Ft8 gas turbine

FT8 Gas Turbine Aeroderivative Gas Turbine for Industrial Applications Engineering the Future — since 175 8. MAN Turbo Introduction 1 FT8 on base frame during workshop assembly 2 Cutaway view of the FT8 (with standard combustion system) 1 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. 2 2 FT8 Gas Turbine The LPC (Low Pressure Compressor) By mid-2008 more than 370 of the has 8 rotor stages and 7 stator stages. “ Standard Combustion System" which extremely successful FT8 gas turbine The inlet guide vanes as well as the first permits the use of various gaseous and packages had been delivered or were on two stator vane stages have been fitted liquid fuels — with different specifications order. The highly efficient FT8 gas turbine with variable geometry. Variable vane as well as combinations in any percent- The basic version comprises a so-called consists of a GG8 gas generator and a movement provides optimum efficiency age mix and thereby offering high fuel PT8 power turbine (also referred to as a for the compressor over the complete flexibility. “ free-running" turbine). The gas genera- speed range and excellent part-load tor provides high-energy gas to the power efficiency. The LPC rotor is connected A DLN (DryLowNOx) combustion system turbine,

where this gas performs work to the 2-stage LPT (Low Pressure for gaseous fuel operation is available as when mechanically coupled to a driven Turbine) rotor by the LP-shaft which is an option. The extremely robust DLN load through a flexible coupling. conducted through the tubular HP-shaft system allows quick load changes and is connecting the HPC (High Pressure insensitive to changing gas compositions GG8 - Gas Generator Compressor) and ambient conditions. The two-shaft gas generator has been Pressure Turbine). with the HPT (High derived from the latest version of the most Standard Combustion System successful aero-engine in commercial The HPC consists of seven rotor stages In the case of the standard combustion service, the Pratt&Whitney JT8D-219, and seven stator stages and is driven by system the combustion section has nine which has achieved highest recorded the single-stage HPT. W ith this arrange- chambers (cans) arranged in an annulus sales of > 14, 500 engines. ment the LP-system and HP-system are around the turbine shafts and positioned running at their own optimum speed between the High Pressure Compressor without mechanical interaction. and the High Pressure Turbine. The The major components of the gas generator are the two compressor combustion chambers are enclosed by modules (LP and HP), the combustion Combustion System inner and outer casings. The outer casing section and the two turbine modules Depending on the application the FT8 can be unbolted and moved rearward to (HP and LP). gas turbine can be equipped with two allow for easy inspection or removal of different combustion systems. the combustion chambers and fuel nozzles. 3 1 Combustion section with bur ner cans (standard combustion system) 2 FT8 gas turbine on base frame with DLN combustion system Two combustion chambers accommo- 1 2 The centrebody pilot zone provides is suspended in

antifriction bearings date each one spark plug. During initial stabilisation of the lean premix flame which are supplied with synthetic lube ignition, a flame is propagated from these and can be used to control combustor oil by a common gas generator/ power turbine lube oil system. two chambers to the remaining chambers dynamics. The third fuel zone comprises through integral a flame crossover tubes, the diffusion sidewall pilot nozzles used which interconnect all nine chambers. for starting, low power operation and for For power generation with grid frequen- additional combustor stabilisation. cies of 50Hz or 60Hz, 4-stage power Besides the fuel flexibility, another feature turbines are available with design of the standard combustion system is As for the standard combustion system, speeds of 3, 000 or 3, 600 rpm for CW its capability to utilize water injection for two spark plugs, which are installed into (clockwise) and CCW (counter clock- NOx- reduction. the annular combustor, are utilized. wise) rotation. With this design a direct DLN (Dry Low NOx) Combustion As part of the design, Helmholtz resona- (2-pole) electric generator is possible System tors are incorporated into the combustor without the need for a load gear. The DLN combustion system is based section. The thirteen resonators provide upon an annular Floatwall combustor passive control of dynamic pressure For mechanical drive applications in the which is derived from Pratt& Whitney’s within the combustor. upper speed range up to 5, 500 rpm, coupling of the power turbine to the MAN Turbo has developed a dedicated latest design for new-generation flight engines. PT8 Power Turbine 3-stage power turbine with a variable Different power turbines are available sp e ed r a n ge b e twe en 2, 50 0 an d The combustion system consists of 16 for both generator and mechanical 5, 500 rpm. This speed variant is mainly lean premix fuel nozzles

