FT8 Gas Turbine

Aeroderivative Gas Turbine for Industrial Applications

Engineering the Future – since 1758.

MAN Turbo

Introduction

1 FT8 on base frame during workshop assembly
2 Cutaway view of the FT8 (with standard combustion system)

MAN Turbo offers the world's most comprehensive product line of compressors and turbines. Innovation, ongoing development and modern technology guarantee the competitiveness of our products (single source solutions) for the lifetime of a machine.

Gas turbines have been included in the range of products since 1988. In 1990, the gas turbine product line was expanded by adding the FT8 gas turbine through signing a co-operation agreement with Pratt&Whitney Power Systems (PWPS). With the FT8 gas turbine, MAN Turbo offers a prime mover, enabling customers to obtain the reliable, environmentally sound and economic technology they require for a variety of their applications.

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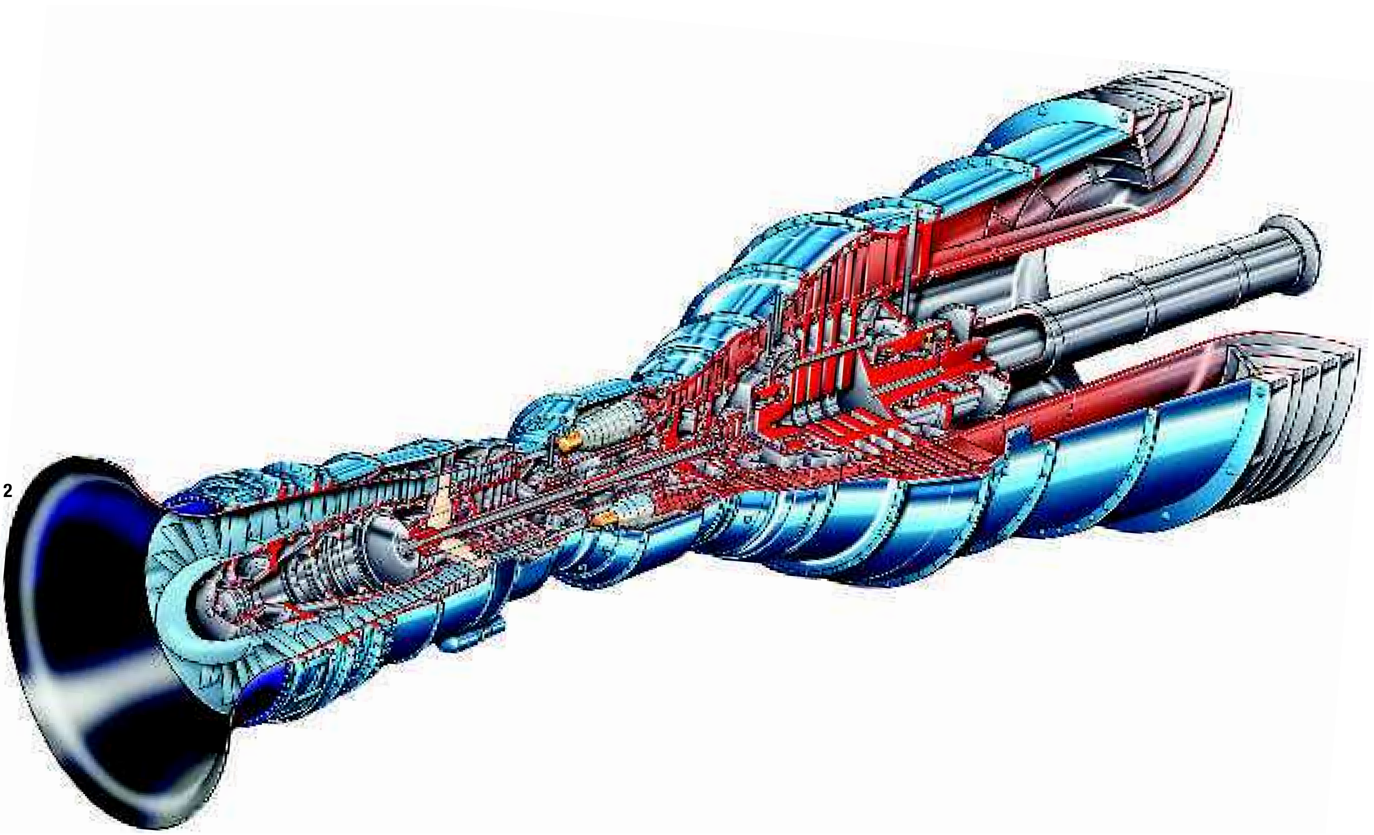


FT8 Gas Turbine

By mid-2008 more than 370 of the extremely successful FT8 gas turbine packages had been delivered or were on order. The highly efficient FT8 gas turbine consists of a GG8 gas generator and a PT8 power turbine (also referred to as a “free-running” turbine). The gas generator provides high-energy gas to the power turbine, where this gas performs work when mechanically coupled to a driven load through a flexible coupling.

GG8 - Gas Generator

The two-shaft gas generator has been derived from the latest version of the most successful aero-engine in commercial service, the Pratt&Whitney JT8D-219, which has achieved highest recorded sales of >14,500 engines.

The major components of the gas generator are the two compressor modules (LP and HP), the combustion section and the two turbine modules (HP and LP).

The LPC (Low Pressure Compressor) has 8 rotor stages and 7 stator stages. The inlet guide vanes as well as the first two stator vane stages have been fitted with variable geometry. Variable vane movement provides optimum efficiency for the compressor over the complete speed range and excellent part-load efficiency. The LPC rotor is connected to the 2-stage LPT (Low Pressure Turbine) rotor by the LP-shaft which is conducted through the tubular HP-shaft connecting the HPC (High Pressure Compressor) with the HPT (High Pressure Turbine).

The HPC consists of seven rotor stages and seven stator stages and is driven by the single-stage HPT. With this arrangement the LP-system and HP-system are running at their own optimum speed without mechanical interaction.

Combustion System

Depending on the application the FT8 gas turbine can be equipped with two different combustion systems.

