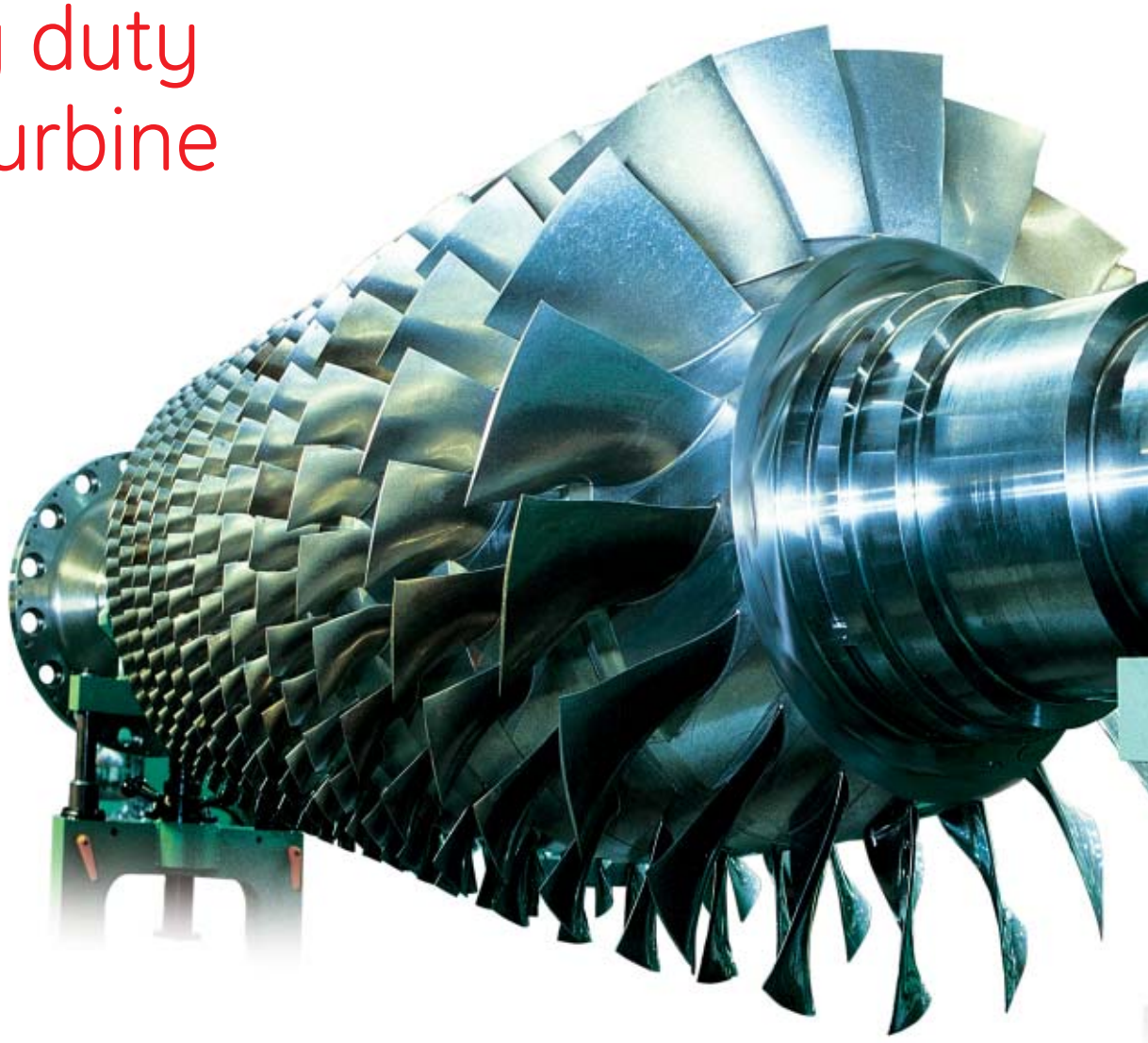
GE
Oil & Gas

MS5002E

A state-of-the-art technology heavy duty Gas Turbine



COMPRESSOR

The compressor is an 11-stage, high pressure ratio (17:1), axial flow design scaled-up directly from the GE10 gas turbine. The GE 10 fleet list contains over 80 installed units and over 700,000 operating hours. During this time, the axial compressor has demonstrated its robustness and high performance. At the nominal operating speed of 7455 rpm, the airflow is 101 Kg/sec. The inlet guide vanes (IGV) and the first and second stage stator blades have hydraulically actuated variable vanes. There are two bleed ports located along the flow-path: the 4th stage bleed is used for LP turbine wheel cooling and bearing sealing, and the 7th stage bleed is used for cooling and for surge control during start-up/shut-down. As in the GE10, the compressor rotor has a forward stub shaft, six discs and five spacers, and an aft stub shaft, all locked together with 26 tie bolts. The compressor casings are horizontally split for on-site maintenance. The air inlet casing supports Bearing #1, a combined tilting-pad journal and thrust bearing. The casing materials are cast iron for the inlet case, nodular cast iron for the intermediate case, and cast steel for the compressor discharge case.

COMBUSTION SYSTEM

The combustion system is a multi-can, reverse flow type, with six cans mounted on the compressor discharge case. It is derived from the GE Oil & Gas DLN2 combustor design installed on "F" Class machines with an installed fleet of over 700 units and more than 11,000,000 operating hours.
