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GT10C
30 MW GAS TURBINE FOR MECHANICAL DRIVE AND POWER GENERATION

by

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Biography Session 1.7

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Education; High school 4 years completed at Teknikum, Växjö, Sweden. Graduated as Bachelor of Science mechanical engineering. University 5 years completed at Linköping University, Sweden. Graduated as Master of Science mechanical engineering in the year of 1991. Project manager GT10B blade 1modification April 1999- November 1999, responsible of turbine blade 1 cooling modification to improve blade life; Project manager Zero Emission Power Plant; June 1999- February 2000, Project utilizing ceramic membrane technology in a gas turbine cycle. Due the function of membranes Carbon dioxide (CO_2) will be separated from the exhaust and can be used for different purposes. The Project is a co- operation between Alstom (Switzerland, Germany and Sweden) and Norsk Hydro. Now (2001) this project is an EU project; Product Manager GT10C, January 2002, Responsible for market introduction of the new developed GT10C.

GT10C - 30 MW GAS TURBINE for MECHANICAL DRIVE and POWER GENERATION

ABSTRACT

ALSTOM Industrial Turbines (AIT) has launched the GT10C, a 30 MW industrial gas turbine upgraded from the 25 MW GT10B. AIT will have a strong presence in the 20-30 MW range with both the GT10B and the new GT10C. The thermal efficiency of the new gas turbine is 37,3 % and 30 MW power (both figures measured shaft) at ISO inlet conditions with no losses. GT10C is also suited for cogeneration and combined cycle application. The new member of AIT gas turbine family has a DLE combustor for both gas and oil. GT10C will be the first engine in its power range with NOx emissions at 15 ppm on gas and 42 ppm on oil, both dry. GT10C was launched on the market in 2002 and is manufactured in parallel with the GT10B.

The general design is from the GT10B and measures are taken for maximum reliability and maintainability in order to keep operational cost to a minimum. AIT strongly believes that this will give our customers the highest value. Improvements for GT10C is mainly derived from GT10B or taken from GTX100.

This paper discusses the market demands and the GT10C development program where the environmental aspects also will be covered. The testing of the first unit is now successfully finalised and project targets are verified.

GT10 has been very successful with its dry low emission system for gas, combined with wet emission control on liquid fuels. In GT10C we take the next step in dry low emission and introduce a dry low emission system for liquid fuel.

The first 3 GT10C units have been sold to customers in Middle East in mechanical drive application. These engines are now in production in the Finspong workshop.

GT10C - 30 MW GAS TURBINE FOR MECHANICAL DRIVE AND POWER GENERATION

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ALSTOM Industrial Turbines

SUMMARY

AIT has launched the GT10C a 30 MW industrial gas turbine (see figure 1) upgraded from the 25 MW GT10B. The thermal efficiency of the new gas turbine is 37.3% (shaft) and 36% electrical at ISO inlet. The new GT10C has a **D**ry **L**ow **E**mission (DLE) combustor for both natural gas and diesel oil fuel. It has NOx emissions at 15 ppmv on gas and 42 ppmv on oil fuel (15% O_2 dry). The first GT10C:s are manufactured and assembled, and has been under testing since October 2001. For this purpose a new test rig has been built in Finspong, Sweden, in order to verify performance and reliability. The GT10C is available to the market and manufactured in parallel with the GT10B.

The general design is based on the GT10B and measures have been taken for maximum reliability and maintenance in order to keep operation costs to a minimum. Improvements for GT10C are mainly derived from the GT10B or taken from AIT Power GTX100 (43 MW gas turbine), as described herein.