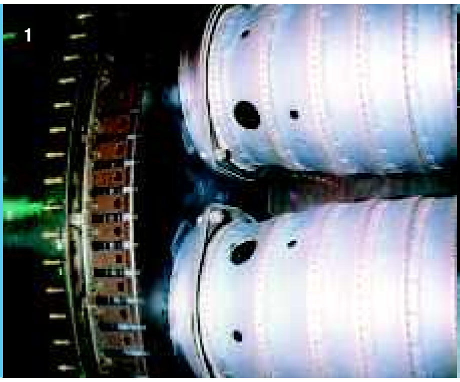
The basic version comprises a so-called “Standard Combustion System” which permits the use of various gaseous and liquid fuels – with different specifications as well as combinations in any percentage mix and thereby offering high fuel flexibility.

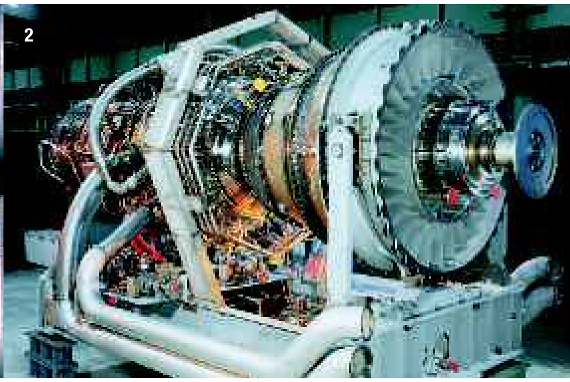
A DLN (DryLowNO_X) combustion system for gaseous fuel operation is available as an option. The extremely robust DLN system allows quick load changes and is insensitive to changing gas compositions and ambient conditions.

Standard Combustion System

In the case of the standard combustion system the combustion section has nine chambers (cans) arranged in an annulus around the turbine shafts and positioned between the High Pressure Compressor and the High Pressure Turbine. The combustion chambers are enclosed by inner and outer casings. The outer casing can be unbolted and moved rearward to allow for easy inspection or removal of the combustion chambers and fuel nozzles.

1 Combustion section with burner cans (standard combustion system)
2 FT8 gas turbine on base frame with DLN combustion system





Two combustion chambers accommodate each one spark plug. During initial ignition, a flame is propagated from these two chambers to the remaining chambers through integral a flame crossover tubes, which interconnect all nine chambers.

Besides the fuel flexibility, another feature of the standard combustion system is its capability to utilize water injection for NO_X-reduction.

DLN (Dry Low NO_X) Combustion System

The DLN combustion system is based upon an annular Floatwall combustor which is derived from Pratt&Whitney's latest design for new-generation flight engines.

The combustion system consists of 16 lean premix fuel nozzles and 15 sidewall pilot nozzles which together establish a 3 zone fuel system to produce the desired emission levels with stable engine operation. The lean premix fuel nozzles have 2 fuel zones, a lean premix zone (main gas flow) and a centrebody pilot zone. The centrebody pilot zone provides stabilisation of the lean premix flame and can be used to control combustor dynamics. The third fuel zone comprises the diffusion sidewall pilot nozzles used for starting, low power operation and for additional combustor stabilisation.

As for the standard combustion system, two spark plugs, which are installed into the annular combustor, are utilized.

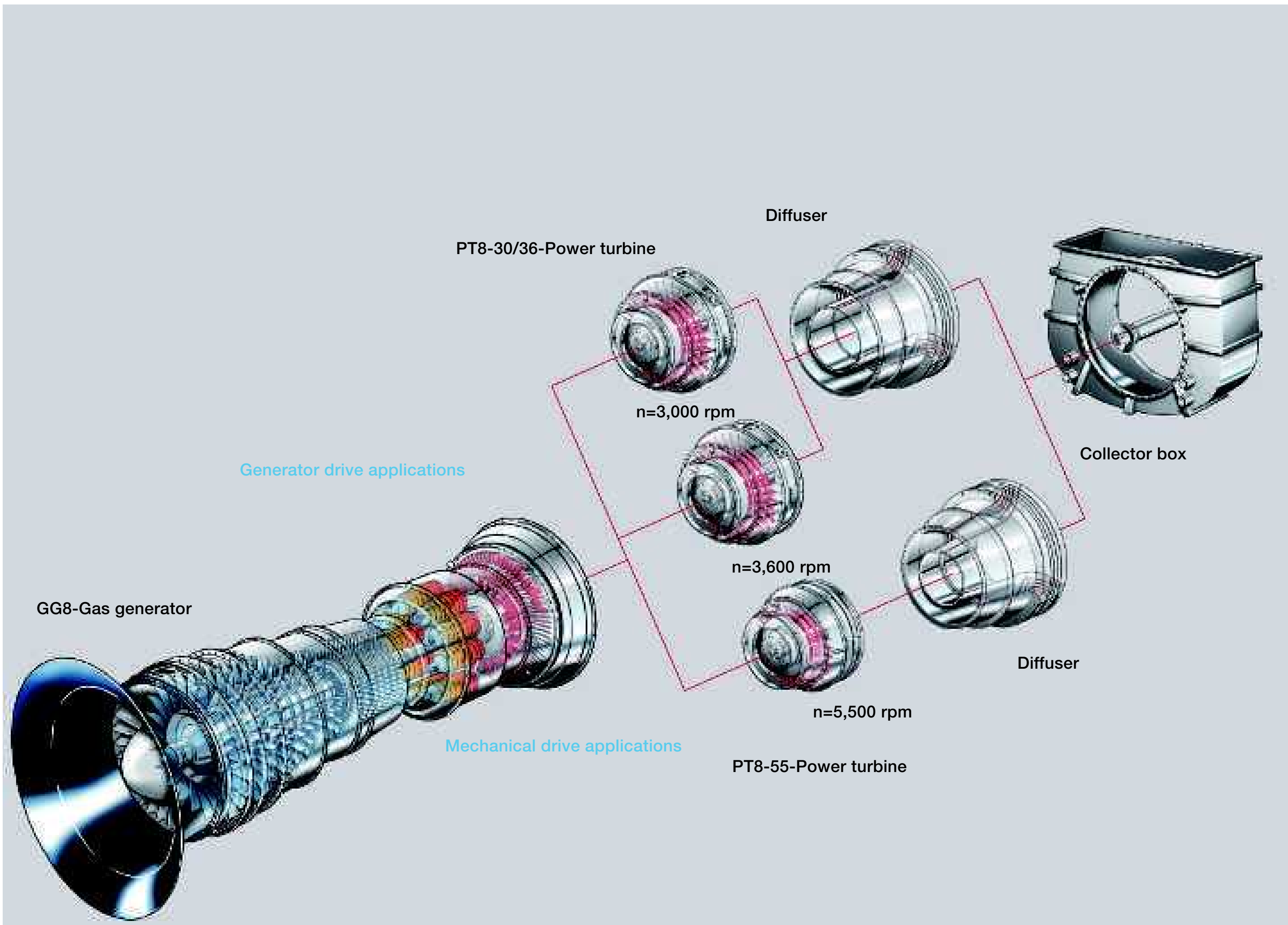
As part of the design, Helmholtz resonators are incorporated into the combustor section. The thirteen resonators provide passive control of dynamic pressure within the combustor.

