AUXILIARIES

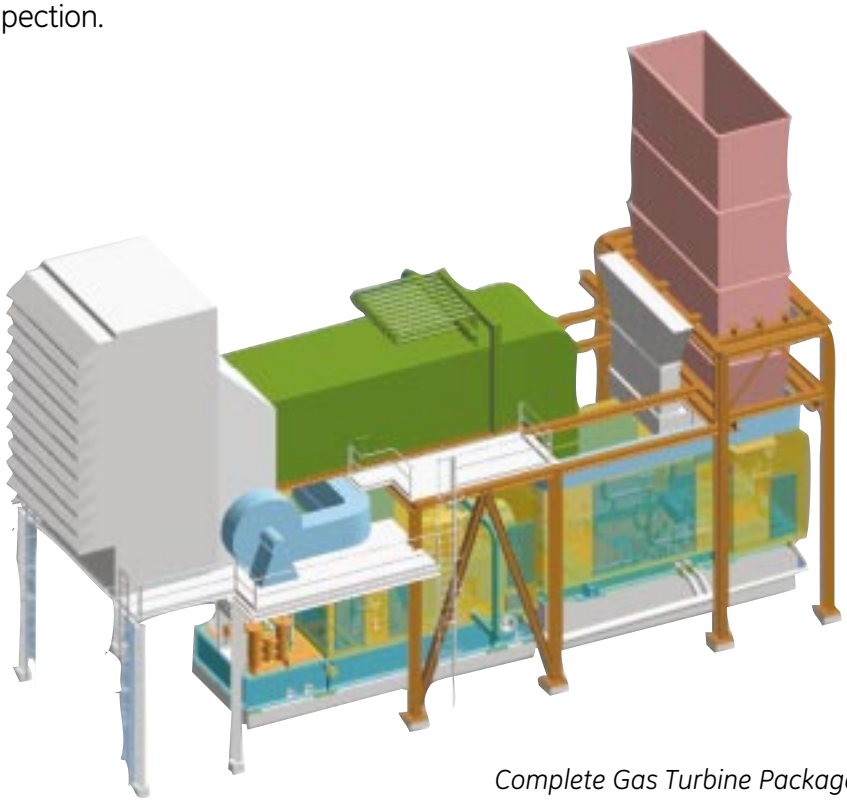
The MS5002E package design is similar to that used in other mature GE Energy gas turbines. As with the MS5002D, two separate structural steel frames make up the base supports of the gas turbine (one for the engine and one for the auxiliaries).
The gas turbine is mounted on its base plate by means of 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, with small modifications, 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.

The general layout of the auxiliary base plate ensures good accessibility to the most critical areas and components. An internal crane is provided for main auxiliary equipment lifting. Filters and instrumentation racks are located outside of the enclosure, to facilitate inspection and repair.