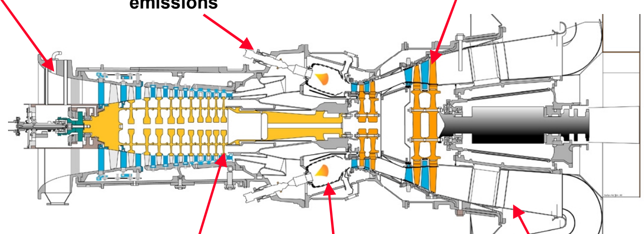


Figure 1. GT10C Main changes in comparison with GT10B

GT10C TARGETS

The main target is to increase power to 30 MW range using the GT10B as a design platform. Table 1 shows nominal ISO performance for the GT10C compared with GT10B Environmental performance is becoming more and more important. Therefore the GT10C has a dry low emission combustor for both gas and oil fuel. Greenhouse gases are decreased by increased efficiency. The gas turbine is also manufactured according to ISO 14001.

Reliability & maintenance were identified in the pre-study as important factors and have been considered throughout the development project. There is also a possibility in the future to retrofit a GT10B with a GT10C.

Nominal ISO performance Power generation	GT10B Natural gas	GT10B Diesel oil No. 2	GT10C Natural gas	GT10C Diesel oil No. 2
Power (kW)	24 770	23 750	29 060	28 290
Spec. heat consumption (kJ/kW)	10 533	10 760	10 002	10 028
Thermal efficiency, electrical (%)	34.2	33.5	36,0	35.9
Exhaust mass flow (kg/s)	80.4	80.2	91,1	89.9
Exhaust temperature (°C)	543	545	518	521

Table 1. Performance GT10B and GT10C

COMPRESSOR

The GT10C gas generator rotor has the same overall length as the GT10B but eleven stages, instead of ten (figure 2). Each stage is an individual disc, which are then electron beam welded together as for the GT10B and the GTX100. A single blade can be easily replaced because of its attachment to the disc; only the casing needs to be disassembled. The blades are machined from steel bar forgings, two different chromium steels being used for resistance against corrosion and to give high temperature strength. In the first blade a titanium alloy is used for its high strength and low weight.

Two vane stages are variable and a linear actuator turns them via unison rings. Stages 3-11 have abradable coating on the stator rings for low leakage without damaging the blade tips. To decrease the leakage even more, a low thermal expansion material is utilized in the rear vane carrier (same design as the GT10B).

The two bleed valves at stage 2 and 6 have are the same as in the GT10B. The 2nd bleed valve has a positioner for accurate adjustment throughout the load range.

The new shortened inlet bellmouth has an elliptical shape to give a continuous acceleration and thus minimize the boundary layer into the compressor blading.

The area of the inlet and stage 1 and 2 were increased by about 15% to meet the increased flow from 79 kg/s to 90 kg/s. A new stage 3 was added to increase the pressure ratio from 14.4 to 18. This means that from stage 4 to 11 the channel height was only slightly modified compared to stages 3 to 10 in the GT10B. The flow field in the compressor is based on the GT10B. However, the outlet velocity profile at the exit guide vane was straightened to improve the pressure recovery of the compressor diffuser.

The profiles of the blading have lower loss levels as well as a considerably broader working range than the old diffusion-controlled airfoil profiles. The average loading of the compressor has been slightly increased. This means that we keep the margin to surge at the same reliable level as the GT10B.

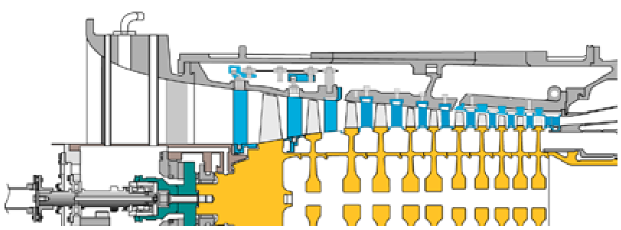


Figure 2. Compressor section

COMBUSTOR AND BURNERS

The GT10C's DLE combustor design is based on that of the GT10B. The annular combustor is made of Hastalloy-X sheet metal and has film-cooled liners with an impingement-cooled front panel. This design has been very reliable in the GT10B and has two million operating hours' experience.