The combustor architecture and materials are the same as for "F" Class machines (e.g., 6FA, 7FA, 9FA) but the firing temperature of the MS5002E was intentionally kept 100°C lower to maximize parts life and maintenance intervals.
Current operation is with gaseous fuel but future development will include liquid fuel capability. There are 5 fuel nozzles in each combustion can. The fuel nozzles contain a premixing tube where fuel gas and air mix together before the primary burning zone, and a central body with a diffusion fuel gas circuit. The combustor operates in diffusion mode at low loads (less than 50%), and in premixed mode at higher loads with an 18 ppm NOx level. The fuel gas delivery system is provided with multiple gas control valves to distribute the fuel to the different gas circuits. An accurate split is maintained during premix operation to ensure both low emissions and low combustion dynamics.

HP TURBINE

The axial flow, two-stage reaction type HP Turbine was designed to deliver high efficiency over a broad power range. It consists of two turbine wheels, first and second stage turbine nozzle assemblies, and turbine casings. Both stages of HPT nozzles are air cooled (convection and film) by compressor discharge air flowing through each vane. Both stages of HPT buckets are cooled by compressor air flowing through the dovetail and shanks into the buckets.

LP TURBINE

The power turbine uses the same general arrangement, materials and mechanical structure as that of the PGT25+ whose installed fleet consists of over 80 units and more than 500,000 operating hours. The flow-path profile and airfoils were redesigned to allow 20% higher airflow than the PGT25+.

HP Rotor Assembly

PERFORMANCE (@ ISO conditions)	MS5002E	
	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