Complete Gas Turbine Package

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COMK/MARK 839/II - Designed by: Studio Tre Fasi
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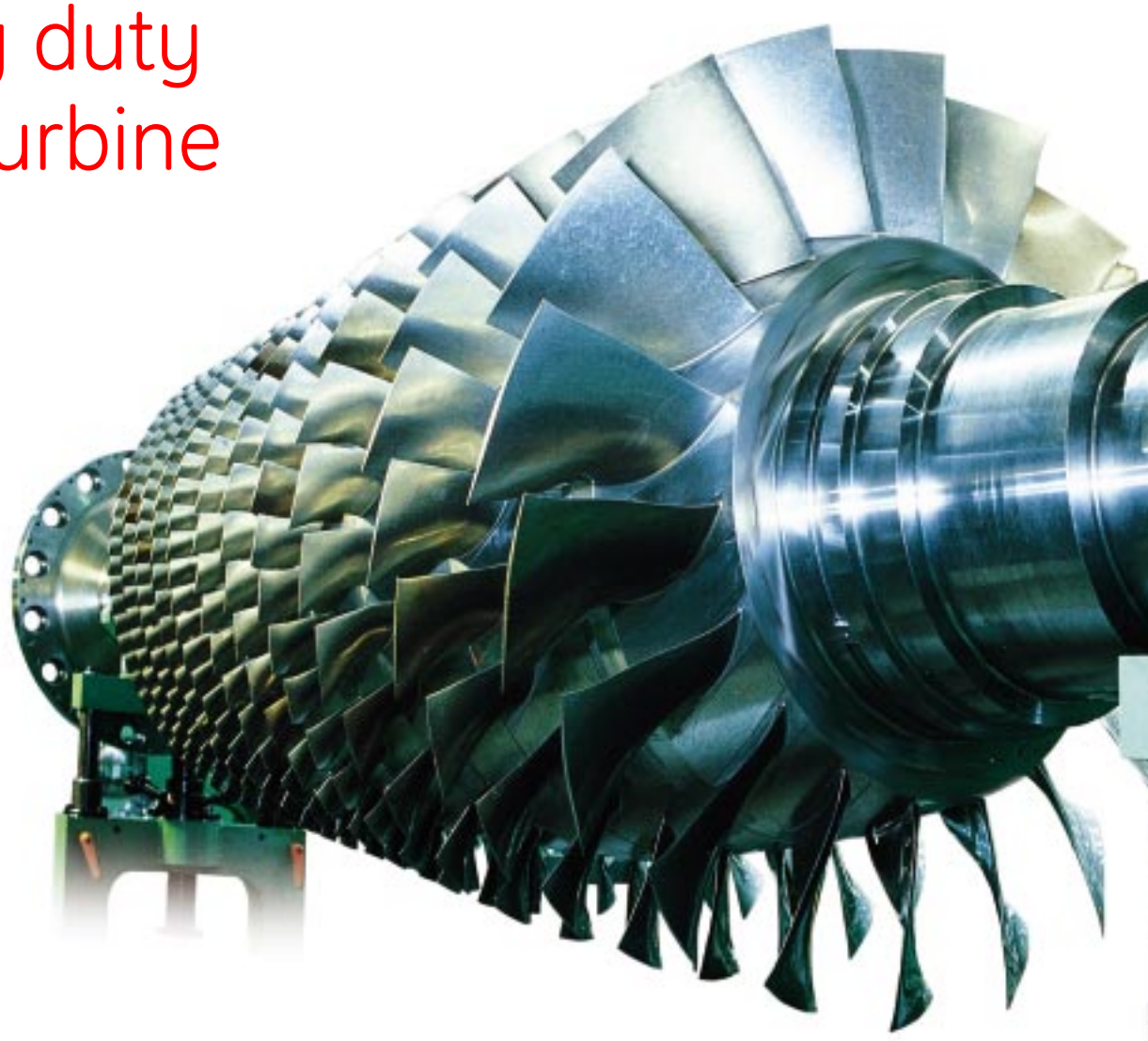
GE Energy
Oil & Gas

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. 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 one forward stub shaft, six discs and five spacers, and one aft stub shaft, all packed together by 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. 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 Energy DLN2 combustor design installed on "F" Class machines.
Current operation is with gaseous fuel but future development will include liquid fuel capability. In each combustion can there are 5 fuel nozzles. 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 a 25 ppm NOx initial guaranteed level. The fuel gas delivery system is provided with multiple gas control valves to distribute the fuel to the different gas circuits. Accurate split is controlled 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 heavy duty design as that used in the LM2500+. The mechanical structure is the same, however the flow-path profile and airfoils were redesigned because of the higher airflow required.

HP Rotor Assembly

Expected Performance

Output Shaft	32 MW
SC Efficiency	36%
Pressure Ratio	17:1
LPT Shaft Speed	5714 rpm
Exhaust Temperature	511 °C
NOx Emission	25 ppm