and 15 sidewall drive applications. Each power turbine employed in the oil & gas industry for pilot nozzles which together establish a incorporates an annular transition duct, driving compressors for miscellaneous 3 zone fuel system to produce the desired an axial-flow reaction turbine and a applications. emission levels with stable engine opera- horizontally split main casing followed tion. The lean premix fuel nozzles have by the annular exhaust casing. The 2 fuel zones, a lean premix zone (main power turbine rotor which is made up of gas flow) and a centrebody pilot zone. turbine disks and front/ rear shaft ends, 4 Diffuser PT8-30/36-Power turbine n= 3, 000 rpm Collector box Generator drive applications n= 3, 600 rpm GG8-Gas generator Diffuser n= 5, 500 rpm Mechanical drive applications PT8-55-Power turbine Modular FT8 concept for generator drive and mechanical drive applications 5 Configurations PowerPac More than 1100 FT4 gas turbines were A further application where the TwinPac The FT8 PowerPac includes the skid- built, with a large number operating in configuration provides some advantages mounted gas turbine directly coupled to the TwinPac configuration. is a growing plant capability. the synchronous generator — mounted In applications where the power demand on a separate base frame — including all As of May 2008 more than 282 FT8 gradually grows, the FT8 TwinPac ancillary equipment required to form a gas turbines have been sold in such concept offers the option of future complete package for outdoor/ indoor TwinPac configurations. expansion. Initially just one gas turbine installation. can be coupled to a generator rated for Due to the concept of free-running twice the power output (“ ½ TwinPac"), TwinPac power turbines it is possible to shut and another FT8 might be added at a A FT8-TwinPac comprises two FT8 gas down one gas turbine whilst the remaining later

stage. All the electrical infrastructure turbines. Each gas turbine is directly gas turbine is kept in operation, provid- can be further utilized so that only the connected to a centrally located double- ing maximum operational flexibility in the second gas turbine package needs to end synchronous generator. Together with case of an occasionally reduced power be added. The generator efficiency the ancillary equipment, a completely demand. is kept almost constant in the 50-100% self-contained package is formed either for outdoor or indoor installation. power range. Thus, the power station In this case the remaining unit is oper- can be adapted to growing requirements. ating at optimum efficiency even at 50% This particular arrangement is only load of the total TwinPac power MechPac available for the FT8 gas turbine because output. Should this mode of operation The FT8 MechPac includes the skid- of the synchronous speed and the constitute a major portion of the overall mounted gas turbine directly coupled to available CW and CCW power turbines. operational time, overrunning clutches the driven equipment (compressor) — MAN Turbo’s partner, Pratt& Whitney are available to avoid power turbine mounted on a separate base frame — Power Systems (PWPS), has accumu- windmilling losses of the gas turbine including all ancillary equipment required lated many years of sound experience in which is out of operation. The overrunning to form a complete package for outdoor/ the U. S. with their TwinPac units which clutches are fully automatic. indoor installation. are based upon the FT8 and its predecessor, the FT4 gas turbine. 6 1 2 3 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) 7 Package concept 1 2 3 The package concept for the FT8 offers a

minimum. An example of an installation high flexibility as the FT8 is not completely optimized for a building with of less than gas turbine are mounted as a pre- pre-packaged at the manufacturer’s work- 9 metres is shown in fig. 4. engineered lube oil package on an shop compared to a so-called single-lift As an option the gas turbine package ancillary skid — for ease of maintenance — skid. can be of course designed for outdoor next to the gas turbine enclosure Components not integral parts of the A single-lift skid has the advantage in installation on a " greenfield" site as well package. This package contains for regard of minimizing erection time but is in order to avoid an additional building example the lube oil reservoir, filters and less flexible with regard to the arrange- and to reduce the investment cost. motor driven supply — and scavenge ment required for indoor installations or The gas turbine acoustic enclosure is pumps for the power turbine. sites with space restrictions. equipped with its own crane system for rapid exchange of the gas turbine The gas generator lube oil supply and W ith the FT8 package concept the FT8 components during overhauls, thereby scavenge is executed by mechanically gas turbine comes to site first without making the need of an external crane driven pumps coupled to the accessory an enclosure — pre-mounted and pre- system no longer pertinent. drive-mounted gearbox. plate and junction boxes — with the As a matter of course, MAN Turbo Starting System need of minimum space and access provides not only supervision but turnkey The starting system consists of a requirements. Having placed the gas installation of its supplied FT8 gas hydraulic starter motor mounted on the turbine onto the foundation, the enclosure turbine packages. gas generator accessory drive gearbox wired on a base frame including the fuel consisting of pre-fabricated compact and a