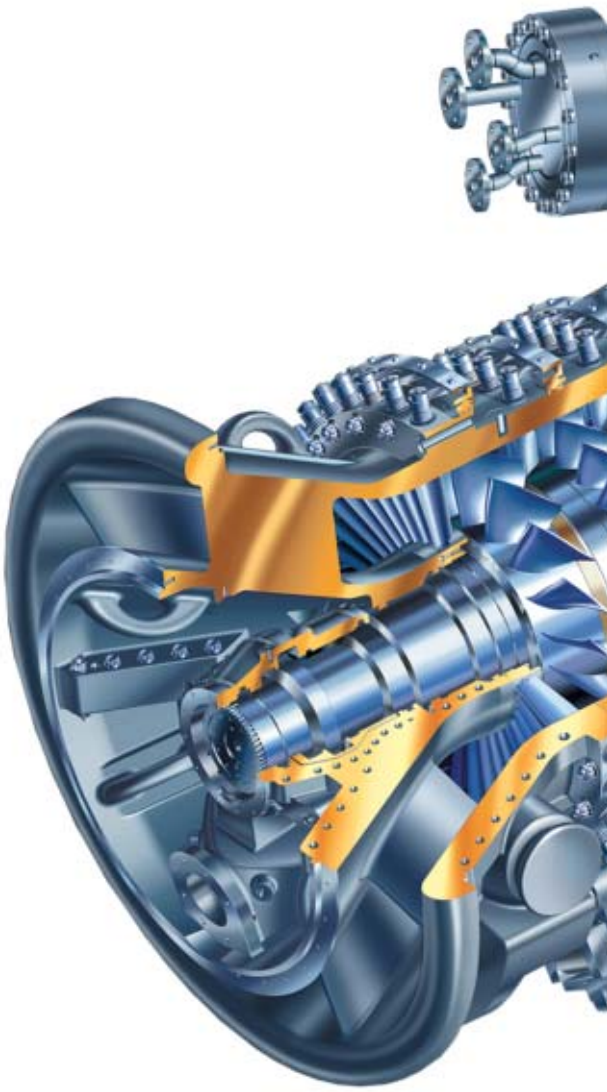
The MS5002E, the latest addition to the GE Oil & Gas family of gas turbines, is a 32MW-class machine designed for high efficiency, low environmental impact and high reliability. This latest machine was developed in response to Customer demand for a machine in the 32 MW range with low fuel consumption, reduced emissions and high availability and reliability.

In order to guarantee high reliability and availability, the MS5002E has a conservative firing temperature with respect to the state-of-the-art.

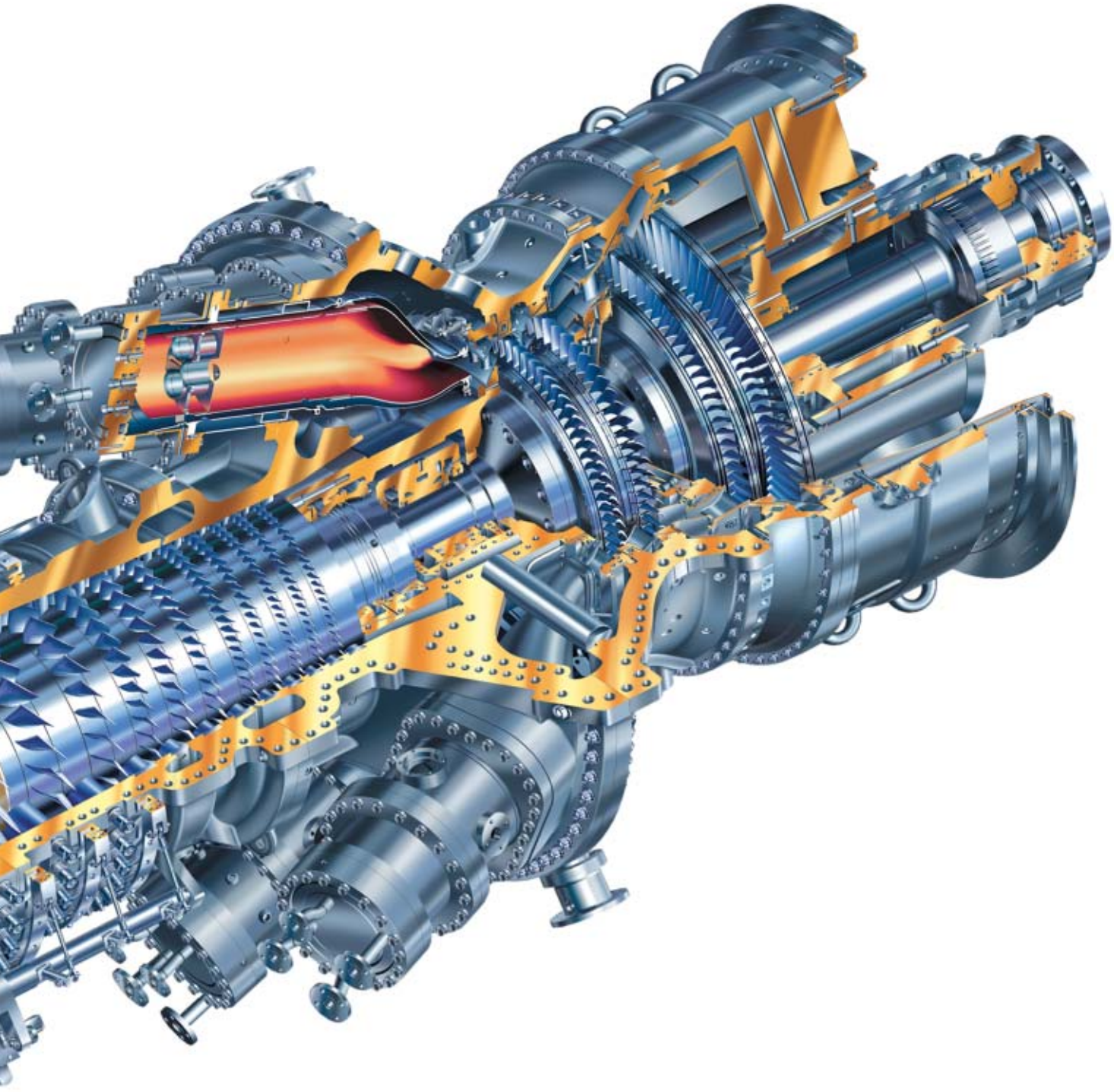
High efficiency was achieved through the use of advanced design tools to optimize airfoils, clearances, leakages and the distribution of cooling flows.