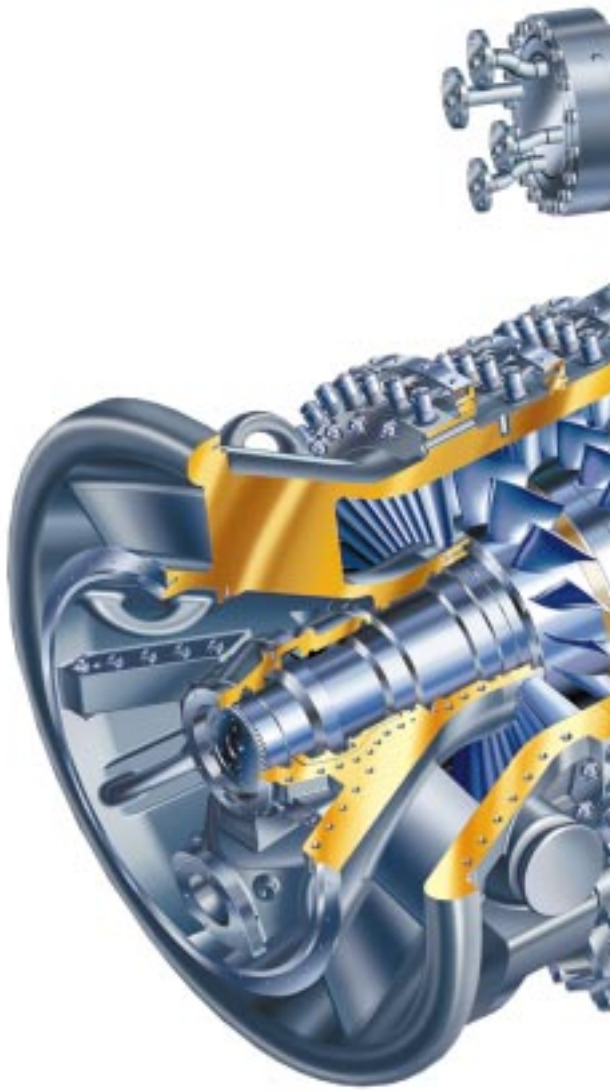
The MS5002E, the latest addition to the GE Energy's Oil & Gas family of gas turbines, is a 32MW-class machine designed for high efficiency, low environmental impact and high reliability. This latest machine was developed in response to Customer demand for a machine in the 32 MW range with low fuel consumption,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

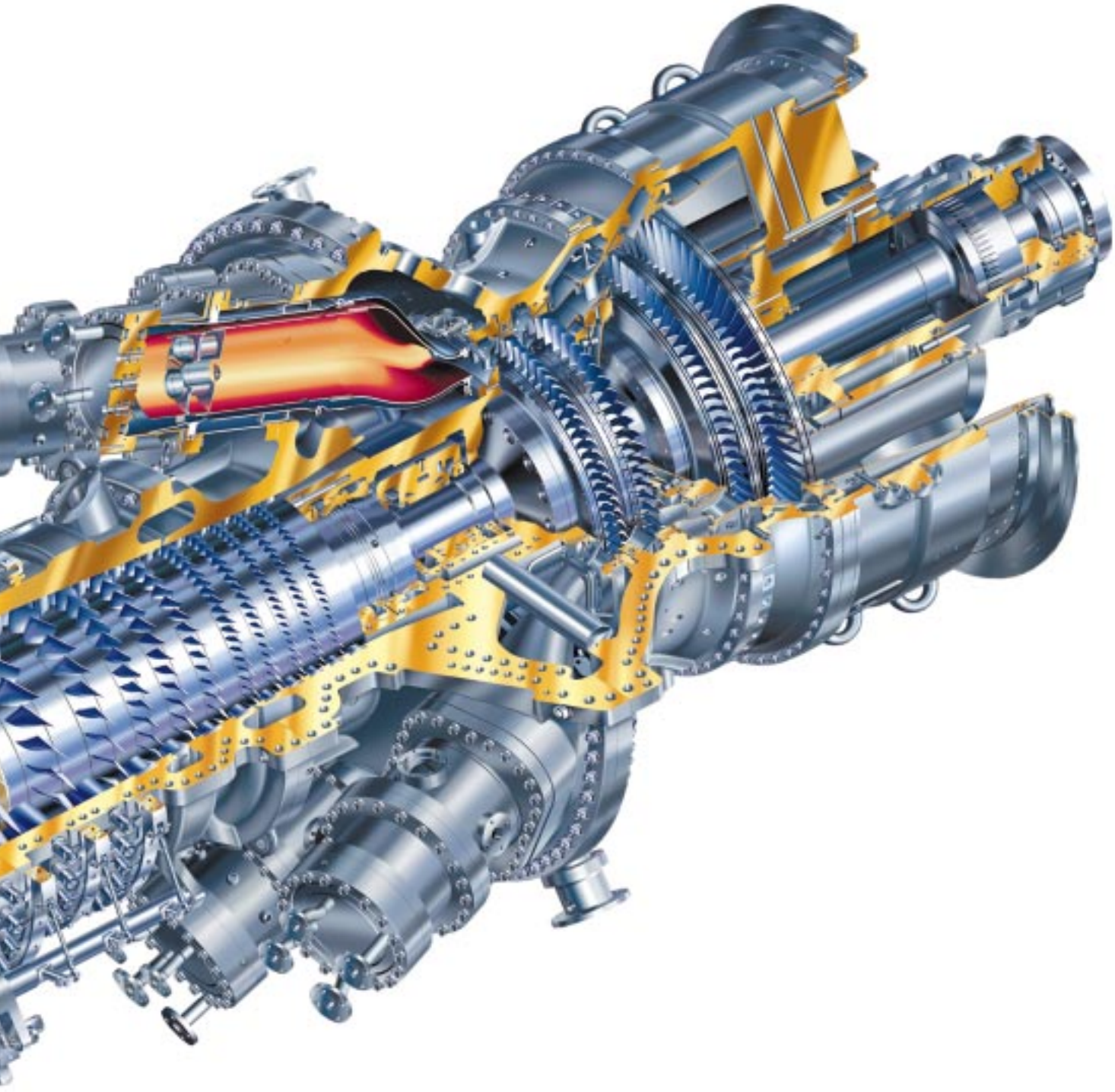
High efficiency was achieved through the use of advanced design tools to optimize airfoils, clearances, leakages and the distribution of cooling flows.