PT8 Power Turbine

Different power turbines are available for both generator and mechanical drive applications. Each power turbine incorporates an annular transition duct, an axial-flow reaction turbine and a horizontally split main casing followed by the annular exhaust casing. The power turbine rotor which is made up of turbine disks and front/rear shaft ends, is suspended in antifriction bearings which are supplied with synthetic lube oil by a common gas generator/power turbine lube oil system.

For power generation with grid frequencies of 50Hz or 60Hz, 4-stage power turbines are available with design speeds of 3,000 or 3,600 rpm for CW (clockwise) and CCW (counter clockwise) rotation. With this design a direct coupling of the power turbine to the (2-pole) electric generator is possible without the need for a load gear.

For mechanical drive applications in the upper speed range up to 5,500 rpm, MAN Turbo has developed a dedicated 3-stage power turbine with a variable speed range between 2,500 and 5,500 rpm. This speed variant is mainly employed in the oil & gas industry for driving compressors for miscellaneous applications.



Modular FT8 concept for generator drive and mechanical drive applications

Configurations

PowerPac

The FT8 PowerPac includes the skid-mounted gas turbine directly coupled to the synchronous generator – mounted on a separate base frame – including all ancillary equipment required to form a complete package for outdoor/indoor installation.

TwinPac

A FT8-TwinPac comprises two FT8 gas turbines. Each gas turbine is directly connected to a centrally located double-end synchronous generator. Together with the ancillary equipment, a completely self-contained package is formed either for outdoor or indoor installation.

This particular arrangement is only available for the FT8 gas turbine because of the synchronous speed and the available CW and CCW power turbines. MAN Turbo's partner, Pratt&Whitney Power Systems (PWPS), has accumulated many years of sound experience in the U.S. with their TwinPac units which are based upon the FT8 and its predecessor, the FT4 gas turbine.

More than 1100 FT4 gas turbines were built, with a large number operating in the TwinPac configuration.

As of May 2008 more than 282 FT8 gas turbines have been sold in such TwinPac configurations.

Due to the concept of free-running power turbines it is possible to shut down one gas turbine whilst the remaining gas turbine is kept in operation, providing maximum operational flexibility in the case of an occasionally reduced power demand.

In this case the remaining unit is operating at optimum efficiency even at 50% load of the total TwinPac power output. Should this mode of operation constitute a major portion of the overall operational time, overrunning clutches are available to avoid power turbine windmilling losses of the gas turbine which is out of operation. The overrunning clutches are fully automatic.

A further application where the TwinPac configuration provides some advantages is a growing plant capability.
In applications where the power demand gradually grows, the FT8 TwinPac concept offers the option of future expansion. Initially just one gas turbine can be coupled to a generator rated for twice the power output ("½ TwinPac"), and another FT8 might be added at a later stage. All the electrical infrastructure can be further utilized so that only the second gas turbine package needs to be added. The generator efficiency is kept almost constant in the 50-100% power range. Thus, the power station can be adapted to growing requirements.

MechPac

The FT8 MechPac includes the skid-mounted gas turbine directly coupled to the driven equipment (compressor) – mounted on a separate base frame – including all ancillary equipment required to form a complete package for outdoor/indoor installation.

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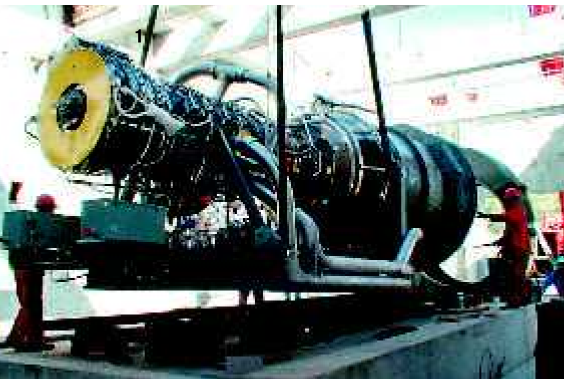
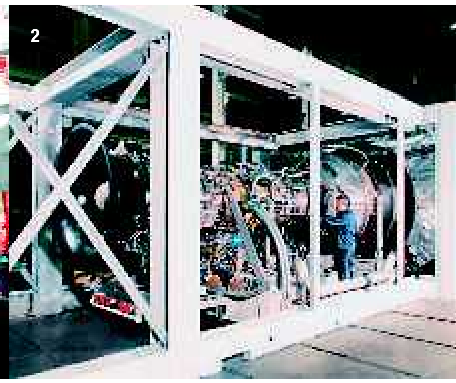
1 Typical MechPac, (Plant of Wingas, Rueckersdorf, Germany)
2 Typical PowerPac (Plant of BOREMER, San Martin de la Vega, Spain)
3 Typical TwinPac (Plant of Solvay, Rheinberg, Germany)

Package concept





The package concept for the FT8 offers a high flexibility as the FT8 is not completely pre-packaged at the manufacturer's workshop compared to a so-called single-lift skid.
A single-lift skid has the advantage in regard of minimizing erection time but is less flexible with regard to the arrangement required for indoor installations or sites with space restrictions.