The GT10C has **A**dvanced **E**nvironmental **V**ortex burners (AEV) (figure 3). This type of burner was originally developed for the GTX100 and has also been used in a GT35 (AIT Power 17 MW gas turbine) application for dry oil combustion. The experience from the GTX100 program is that the burners can produce emissions below 15 ppmv (15% O_2 dry) on gas and around 42 ppmv (15% O_2 dry) on oil fuel without water or steam injection. The GT10C has 18 AEV-burners, i.e. the same number of burners as the GT10B.

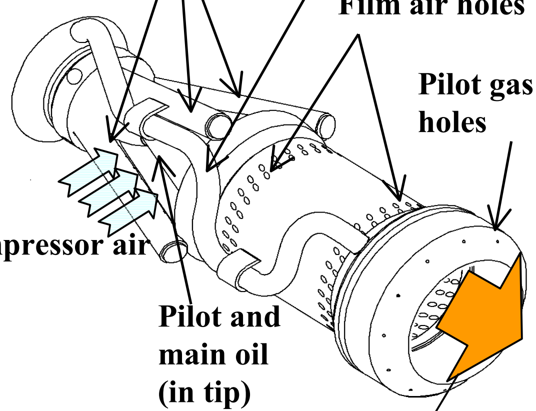


Figure 3. AEV burner

For emission control at part load, the GT10C has a combustor bypass, which allows air to go around the combustion primary zone. This makes it possible to keep a constant flame temperature down to 70% load. The combustor bypass has no impact on performance since the conditions in front of vane 1 are the same as without the bypass system.

In the range 50-70 % load, compressor bleed is used. For emission control the second bleed valve is used having variable control. If the compressor bleed is operated, the air temperature at the compressor inlet is higher and the mass flow is reduced for a specific load. This results in an increased flame temperature and decreased CO emissions.

From a maintainability point of view, an improvement is that the burners are easily removable for service and inspection. Therefore the GT10C combustor is angled compared with the inline combustor of the GT10B.

GT10C TURBINE

Besides the main performance and life data requirements, the following boundaries were specified in an early stage of the GT10C turbine design:

- size limits in order to keep the total engine length and diameter as close as possible to the existing GT10B,
- minimization of number of components/parts
- existing GT10B tools, material and blanks to be used as much as possible,
- turbine assembly and maintenance should be the same as for the GT10B.

All terms mentioned above were taken as additional inputs while the design was carried out and the concrete decisions made.

Flow path

The turbine is similar to the GT10B, i.e. a 2-stage compressor turbine (CT) and a 2-stage power turbine (PT). The flow path was designed to achieve high blading efficiency with the relatively simple end-wall configuration in order to get the proper sealing of the blade/vane platform tangential gaps.

The stage-to-stage heat drop was chosen with respect to reduction of the number of cooled components. Together with the increase in turbine reliability, this helped to keep reasonably small cooling air consumption.

When the blading components were developed, the GTX100 turbine development and operation experience was utilized, i.e. full 3D flow path aerodynamic optimization has been applied with regard to cooling, mechanical integrity and manufacturing demands. The 3D method helped not only to get an optimal gas velocity distribution around the airfoil and minimize the profile losses, but also to re-arrange the flow work along the radius by suppressing the secondary flows and end-wall air leakage.

The intermediate duct incorporation was dictated by the reduction, in comparison with the GT10B version, of the power turbine rotation speed. The intermediate duct was designed as a "double-skin" construction where the structural parts of the stator are protected by the heat shields. It helps to keep relatively low casing parts temperature and temperature gradients during transient modes and, at the same time, to form the sophisticated channel from the sheet metal with no complicated machining.

The main focus of the design team was on air leakage reduction. Therefore, besides the 3D effects achieved from the blading design, the individual air feeding system has been incorporated, where air goes through the calibrated holes to every individual particular vane or vane segment.

Compressor Turbine

The compressor turbine is similar to the proven GT10B, and can be assembled together with the new or existing power turbine.