skid-mounted hydraulic start-pac. modules is quickly built up. Lubrication system Like the ancillary lube oil skid, the A further package feature of the FT8 Unlike other industrialized aero-derived hydraulic starter skid is located outside gas turbine is given by the flexibility of gas turbines, the FT8 gas turbine uses a of the gas turbine enclosure package being able to arrange the auxiliary systems common lube oil system for both the and can be arranged according to the such as the lube oil system and the gas generator and the power turbine — present specific space constraints. starter equipment module on separate based on synthetic oil — which is totally It will supply high-pressure fluid to the skids thereby reducing the dimensions independent of the mineral lube oil starter motor geared to the HP com- of the main package module to a system of the driven equipment. pressor rotor shaft of the gas generator. 8 1 2 3 4 4 FT8 during erection Assembly of gas turbine enclosure Gas turbine enclosure FT8 PowerPac at CMST in Graz / Austria 4 approx. 18, 900 mm 1 2 3 4 5 6 7 8 1 approx. 8, 900 mm 2 7 5 8 Electro hydraulic start skid Water injection skid Lube oil skid gas turbine Lube oil cooler gas turbine Lube oil skid electrical generator Lube oil cooler electrical generator FT8 PowerPac Electrical Generator 3 4 6 9 Applications 1 Emergency power station of KraftnÃ¤t 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 1 2 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 been modified from a 50 MW helium and thus for peaking applications, i. e. W ith respect to power generation there gas turbine installation to an ultra-

peak shaving and emergency plants. are essentially two different modes of moder n, automated gas turbine power operation, namely “ base load" and station, which supplies the city of Ober- “ peak load" operation. W ithin the so- hausen with electric power and heat FT8 are utilized for peak shaving called “ downstream" sector (e. g. utili- (district heating). MAN Turbo’s scope purposes. Due to the excellent starting ties, paper mills, chemical plants) nu- comprises beside the FT8 PowerPac reliability the FT8 is ideally suited for merous FT8 packages are installed for installation the revamping of the existing emergency power generation as well. Almost all peaking applications of the base load as well as for peak load ope- components and building structures. ration. The gas turbine is equipped with a standard combustion system allowing station (fig. 1) which is equipped with Base load for dual fuel operation. NOx reduction is FT8 gas turbines is one example of Due to economical reasons most FT8 performed by means of water injection. The KraftnÃ¤t Aland — power generation such an emergency power generation application. The contractor is the grid base load applications take advantage of the additional use of the exhaust heat, Peak load operator KraftnÃ¤t Aland of the island i. e. are working in a cogeneration process. Due to its aero-derivative design with group Aland which belongs to Finland. One example of an FT8 cogeneration fast start-up and quick loading capability, The PowerPac is located in T ingsbacka plant is shown in fig. 2. The Oberhausen the FT8 gas turbine is furthermore ideally close to the connection point of the Public Utilities (EVO) power station has suited for daily start and stop operation subsea power supply cable — coming 10 3 from Sweden — which provides electrical transmission system including organiza- only 5 min from standstill until reaching energy to the island group.

The purpose tion of spinning and rapid start capacity full load, i. e. about 100 MW. These units were taken into operation in 2007. of the FT8 PowerPac is to maintain the reserves in Finland. The plant, consisting power supply for the island group in of two TwinPacs, is located close to the the case of a power supply outage via nuclear power plant OL 1-3 in Olkiluoto, the subsea cable. Furthermore the FT8 Finland. On the one hand the plant PowerPac is being used as a peak shaver is used to stabilize the public power for the electrical grid of the island group. grid and on the other hand to supply Consequently, rapid start capability is emergency power to the nuclear power of extreme importance. The liquid fuel plant in the case of an outage of the operated unit needs only 5 min from public grid and other emergency power standstill until reaching full load, i. e. supplies in order to keep the cooling about 25 MW. This unit was taken into pumps running. Both the stabilizing of operation in 2005. the public grid as well as the secured power supply to the nuclear power plant A further emergency power station — are of highest public interest. Of course, based on FT8-TwinPacs — is shown in rapid start capability is therefore of fig. 3. The contractor is Fingrid Oyj, extreme importance for this installation which is in charge of the national power too. The liquid fuel operated units need 11 1 Plant design of the Ruhrgas compressor station in Wer ne /Germany 2 FT8 MechPac at Ruhrgas’s compressor station in Wer ne /Germany 3 Three FT8 MechPacs at Wingas’s compressor station in Mallnow /Germany 1 2 Mechanical Drives distributing companies (Wingas and station was expanded by adding a The outstanding efficiency figures, Ruhrgas) rely. waste heat recovery system utilizing based on the two-shaft design of the exhaust heat of the gas turbines to gas generator and the use of the latest The compressor station of Ruhrgas AG

