorium seating for 230 (under completion)

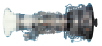
## TRAINING SOLUTIONS:

- For all levels in your organization
- Tailored to your specific needs
- Prescheduled offerings or on request
- Provided in various languages
- Formal classroom training and interactive learning

## COVERED EQUIPMENT

Nuovo Pignone, Thermodyn, Rotoflow, Bently Nevada and other GE equipment.

# Generator Drive (ISO conditions - natural gas - electrical generator terminals)

| | ISO RATED POWER | HEAT RATE | EFFIC. | PRESSURE RATIO | EXHAUST FLOW | | TURBINE SPEED | EXHAUST TEMPERATURE | |
|---|---|---|---|---|---|---|---|---|---|
| | kW | kJ/kWh | % | | kg/sec | lbs/sec | RPM | °C | °F |
|  GE10-1 | 11,250 | 11,489 | 31.4 | 15.5 | 47.5 | 104.7 | 11,000 | 482 | 900 |
|  PGT16 | 13,720 | 10,295 | 35.0 | 20.2 | 47.3 | 104.3 | 7,900 | 491 | 919 |
|  PGT20 | 17,464 | 10,238 | 35.2 | 15.7 | 62.5 | 137.7 | 6,500 | 475 | 887 |
|  PGT25 | 22,417 | 9,919 | 36.3 | 17.9 | 68.9 | 151.9 | 6,500 | 525 | 976 |
|  PGT25+ | 30,226 | 9,084 | 39.6 | 21.5 | 84.3 | 185.9 | 6,100 | 500 | 931 |
|  PGT25+G4 | 33,057 | 9,047 | 40.0 | 23.2 | 89.6 | 197.7 | 6,100 | 510 | 950 |
|  LM6000* | 42,262 | 8,787 | 41.1 | 28.0 | 125.0 | 275.0 | 3,600 | 455 | 851 |
|  LMS100* | 98,196 | 7,997 | 45.0 | 40.0 | 206.9 | 456.0 | 3,600 | 417 | 782 |
|  MS5001 | 26,830 | 12,687 | 28.4 | 10.5 | 125.2 | 276.1 | 5,094 | 483 | 901 |
|  MS5002E* | 31,100 | 10,285 | 35.0 | 17.0 | 102.0 | 225.0 | 5,714 | 511 | 952 |
|  MS6001B | 42,100 | 11,230 | 32.1 | 12.2 | 141.1 | 311.0 | 5,163 | 548 | 1,026 |
|  MS7001EA | 85,400 | 10,990 | 32.7 | 12.6 | 292.0 | 643.0 | 3,600 | 537 | 998 |
|  MS9001E | 126,100 | 10,650 | 33.8 | 12.6 | 418.0 | 921.0 | 3,000 | 543 | 1,009 |