Vane 1 and Vane 2 are suspended on the inner and outer carriers respectively. The cooling air ventilation flows arranged at the guide vanes end-walls aim to keep reasonably low temperature in the vane carriers and avoid thermo-shocks during start-up and shutdown.

The air taken from the compressor exit cools the vanes and blades. The air feeding system is kept as it is on the GT10B turbine: vanes are fed through the holes in the casings, blades – through the swirl generator located under the first guide vane.

The first blade (figure 4) has no shroud, while the second stage blade is equipped with an aerodynamic shroud. However, the efficiency of the first stage has not been sacrificed because of the shroudless blade thanks to the 3D stage profiling and minimized radial gap.

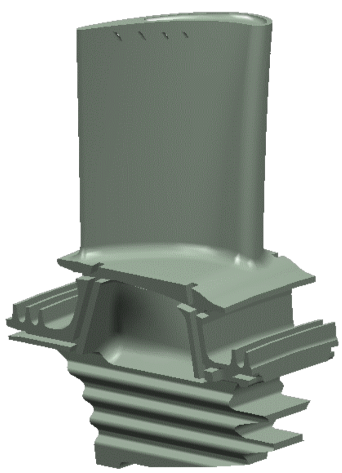


Figure 4. Blade 1

Power Turbine

The two-stage power turbine is of modular design enabling easy inspection and replacement of components.

Uncooled blade 3 and blade 4 are equipped with the Z-shape dynamic shrouds. Guide vanes are also uncooled. Vane 3 has a cavity inside the airfoil and works also as a cooling air supplier toward the compressor turbine and power turbine disks and turbine intermediate duct inner parts attached to the vane.

The power turbine rotor, as well as the compressor turbine rotor, can be finally balanced on an assembled engine by installation of the additional weight-screws through the inspection ports located at the stator parts.

Exhaust

The exhaust diffuser was designed, bearing in mind the strong requirement to have exactly the same position of the turbine supports at the rear part of the engine. That circumstance made the task of allocating the "double-skin" construction fairly complicated. However, thanks to the experience of the GTX100, that task has been successfully completed.

Design validation

Besides the prototype testing, the most critical components, such as the first stage guide vane and blade were tested in Finspong at the hot test facility.

Tests allow confirmation of the assumed component performance and to compare the different versions at the same time.

INSTALLATION

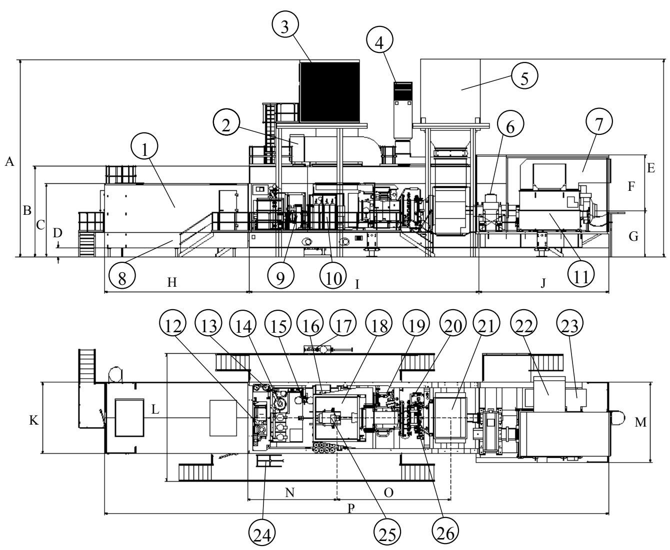
The GT10C installation meets requirements for compactness, short erection and commissioning times and easy maintenance. The gas turbine is skid-mounted, with the auxiliaries grouped in modules placed in the auxiliary room. The layout is basically the same for all applications, whether simple or combined cycle, indoor or outdoor installation.