The MS5002E offers NOx emission levels down to 18 ppm through the use of a dry low emission combustion system derived from the GE Oil & Gas DLN2 combustion technology.

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



MS5002E
Gas Turbine



TEST PROGRAM

ROTORDYNAMIC TEST

A full scale engine rotordynamic test was carried out to validate the lateral and torsional dynamic behavior of the entire engine. The test stand consisted of the engine (casings, supports, bearings and rotors), two variable speed electric motors, gears, couplings and support frames. The test, preceded by validation of rotor natural frequencies (free test), was successfully completed in June '02. The test results confirmed, as predicted by analysis, that there are no critical speeds within the HP or LP operating ranges, and API 616 criteria and limits of damped unbalanced analysis and experimental results were met. Rotor and casing vibration levels were found to be within acceptable limits both in the normal operating range and during transients (start-up, shut down).

COMBUSTION TEST

A thorough test campaign was performed at the GE Global Research and Development Center, to assess the combustor behavior over the entire range of operation. Design validation tests were also performed in a GE Oil & Gas full-scale test rig using a single can, full-scale combustor. The test program was carried out operating in both diffusion and premix modes. In the diffusion mode, the combustion system was tested for loads (from 50% to 100% load) at different gas turbine speeds and different ambient conditions. These tests showed low emissions and low dymanics, excellent margin to lean blow out and metal temperatures as predicted by analysis. Specific tests were also performed to verify ignition and cross fire capability. Tests with methane fuel were completed in Sept. '03. Other tests to explore and expand the ability to use different gas compositions (particularly inert gases, hydrocarbon, and heavy hydrocarbon) are ongoing. In addition, the test rig remains available to test the combustor performance with specific fuels as required for customer applications.