(*) DLE Combustion

# Mechanical Drive (ISO conditions - natural gas - shaft output)

| | ISO RATED POWER | | HEAT RATE | | EFFIC. | PRESSURE RATIO | EXHAUST FLOW | | TURBINE SPEED | EXHAUST TEMPERATURE | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | kW | shp | kJ/kWh | btu/shp-h | % | | kg/sec | lbs/sec | RPM | °C | °F |
|  GE10-2 | 11,982 | 16,068 | 10,822 | 7,651 | 33.3 | 15.5 | 46.7 | 103.0 | 7,900 | 480 | 896 |
|  PGT16 | 14,240 | 19,096 | 9,924 | 7,016 | 36.3 | 20.2 | 47.3 | 104.3 | 7,900 | 491 | 916 |
|  PGT20 | 18,121 | 24,300 | 9,867 | 6,975 | 36.5 | 15.7 | 62.6 | 137.9 | 6,500 | 475 | 887 |
|  PGT25 | 23,266 | 31,200 | 9,548 | 6,750 | 37.7 | 17.9 | 68.9 | 151.9 | 6,500 | 525 | 976 |
|  PGT25+ | 31,372 | 42,070 | 8,751 | 6,187 | 41.1 | 21.5 | 84.3 | 185.8 | 6,100 | 500 | 932 |
|  PGT25+G4 | 34,302 | 46,000 | 8,719 | 6,162 | 41.2 | 23.8 | 89.6 | 197.7 | 6,100 | 510 | 950 |
|  LM6000* | 43,854 | 58,809 | 8,468 | 5,985 | 43.0 | 28.0 | 125.0 | 275.0 | 3,600 | 455 | 851 |
|  LMS100* | 100,200 | | 8,160 | | 44.1 | 40.0 | 206.9 | 456.0 | 3,600 | 417 | 782 |
|  MS5002C | 28,340 | 38,005 | 12,467 | 8,814 | 28.8 | 8.8 | 124.3 | 274.1 | 4,670 | 517 | 963 |
|  MS5002E* | 32,000 | 42,912 | 10,000 | 7,070 | 36.0 | 17.0 | 102.0 | 225.0 | 5,714 | 511 | 952 |
|  MS5002D | 32,580 | 43,690 | 12,235 | 8,650 | 29.4 | 10.8 | 141.4 | 311.7 | 4,670 | 509 | 948 |
|  MS6001B | 43,530 | 58,380 | 10,820 | 7,650 | 33.3 | 12.2 | 140.0 | 309.0 | 5,111 | 544 | 1,011 |
|  MS7001EA | 86,226 | 115,630 | 10,920 | 7,720 | 33.0 | 12.6 | 296.0 | 652.5 | 3,600 | 535 | 995 |
|  MS9001E | 130,140 | 174,520 | 10,397 | 7,350 | 34.6 | 12.7 | 410.0 | 901.0 | 3,000 | 540 | 1,004 |

(*) DLE Combustion

| | | GENERATOR DRIVE | | MECHANICAL DRIVE | |
|---|---|---|---|---|---|
| | | Approx. Weight (**) | Approx. Dimensions (**) | Approx. Weight (**) | Approx. Dimensions (**) |
| | | Kg. | m. | Kg. | m. |
|  | GE10 | 34,000 | 9.0 x 2.5 x 6.0 | 38,000 | 10.5 x 2.5 x 6.0 |
|  | PGT16 | 19,000 | 8.1 x 2.5 x 3.8 | 19,000 | 8.1 x 2.5 x 3.8 |
|  | PGT20 | 37,650 | 9.1 x 3.5 x 3.5 | 37,650 | 9.1 x 3.5 x 3.5 |
|  | PGT25 | 37,650 | 9.1 x 3.5 x 3.5 | 37,650 | 9.1 x 3.5 x 3.5 |
|  | PGT25+ | 30,750 | 6.5 x 3.6 x 3.9 | 30,750 | 6.5 x 3.6 x 3.9 |
|  | PGT25+G4 | 30,850 | 6.5 x 3.6 x 3.9 | 30,850 | 6.5 x 3.6 x 3.9 |
|  | LM6000 | 31,000 | 9.3 x 4.2 x 4.4 | 31,000 | 9.3 x 4.2 x 4.4 |
|  | MS5001 | 87,430 | 11.6 x 3.2 x 3.7 | | |
|  | MS5002C/D | | | 110,000 (*) | 15.0 x 3.2 x 3.8 (*) |
|  | MS5002E | 117,000 | 17 x 3.4 x 4 | 117,000 | 17x 3.4 x 4 |
|  | MS6001B | 96,000 (*) | 15.9 x 3.2 x 3.8 (*) | 96,000 (*) | 15.9 x 3.2 x 3.8 (*) |
|  | MS7001EA | 121,000 | 11.6 x 3.3 x 3.8 | 121,000 (*) | 11.6 x 3.3 x 3.8 (*) |
|  | MS9001E | 217,500 (*) | 22.1 x 4.5 x 6.3 (*) | 256,000 (***) | 16 x 4.5 x 5 (***) |

(*) including auxiliary skid
(**) gas turbine skid without enclosure
(***) gas turbine package

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GE imagination at work

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