The gas turbine skid is built from steel beams and carries the gas turbine, speed reduction gear, auxiliary systems and starter motor. The gas turbine skid is then bolted to the generator skid and the whole package thus forms a single lift unit, with a total dry weight of approximately 78 metric tons for mechanical drive and 172 metric tons for power generation.

The electrical and control module containing batteries and control unit cubicles is in the standard version, standing on its own support adjacent to the gas turbine/generator skid on the air intake side.

A fully assembled standard package complete with air intake, exhaust system and control room has an “in operation” weight of approximately 150 metric tons for mechanical drive and 215 metric tons for power generation.

A standard layout for an outdoor simple cycle installation is shown in figure 5.



	A	B	E	H	I	J	K	P
Meter	11.8	5.1	12.3	8.0	12.8	7.2	4.0	28.2
Feet	38.7	16.7	40.3	26.2	42.0	23.6	13.1	92.5

1. Control room	14. Oil mist filter
2. Ventilation air inlet	15. Lube oil filter
3. Air inlet filter	16. Compressor wash unit
4. Ventilation air outlet	17. External gas unit
5. Exhaust silencer	18. Air inlet plenum
6. Gear	19. Gas fuel unit
7. Gen. cooling, air outlet	20. Purge air unit
8. Batteries	21. Exhaust
9. Lube oil unit	22. Generator cooling, air inlet
10.Fire suppress unit	23. Generator cubical box
11.Generator	24. Lube oil cooler
12. Liquid fuel unit	25. Starter motor
13. Ignition gas bottles	26. Seal air cooler

Figure 8 Package layout

MAINTENANCE

The GT10C has a number of features that simplify maintenance and inspection. Borescope ports are available on one side for inspection of five of the compressor stages. At the front of the air inlet plenum, a door is fitted allowing access to the compressor.

The compressor casing has a horizontal split, allowing half of it to be removed for easy access to the rotor and stator parts.

The combustion chamber can be inspected from borescope access ports located at the end of the combustion chamber. The burners can easily be dismantled for inspection or visual inspection of the combustor chamber. The turbine can be inspected from the combustor and through three inspection ports.

An overhead crane is installed inside the gas turbine enclosure to facilitate maintenance and enough space is available to allow operating personnel to walk around the machine. For flexibility, the gas turbine can be removed from either side (to be selected) of the installation.

Maintenance program

A well-established maintenance program is available for the GT10C, basically the same as for the GT10B. Inspections and maintenance are carried out at intervals of 10,000 equivalent operating hours and are provided at five levels, a philosophy that has ensured high reliability of the gas turbine type. The time between major overhauls is 40,000 equivalent hours.

If required, the whole gas generator may be replaced. The gas generator is then disconnected from the air intake and power turbine and removed sideways on a rail assembly.

Depending on the individual customer requirements, AIT has a comprehensive service program to offer our customers. It includes a full range from a simple support agreement up to taking full responsibility for preventive as well as corrective maintenance.

AIT also stores emergency spares and a spare gas generator for emergency back-up as part of its service agreements.

GT10C validation

For GT10C a new test bed has been built in Finspong being first used for prototype test of engine #1. The test bed has full load capability on both liquid fuel and natural gas. To enable testing on gas, a new liquid natural gas plant has been built, designed to cope with gas flows for GTX100 (43 MW).

The purpose of the engine test is to validate component life and performance. The test program for the GT10C covers temperatures, pressures, blade dynamics and performance. For this the engine is equipped with about 1200 measuring points, both static and rotating.

The prototype will go through a test program to cover different load cases on both natural gas and oil. T esting was started in October 2001 and testing on gaseous fuel is now finalized with a good result, which fulfills the development targets.

CONCLUSION

The GT10C has been developed based on the GT10B and the latest technology and experience within AIT. Compared to the GT10B, power has been increased from 25.4 MW to 30 MW (shaft) and the efficiency has been raised from 35.0% to 37.3%. Lots of effort were devoted during the development phase to the increase maintainability and reduce operational costs. The first engine will be verification-tested in Finspong.