produce steam for a steam turbine developments in the aircraft industry, in Werne, Germany, (fig. 2) is a key driving a fourth pipeline compressor which are maintained over a wide load installation for gas distribution within (delivered by MAN Turbo). range, in combination with the extreme Germany. robust DLN combustion system, which Because the Mallnow compressor station allows quick load changes and being In order to expand transport capacities, is running 24 hours a day, 365 days a insensitive to changing gas compositions two gas turbine compressor units year — thus a base load installation — and ambient conditions make the FT8 based upon the FT8 were added to steam is permanently available to power MechPac configuration a reliable and complement the compressor plant the steam turbine. thus cost-advantageous solution for already installed. Both FT8 units are mechanical drive applications. equipped with the DLN combustion In total, WINGAS operates 8 FT8 system. MechPacs distributed on 4 compressor Aside from mechanical drive installations stations. All these FT8 units are equipped for UGS (underground storage) and MAN Turbo’s scope comprised aside booster stations (e. g. re-gasification from the delivery of the turbo machinery plants) especially pipeline compressor and its accessories the tur nkey erection stations do have a significant share in and commissioning of the gas turbine the so called midstream sector. compressor units. Especially for the application in pipeline At the Polish border, near Frankfurt compressor stations, the FT8 — driving Oder, where the JAGAL pipeline is centrifugal compressors out of the MAN connected to the JAMAL pipeline, Turbo’s product portfolio — has demon- W ingas GmbH operates a compressor strated to be a proven and reliable con- station which relies on three FT8 cept on which the main German gas MechPacs. In the course of 2007 this 12

with the DLN combustion system. 3 13 Service 1 Borescope inspection on the FT8 2 Test arrangement for FT8 1 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 It is our aim to be there whenever and Derived from these tasks MAN Turbo Early recognition of critical machine wherever you need us, and in consultation has established a service concept for its conditions and of faults or malfunctions with you, to offer a service tailored to FT8 product programme which offers that are about to have an impact is an your requirements — thereby securing the following features: essential safeguard for the smooth the value of your long-term investment. MAN Turbo operates a Pratt & Whitney operation of the gas turbine and thus MAN Turbo is today responsible for the approved service shop at the Ober- the availability of the plant as a whole. Nevertheless experience has shown service of around 500 gas turbines hausen works taking advantage of the worldwide, and has experts and special expertise and skills developed by the facilities at its disposal for: OEM (PWPS) erection and commissioning proactive maintenance caused not only by the core equipment customer support and diagnosis systems for the recording and analysis (gas generator /power turbine / driven spare parts procurement and job of operating and maintenance parame- that often unplanned shutdowns are equipment) but also by ancillary systems. execution ters (remote data transmission for trend Our approach to provide service support corrective maintenance and inspections monitoring and diagnosis of machine consequently covers the complete gas full-load testing data) turbine plant including all ancillary systems materials examination supplied by MAN Turbo. 14 2 Cooling water Compressed air tank