The MS5002E offers NOx emission levels down to 25 ppm (introductory) through the use of a dry-low emission combustion system derived from the GE Energy 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. The MS5002E 32MW-class machine represents a world-class engineering achievement to provide Customers with a high efficiency, low emissions machine with outstanding reliability matched for Oil & Gas Industry applications.



MS5002E
Gas Turbine



TESTING 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 rotors contained enlarged turbine discs to simulate blade masses, permitting normal speeds to be reached by reduction of the ventilation losses. The objective of the testing was to validate the design with respect to:

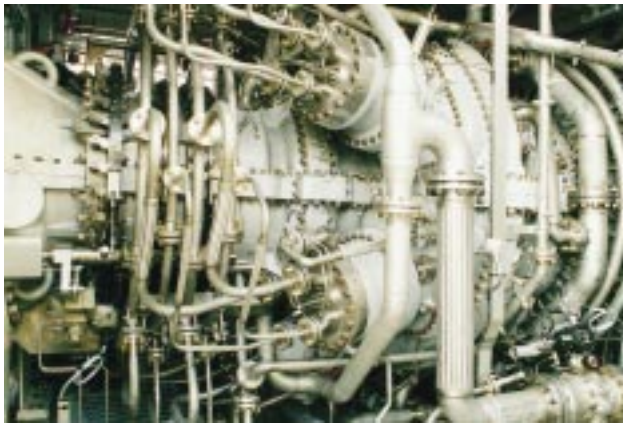
- steady state rotor and casing vibrations
- transient vibrations
- journal bearing behavior and performance
- rotor critical speeds and modal damping

This last activity was charged with tuning the process and extending experience for future work. The test, preceded by validation of rotor natural frequencies (free test), was successfully completed in June '02. 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 in terms 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 Corporate Research and Development Center, to assess the combustor behavior over the entire range of operation. Design validation tests were also performed in a GE Energy 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 dynamics, excellent margin to lean blow out and metal temperatures as predicted by analysis. In the premix mode the combustion system test results showed low emission levels, well below the target, and dynamics levels and lean blow out margin within the expected range and adequate for gas turbine off design operation.
Specific tests were also performed to verify ignition and cross fire capability.
Tests with methane fuel were completed in Sept. '03. Other tests are on going to explore and expand the ability to use different gas compositions (particularly inert gases and hydrogen).
In addition, the test rig remains available to test the combustor performance with specific fuels as required for customer applications.

Rotordynamic test stand



Engine

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 developed based on prior GE Energy experience 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 compressor was extensively instrumented with flowpath aerodynamic instrumentation (static pressure probes, total pressure and temperature multiple probes) to measure the individual stage characteristics. The test was successfully completed in December '02 and the compressor design was validated:

- No compressor blade aero-mechanical issues were identified and measured modal frequencies matched prediction within 3%
- Compressor performance was met for both mass flow and efficiency at design point and off-design conditions
- Extensive measurements close to the surge limit indicated a large safety margin on compressor surge.

Clearance meter data were also taken to evaluate rotor/stator clearances both at steady state and during transients and to assess their impact on compressor performance.

FIRST PACKAGED UNIT TEST

A complete MS5002E prototype test was completed in December '03 at the GE Energy 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 FSFL, premixed FSFL, 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 (rotordynamics, performance, aeromechanics, combustion, operability, thermo-mechanical assessment, auxiliaries validation, etc.) were collected, processed and analyzed during test execution using thoroughly validated GE Energy software and quality assessment processes.

The new MS5002E is ready for Oil & Gas application, offering a value added product and service to Customers for succesful, low cost and flawless operation.

Compressor test rig

Compressor test rig