With the FT8 package concept the FT8 gas turbine comes to site first without an enclosure – pre-mounted and pre-wired on a base frame including the fuel plate and junction boxes – with the need of minimum space and access requirements. Having placed the gas turbine onto the foundation, the enclosure consisting of pre-fabricated compact modules is quickly built up.
A further package feature of the FT8 gas turbine is given by the flexibility of being able to arrange the auxiliary systems such as the lube oil system and the starter equipment module on separate skids thereby reducing the dimensions of the main package module to a minimum. An example of an installation optimized for a building with of less than 9 metres is shown in fig. 4.
As an option the gas turbine package can be of course designed for outdoor installation on a "greenfield" site as well in order to avoid an additional building and to reduce the investment cost. The gas turbine acoustic enclosure is equipped with its own crane system for rapid exchange of the gas turbine components during overhauls, thereby making the need of an external crane system no longer pertinent.

As a matter of course, MAN Turbo provides not only supervision but turnkey installation of its supplied FT8 gas turbine packages.

Lubrication system

Unlike other industrialized aero-derived gas turbines, the FT8 gas turbine uses a common lube oil system for both the gas generator and the power turbine – based on synthetic oil – which is totally independent of the mineral lube oil system of the driven equipment.
Components not integral parts of the gas turbine are mounted as a pre-engineered lube oil package on an ancillary skid – for ease of maintenance – next to the gas turbine enclosure package. This package contains for example the lube oil reservoir, filters and motor driven supply – and scavenge pumps for the power turbine.

The gas generator lube oil supply and scavenge is executed by mechanically driven pumps coupled to the accessory drive-mounted gearbox.

Starting System

The starting system consists of a hydraulic starter motor mounted on the gas generator accessory drive gearbox and a skid-mounted hydraulic start-pac. Like the ancillary lube oil skid, the hydraulic starter skid is located outside of the gas turbine enclosure package and can be arranged according to the present specific space constraints.
It will supply high-pressure fluid to the starter motor geared to the HP compressor rotor shaft of the gas generator.

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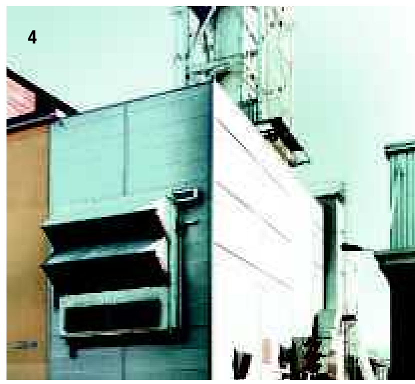

1 FT8 during erection
2 Assembly of gas turbine enclosure
3 Gas turbine enclosure
4 FT8 PowerPac at CMST in Graz/Austria

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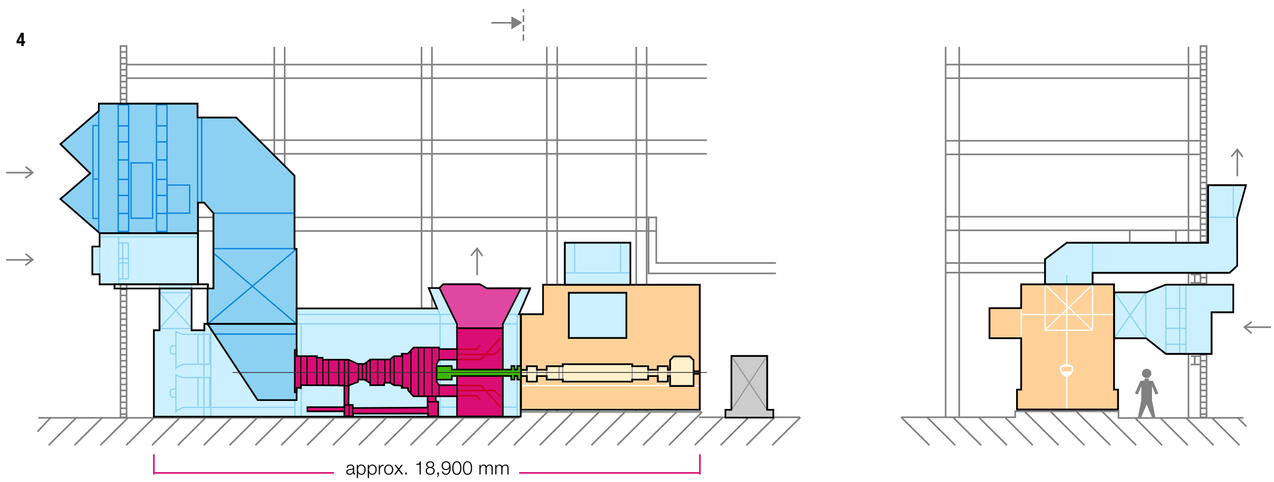