for air starter Nitrogen cooler 25 MW Throttle valve Piping 28" Fuel pumps FT8 Gas Turbine Package Pipeline compressor compressor for air starter Intake Silencer Air Filter Package Ventilation Fuel filter Gear Box Torquemeter Water injection system Lube oil system pool gas generators and power turbines technical information in the form of The test arrangement allows maximum on standby for rental purposes in the service bulletins flexibility with regard to different speeds event of scheduled or unscheduled round-the-clock availability of service of testing FT8 Gas Turbines (50Hz, downtimes so as to minimize downtime personnel 60Hz and variable speed in the case of periods company’s own government-approved mechanical drives). Besides that, an care, support and coordination at the laboratory for materials examination, option had to be left open for power tur- works of MAN Turbo of all aspects research and development bines having either right or left direction of rotation. A precision dynamometer, relating to components supplied by MAN Turbo, including driven equipment Test facilities located between the power turbine and spare parts storage at the Oberhausen Our test facilities incorporate a dedicated a three-shaft special gearbox, is used works FT8 gas turbine test stand allowing us for measuring the power turbine torque. exchange of main modules (gas to test the FT8 gas turbines even at full The gearbox steps up /down the output generator / power turbine) and / or sub- load. Natural gas and /or liquid fuel firing speed of the gas turbine to correspond modules within a minimum of time is possible, permitting simulations of to the speed range of a double- stage facilities for full-load testing of the FT8 original operating conditions. The most 25 MW pipeline compressor (test stand at the Oberhausen works (see descrip- moder n monitoring systems allow real- equipment) which

operates in a closed tion below) time analysis of the gas turbine during loop with nitrogen at pressures between wide range of training facilities (see the test run. 28 and 76 bar. description below) 15 This gas turbine test is in accordance to To achieve these targets we can offer Should the overall plant contain other ASME PTC-22 with standard exceptions. you a training course that is made-to- turbo machinery products manufactured measure, like your gas turbine plant. and/ or supplied by MAN Turbo, such as Training We take your specific requirements into compressors, generators or steam Skilled, motivated staff makes a major account when focusing on the content turbines, the subjects of the training contribution to ensuring maximum long- in order to establish a programme which programmes of course are expanded accordingly. term availability with minimum service fits best to your specific installation and and maintenance costs. We offer you constraints. Among other things, our training programmes for your staff, from training courses comprise the following operators to plant managers. The primary options/ services: aims of our training courses are: Training for specialized staff, fitters, To complement and elaborate on the foremen, technicians, engineers and information contained in the operating plant managers manuals Training in your company, on our To optimize operation of the turbo premises or a combination of the two machinery set Training in German, English or French Early detection and elimination of as well as in your native language with critical machine states, malfunctions simultaneous translation and faults — including auxiliary systems Organization and coordination of all Prompt detection of minor damage measures by a single body — from that could result in more extensive compilation of the training documen- damage if ignored tation to hotel bookings and outline Use of

detailed knowledge in main- programmes. tenance, inspection, cleaning and preservation work 16 FT8 test stand with full-load capability 17 Technical data Power versus temperature (PowerPac) Sea level, rel. humidity = 60% Natural gas No inlet /outlet losses Standard combustion system Generator efficiency: 98% Power at Generator Terminals (MW) 33 30 27 24 21 18 -30 - 15 0 Inlet temperature (°C) 18 15 30 45 Mechanical Drive FT8 PowerPac Heat rate FT8 MechPac - - 25, 870 HP - - 34, 690 % Thermal efficiency FT8 TwinPac kW Shaft power - - 38. 6 kJ/kWh - - 9, 330 Btu/HPh - - 6, 594 kWe 25, 570 51, 140 - Generator Drive Power at generator terminals Electrical efficiency % 38. 1 38. 1 - kJ/kWh 9, 440 9, 440 - Btu/kWh Heat rate 8, 950 8, 950 - °C 458 458 457 Exhaust Gas Data Exhaust gas temperature °F 856 856 855 kg/s 85. 1 170. 2 85. 9 lb/s 188 376 189 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 kg 3, 000 (3, 950) 3, 000 (3, 950) 3, 000 (3, 950) rpm 3, 000* 3, 000* 2, 500 - 5, 500 4 4 3 kg 6, 000 6, 000 5, 100 Exhaust gas mass flow Gas Generator (LP/HP) Speed Weight approx. (DLN) Power Turbine Speed Stages Weight approx. Above specifications valid under the following conditions: 15°C (59°F), sea level, no inlet /outlet losses, RH = 60 %, natural gas, gen. = 98% * 3, 600 rpm available on request 19 MAN Turbo AG Steinbrinkstrasse 1 In the interests of technical progress, 46145 Oberhausen/Germany subject to change without notice. Phone +49. 208. 6 92-01 Printed in Germany. February 2009 Fax +49. 208. 6 92-20 19 www. manturbo. com MAN Turbo — a member of the MAN Group Turbo 1005 e 0109 0, 1 ba