COMPRESSOR TEST

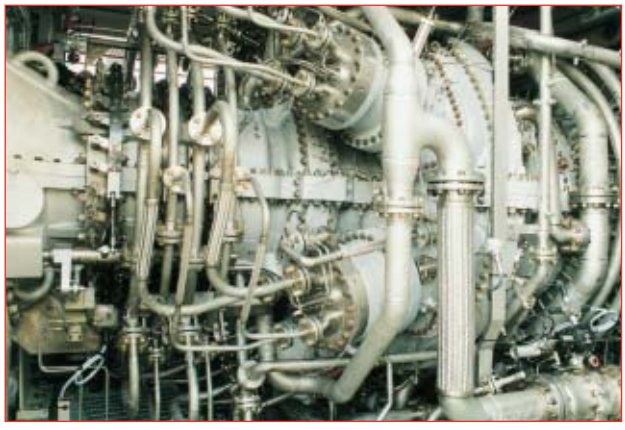
The purpose of the compressor testing was to evaluate both the mechanical behavior and the aerodynamic performance of the compressor. The main test objectives were:

— Define the axial compressor maps over the entire operating range (from 80% to 110% of corrected speed) and at low speed (from 20% to 75% of corrected speed) up to the surge limit.
— Assess the stator vane and rotor blade stresses and natural frequencies through strain gage data analysis.
— Validate rotor and casing thermal models through metal temperature measurements and clearance meter data.

The test rig consisted of the compressor (inlet plenum, casings and rotor) driven by a PGT25 gas turbine, an inlet system with air flow measurement tubes, an inlet throttle valve, and a compressor air discharge system.
The test was successfully completed in December '02 and the compressor design was validated:

— No compressor blade

Rotordynamic test stand



Engine

aeromechanical issues were identified and measured modal frequencies matched the predicted values within 3%
— The compressor performance was met for both mass flow and efficiency at the design point and off-design conditions
— Extensive measurements close to the surge limit indicated a large compressor surge safety margin.

MECHANICAL DRIVE TEST

A complete MS5002E prototype test was completed in December '03 at the GE Oil & Gas facility in Massa (Italy), and the overall system (engine and auxiliaries) was validated. The first unit used the previously tested MS5002E compressor as the driven load. The test plan covered all critical operating phases (pre-start, crank, idle, diffusion full load, premixed full load, DLN tuning, LP turbine mapping, etc.) to address all potential areas of machine risks and to cover all aspects necessary for validation of the design. The data relevant to test objectives.

GENERATOR DRIVE TEST

Following the first test campaign aimed at validating the machine under the demanding mechanical drive requirements, a second campaign was conducted to prove the machine capabilities in power generation applications. The test stand arrangement included an MS5002E coupled with a 40MW electric generator through a speed reduction gearbox. The electrical power output was absorbed by a resistor bank.
Twenty-four successful full load rejections, twenty-nine successful partial load rejections, and thirty one successful step load acceptances were conducted. The test results proved that the MS5002E is capable of stable operation at Full-Speed-No load, achieves full load rejections (32+ MW) with deceleration to flamed idle without trips, and can exceed 5 MW load steps (up or down) from any initial load with frequency recovery in compliance with international standards.
Test runs were completed in January '06 and proved the power generation.
Capability of the MS5002E for both grid connected conditions and operation in an island mode. A post-test engine disassembly was also conducted and no machine integrity issues were found.
The successful validation test also led to the first order for an MS5002E gas turbine for installation in the Netherlands. Operating in a cogeneration mode with a waste heat recovery generator, the new machine will produce 30 megawatts of electric power for the plant and 50 tons per hour of steam to be used for production processes. A contractual service agreement was also purchased. This agreement includes an extended warranty on the equipment, an availability guarantee, supply of capital spare parts, and full coverage for 15 years of planned maintenance, as well as provisions for unplanned maintenance activities.