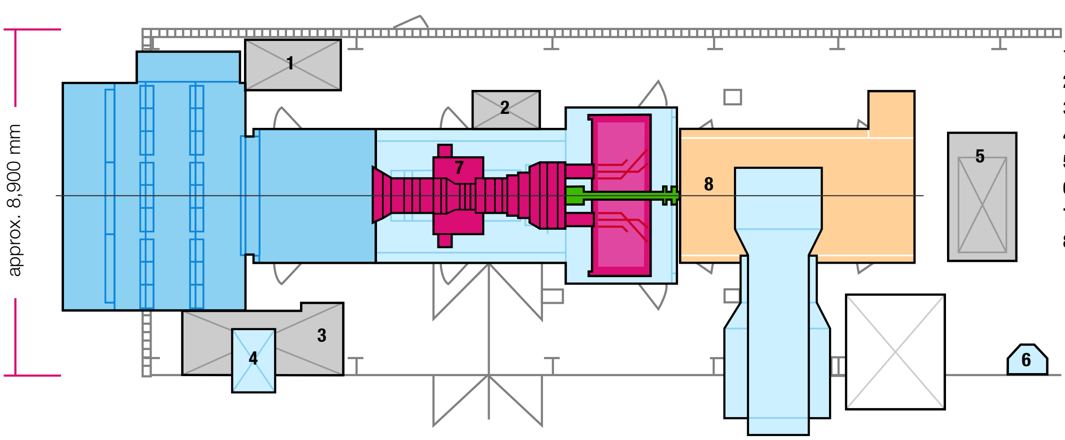

1 Electro hydraulic start skid
2 Water injection skid
3 Lube oil skid gas turbine
4 Lube oil cooler gas turbine
5 Lube oil skid electrical generator
6 Lube oil cooler electrical generator
7 FT8 PowerPac
8 Electrical Generator

Applications

1 Emergency power station of Kraftnät Aland with one FT8 PowerPac
2 Combined power and heat station II (district heating) of EVO/Germany
3 Emergency power station of Fingrid Oyj with two FT8 TwinPacs Source: Fingrid Oyj, Finland

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The above-described features of the FT8 gas turbine in conjunction with its inherent package concept have mainly led to the following areas of applications for the FT8 gas turbine:

Generator Drives

With respect to power generation there are essentially two different modes of operation, namely “base load” and “peak load” operation. Within the so-called “downstream” sector (e.g. utilities, paper mills, chemical plants) numerous FT8 packages are installed for base load as well as for peak load operation.

Base load

Due to economical reasons most FT8 base load applications take advantage of the additional use of the exhaust heat, i.e. are working in a cogeneration process. One example of an FT8 cogeneration plant is shown in fig. 2. The Oberhausen Public Utilities (EVO) power station has been modified from a 50 MW helium gas turbine installation to an ultra-modern, automated gas turbine power station, which supplies the city of Oberhausen with electric power and heat (district heating). MAN Turbo’s scope comprises beside the FT8 PowerPac installation the revamping of the existing components and building structures. The gas turbine is equipped with a standard combustion system allowing for dual fuel operation. NO_X reduction is performed by means of water injection.

Peak load

Due to its aero-derivative design with fast start-up and quick loading capability, the FT8 gas turbine is furthermore ideally suited for daily start and stop operation and thus for peaking applications, i.e. peak shaving and emergency plants.

Almost all peaking applications of the FT8 are utilized for peak shaving purposes. Due to the excellent starting reliability the FT8 is ideally suited for emergency power generation as well.

The Kraftnät Aland – power generation station (fig. 1) which is equipped with FT8 gas turbines is one example of such an emergency power generation application. The contractor is the grid operator Kraftnät Aland of the island group Aland which belongs to Finland. The PowerPac is located in Tingsbacka close to the connection point of the subsea power supply cable – coming

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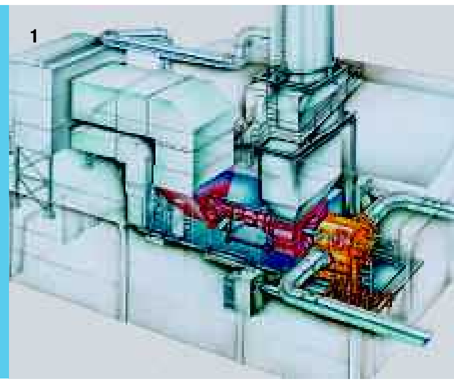
from Sweden – which provides electrical energy to the island group. The purpose of the FT8 PowerPac is to maintain the power supply for the island group in the case of a power supply outage via the subsea cable. Furthermore the FT8 PowerPac is being used as a peak shaver for the electrical grid of the island group. Consequently, rapid start capability is of extreme importance. The liquid fuel operated unit needs only 5 min from standstill until reaching full load, i.e. about 25 MW. This unit was taken into operation in 2005.

A further emergency power station – based on FT8-TwinPacs – is shown in fig. 3. The contractor is Fingrid Oyj, which is in charge of the national power transmission system including organization of spinning and rapid start capacity reserves in Finland. The plant, consisting of two TwinPacs, is located close to the nuclear power plant OL 1-3 in Olkiluoto, Finland. On the one hand the plant is used to stabilize the public power grid and on the other hand to supply emergency power to the nuclear power plant in the case of an outage of the public grid and other emergency power supplies in order to keep the cooling pumps running. Both the stabilizing of the public grid as well as the secured power supply to the nuclear power plant are of highest public interest. Of course, rapid start capability is therefore of extreme importance for this installation too. The liquid fuel operated units need only 5 min from standstill until reaching full load, i.e. about 100 MW. These units were taken into operation in 2007.

1 Plant design of the Ruhrgas compressor station in Werne/Germany
2 FT8 MechPac at Ruhrgas's compressor station in Werne/Germany
3 Three FT8 MechPacs at Wingas's compressor station in Mallnow/Germany



Mechanical Drives

The outstanding efficiency figures, based on the two-shaft design of the gas generator and the use of the latest developments in the aircraft industry, which are maintained over a wide load range, in combination with the extreme robust DLN combustion system, which allows quick load changes and being insensitive to changing gas compositions and ambient conditions make the FT8 MechPac configuration a reliable and thus cost-advantageous solution for mechanical drive applications.

Aside from mechanical drive installations for UGS (underground storage) and booster stations (e.g. re-gasification plants) especially pipeline compressor stations do have a significant share in the so called midstream sector.

Especially for the application in pipeline compressor stations, the FT8 – driving centrifugal compressors out of the MAN Turbo's product portfolio – has demonstrated to be a proven and reliable concept on which the main German gas distributing companies (Wingas and Ruhrgas) rely.

The compressor station of Ruhrgas AG in Werne, Germany, (fig. 2) is a key installation for gas distribution within Germany.

In order to expand transport capacities, two gas turbine compressor units based upon the FT8 were added to complement the compressor plant already installed. Both FT8 units are equipped with the DLN combustion system.

MAN Turbo's scope comprised aside from the delivery of the turbo machinery and its accessories the turnkey erection and commissioning of the gas turbine compressor units.

At the Polish border, near Frankfurt Oder, where the JAGAL pipeline is connected to the JAMAL pipeline, Wingas GmbH operates a compressor station which relies on three FT8 MechPacs. In the course of 2007 this station was expanded by adding a waste heat recovery system utilizing exhaust heat of the gas turbines to produce steam for a steam turbine driving a fourth pipeline compressor (delivered by MAN Turbo).

Because the Mallnow compressor station is running 24 hours a day, 365 days a year – thus a base load installation – steam is permanently available to power the steam turbine.

In total, WINGAS operates 8 FT8 MechPacs distributed on 4 compressor stations. All these FT8 units are equipped with the DLN combustion system.

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Service

1 Borescope inspection on the FT8
2 Test arrangement for FT8

It is essential how effectively the value of the machinery is maintained especially when the gas turbines following their purchase are dedicated to have a service life running into decades.

Service concept

Early recognition of critical machine conditions and of faults or malfunctions that are about to have an impact is an essential safeguard for the smooth operation of the gas turbine and thus the availability of the plant as a whole.

Nevertheless experience has shown that often unplanned shutdowns are caused not only by the core equipment (gas generator/power turbine/driven equipment) but also by ancillary systems. Our approach to provide service support consequently covers the complete gas turbine plant including all ancillary systems supplied by MAN Turbo.

It is our aim to be there whenever and wherever you need us, and in consultation with you, to offer a service tailored to your requirements – thereby securing the value of your long-term investment. MAN Turbo is today responsible for the service of around 500 gas turbines worldwide, and has experts and special facilities at its disposal for:

- erection and commissioning
- customer support and diagnosis
- spare parts procurement and job execution
- corrective maintenance and inspections
- full-load testing
- materials examination

Derived from these tasks MAN Turbo has established a service concept for its FT8 product programme which offers the following features:

- MAN Turbo operates a Pratt&Whitney approved service shop at the Oberhausen works taking advantage of the expertise and skills developed by the OEM (PWPS)
- proactive maintenance
- systems for the recording and analysis of operating and maintenance parameters (remote data transmission for trend monitoring and diagnosis of machine data)

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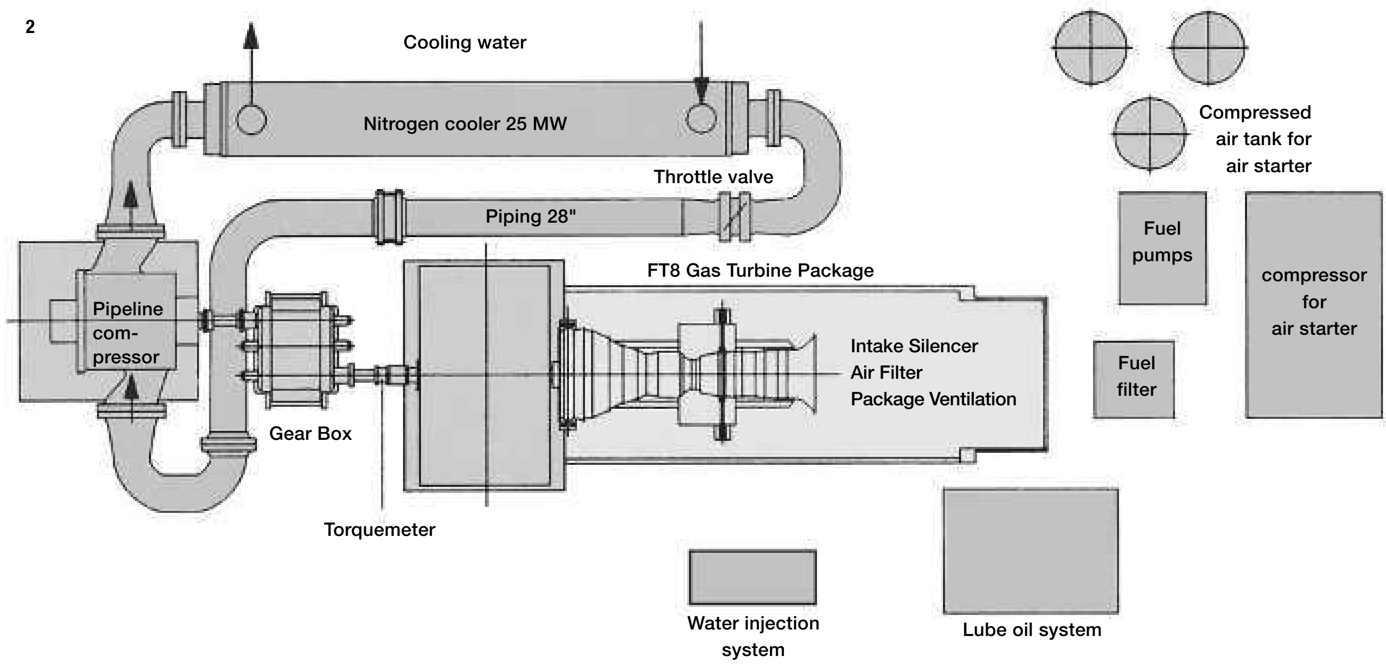


- pool gas generators and power turbines on standby for rental purposes in the event of scheduled or unscheduled downtimes so as to minimize downtime periods
- care, support and coordination at the works of MAN Turbo of all aspects relating to components supplied by MAN Turbo, including driven equipment
- spare parts storage at the Oberhausen works
- exchange of main modules (gas generator/power turbine) and/or sub-modules within a minimum of time
- facilities for full-load testing of the FT8 at the Oberhausen works (see description below)
- wide range of training facilities (see description below)
- technical information in the form of service bulletins
- round-the-clock availability of service personnel
- company's own government-approved laboratory for materials examination, research and development

Test facilities

Our test facilities incorporate a dedicated FT8 gas turbine test stand allowing us to test the FT8 gas turbines even at full load. Natural gas and/or liquid fuel firing is possible, permitting simulations of original operating conditions. The most modern monitoring systems allow real-time analysis of the gas turbine during the test run.