Compressor test rig

Generator drive test rig

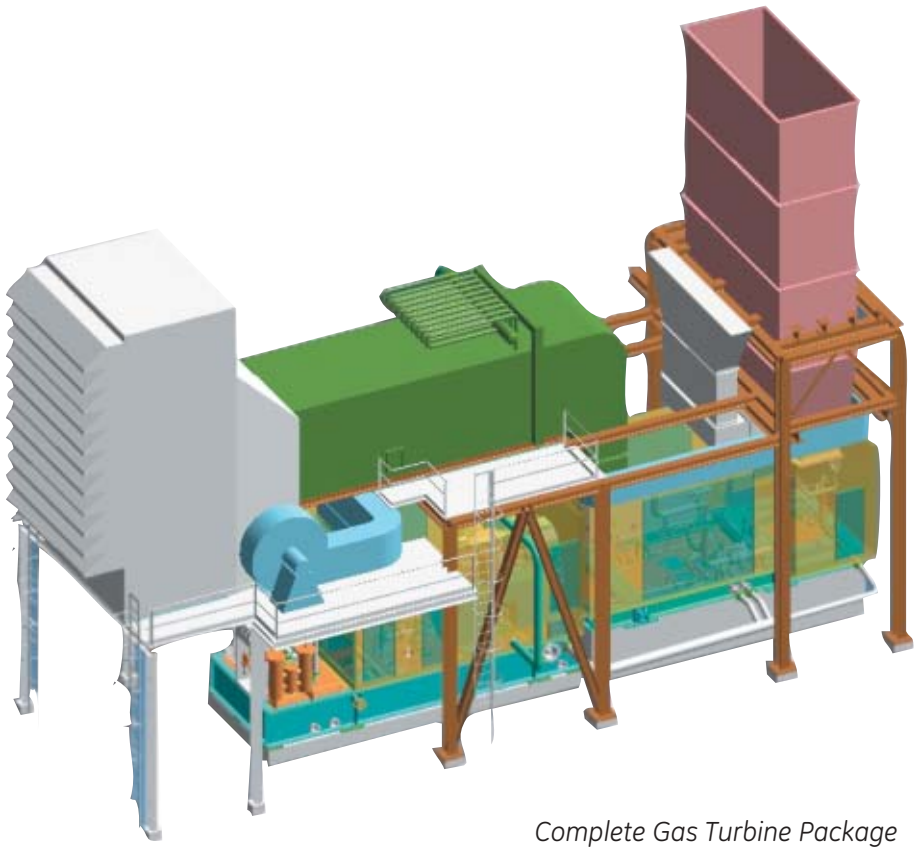
AUXILIARIES

The MS5002E package design is similar to that used in other mature GE Oil & Gas gas turbines. As with the MS5002D, two separate structural steel frames make up the base supports of the gas turbine (one for the engine and one for the auxiliaries).
The gas turbine is mounted on its base plate by means of two forward supports, (flexible in the axial direction), and two rear support legs. The engine base plate has approximately the same footprint as that of the MS5002D and contains both inlet and exhaust plenums. These plenums are suitable for both vertical and lateral orientation.
The auxiliary base plate contains the lube oil system and reservoir, hydraulic oil system, starting system with rotor turning device, and the fuel gas skid. This modular design permits different installation configurations for optimization of the plant layout to meet Customer requirements. The MS5002E is equipped with a SPEEDTRONIC Mark VI control system currently used on all GE gas turbine models.

MAINTAINABILITY

The MS5002E was designed for maintainability with special consideration given to:
— Planned maintenance
— Handling and lifting of gas turbine components and main auxiliaries
— Special maintenance tools
— Location of boroscope ports for easy inspection
— Enclosure access doors and openings

The horizontally split gas generator casings and the removable enclosure roof allow on-site maintenance. The power turbine is mounted on a special frame that permits it to be moved axially on the base plate. The module can be either disassembled directly on the base, or can be removed for off-base maintenance. Combustors can be disassembled without removal of the compressor discharge case, and bearings 1, 3 and 4 are easily accessible for inspection.



Complete Gas Turbine Package

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