The test arrangement allows maximum flexibility with regard to different speeds of testing FT8 Gas Turbines (50Hz, 60Hz and variable speed in the case of mechanical drives). Besides that, an option had to be left open for power turbines having either right or left direction of rotation. A precision dynamometer, located between the power turbine and a three-shaft special gearbox, is used for measuring the power turbine torque. The gearbox steps up/down the output speed of the gas turbine to correspond to the speed range of a double-stage 25 MW pipeline compressor (test stand equipment) which operates in a closed loop with nitrogen at pressures between 28 and 76 bar.

This gas turbine test is in accordance to ASME PTC-22 with standard exceptions.

Training

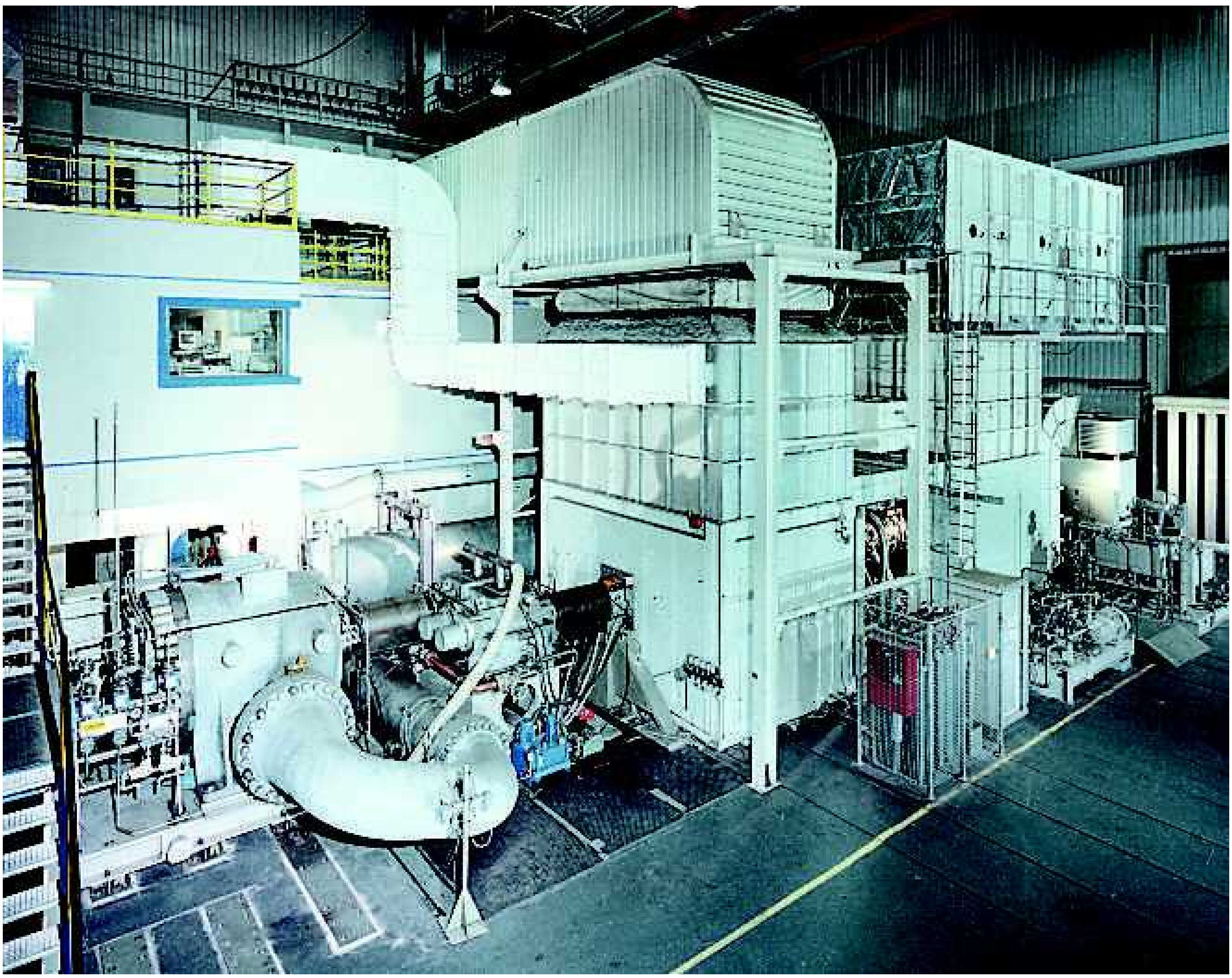
Skilled, motivated staff makes a major contribution to ensuring maximum long-term availability with minimum service and maintenance costs. We offer you training programmes for your staff, from operators to plant managers. The primary aims of our training courses are:

- To complement and elaborate on the information contained in the operating manuals
- To optimize operation of the turbo machinery set
- Early detection and elimination of critical machine states, malfunctions and faults – including auxiliary systems
- Prompt detection of minor damage that could result in more extensive damage if ignored
- Use of detailed knowledge in maintenance, inspection, cleaning and preservation work

To achieve these targets we can offer you a training course that is made-to-measure, like your gas turbine plant. We take your specific requirements into account when focusing on the content in order to establish a programme which fits best to your specific installation and constraints. Among other things, our training courses comprise the following options/services:

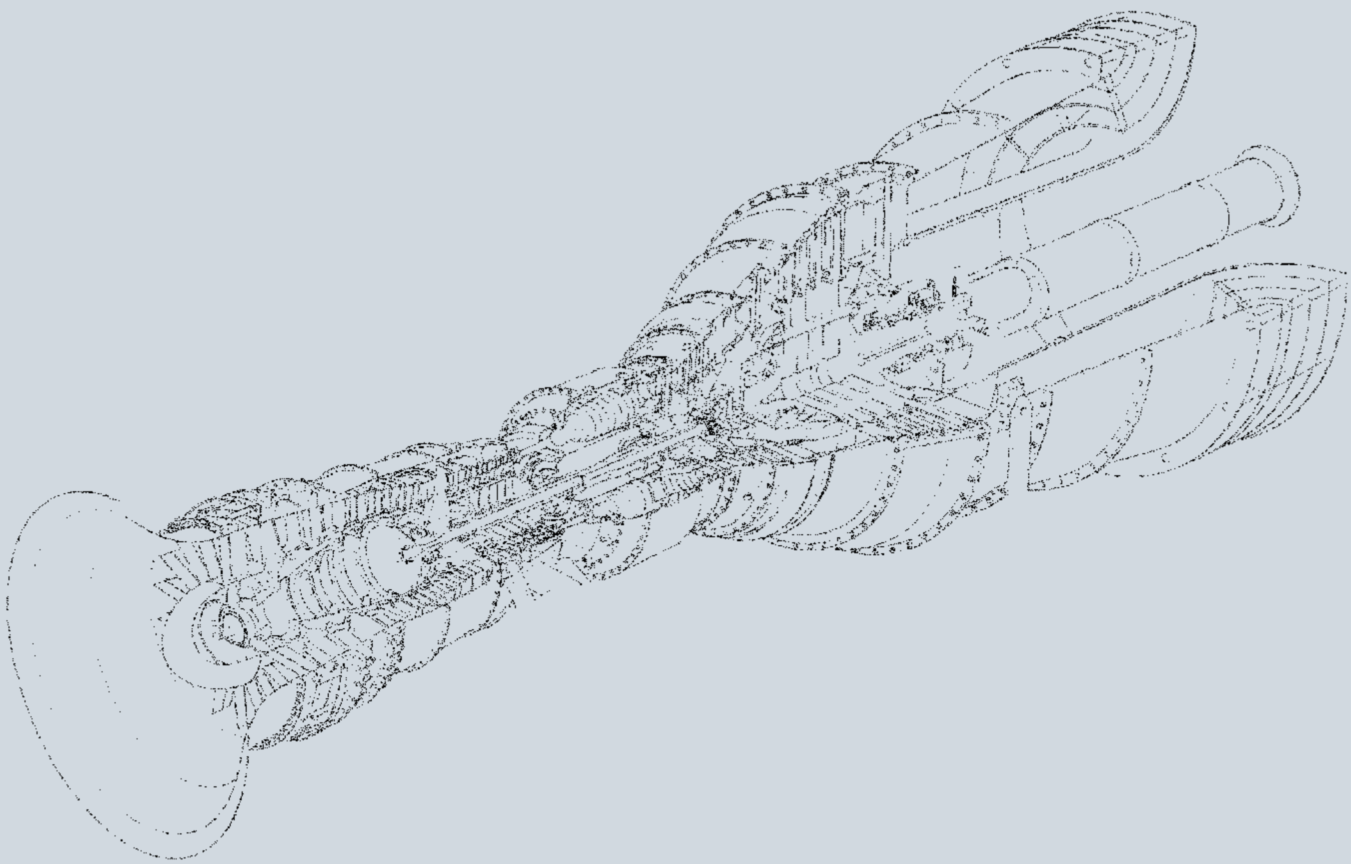
- Training for specialized staff, fitters, foremen, technicians, engineers and plant managers
- Training in your company, on our premises or a combination of the two
- Training in German, English or French as well as in your native language with simultaneous translation
- Organization and coordination of all measures by a single body – from compilation of the training documentation to hotel bookings and outline programmes.

Should the overall plant contain other turbo machinery products manufactured and/or supplied by MAN Turbo, such as compressors, generators or steam turbines, the subjects of the training programmes of course are expanded accordingly.

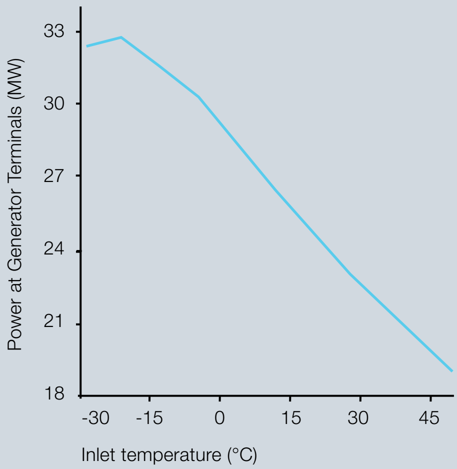


FT8 test stand with full-load capability

Technical data



Power versus temperature (PowerPac)



- Sea level, rel. humidity = 60%
- Natural gas
- No inlet/outlet losses
- Standard combustion system
- Generator efficiency: 98%

Mechanical Drive		FT8 PowerPac	FT8 TwinPac	FT8 MechPac
Shaft power	kW	-	-	25,870
	HP	-	-	34,690
Thermal efficiency	%	-	-	38.6
Heat rate	kJ/kWh	-	-	9,330
	Btu/HPh	-	-	6,594
Generator Drive				
Power at generator terminals	kWe	25,570	51,140	-
Electrical efficiency	%	38.1	38.1	-
Heat rate	kJ/kWh	9,440	9,440	-
	Btu/kWh	8,950	8,950	-
Exhaust Gas Data				
Exhaust gas temperature	°C	458	458	457
	°F	856	856	855
Exhaust gas mass flow	kg/s	85.1	170.2	85.9
	lb/s	188	376	189
Gas Generator (LP/HP)				
Speed	rpm	7,100/11,520	7,100/11,520	7,100/11,520
Compressor stages		8/7	8/7	8/7
Turbine stages		2/1	2/1	2/1
Weight approx. (DLN)	kg	3,000 (3,950)	3,000 (3,950)	3,000 (3,950)
Power Turbine				
Speed	rpm	3,000*	3,000*	2,500 - 5,500
Stages		4	4	3
Weight approx.	kg	6,000	6,000	5,100

Above specifications valid under the following conditions:

15°C (59°F), sea level, no inlet/outlet losses, RH = 60%, natural gas, $\eta_{gen.}$ = 98%

* 3,600 rpm available on request

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