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SGT-750 - 37 MW GAS TURBINE

Anders Hellberg (anders.c.hellberg@siemens.com)
Anders Häggmark, Anders Junsten, Thomas Andersson, Christian Troger.

Siemens Industrial Turbomachinery AB
SE-612 83 Finspong
Sweden

Abstract

November 2010 Siemens Energy launched a new industrial gas turbine, the SGT-750. The SGT-750 is a twin shaft gas turbine with a free power turbine and it can be employed both for power generation and as a mechanical drive. This gas turbine attains an efficiency level of 40% and has a capacity of 37 megawatts (MW).

The new industrial machine offers outstanding serviceability. Maintenance work can be performed on site on the installed machine or the gas turbine can be exchanged to minimize downtime. Maintenance downtimes for this machine have been cut to a mere 17 days in 17 years. Long service intervals, rapid gas generator exchange and easy access for borescope inspection all guarantee optimized availability. Another example of this is the possibility to measure the hot section blade temperature during operation to do a "health check" to ensure availability.

Maximized dependability is also ensured by using proven technology and components from other gas turbines in the Siemens fleet. The burners, for example, are based on technology with a proven track record. Thanks to the machine's dry low emission (DLE) combustion system, nitrogen oxide (NO_x) emissions are minimized. The turbine's high exhaust energy provides for an excellent efficiency level when used in cogeneration or combined cycle power plants, resulting in low fuel consumption and allowing carbon dioxide (CO₂) emissions to be reduced.

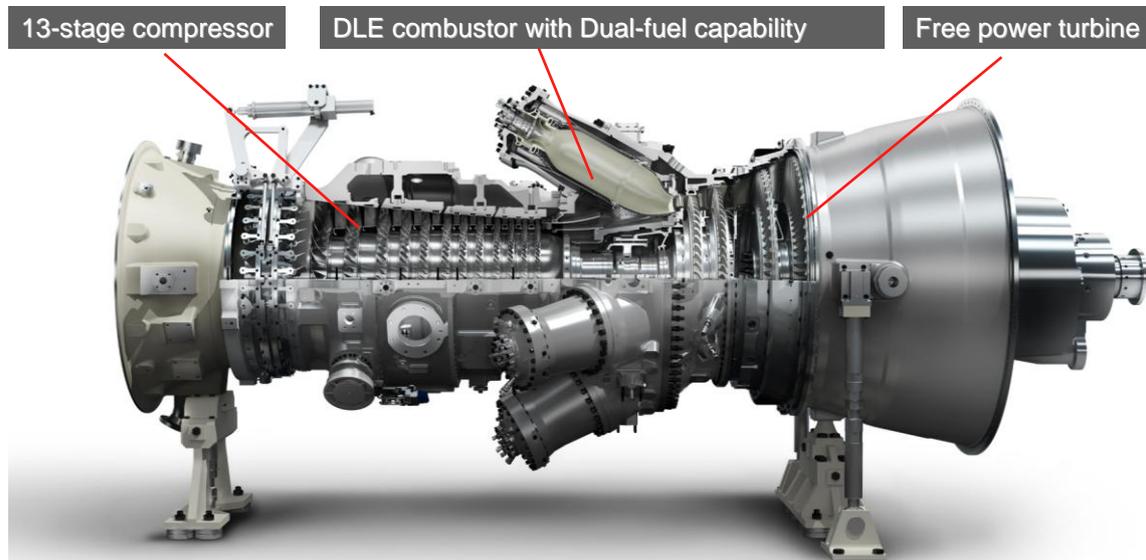
This paper will describe the development of the SGT-750 and the new features which have been built into this gas turbine; the paper will also discuss the testing of the turbine. An important factor for an operator is the uptime and special attention has been dedicated to this aspect during the design phase, as will be highlighted in the paper.

1 Introduction

Reliability is a key customer requirement. Industries are extremely dependent on the smooth and uninterrupted supply of power and heat for their businesses. In order to ensure reliability in the SGT-750, its design philosophy was based upon simplicity, robustness and the use of proven technology.

The SGT-750 is designed to meet customer demands for highly reliable, clean and efficient power generation equipment with state-of-the-art performance. Other customer values, such as low Life Cycle Cost (LCC), plant compactness and short delivery time, are also addressed. It is a heavy duty gas turbine designed and developed to incorporate size and weight advantages of the aircraft derivative gas turbine while at the same time maintaining the robustness, flexibility and long life advantages of the traditional industrial gas turbine.

The SGT-750 is a twin-shaft gas turbine (figure 1) with a free power turbine which makes it suitable for either mechanical drive or power generation. In power generation the free power turbine enables the SGT-750 to cope with fluctuations in the frequency of the grid. It has also the capability for frequent and fast starts where it can reach full load within less than 10 minutes. The complete gas turbine unit is mounted on a single foundation frame into which the lube oil tank is integrated. All the auxiliary systems such as start motor and electrically driven back-up systems are mounted on the base frame.



| | Power | Efficiency |
|----------------|---------|------------|
| Shaft | 37.1 MW | 40.0% |
| Electric | 35.9 MW | 38.7% |
| Combined cycle | 47.7 MW | 51.7% |

Figure 1 SGT-750 gas turbine and performance

The technology in the SGT-750 is taken from the overall Siemens gas turbine fleet, both the industrial and the utility ranges, with the 375 MW SGT5-8000H as top of the range. The main focus of development was on the core engine in order to improve the performance and emissions further, while the design of auxiliary systems was to a large extent based on the SGT-600/700 package. Significant attention has also been devoted to serviceability and increased uptime.

Since environmental performance is becoming more and more important, the SGT-750 has a low carbon footprint with high-efficiency; dry low emissions (DLE) combustor is standard for low nitrogen oxide emissions. The SGT-750 gas turbine is manufactured according to ISO 14000.

New innovative way of working

Challenging targets for the highest availability requires good serviceability with good access for all service operations and an optimized location of all components and features on the gas turbine.

To achieve this new technology has been used. During the SGT-750 development a new way of working has been developed in co-operation with the University in Norrköping. The 3D stereo visualisation approach has been used for the complete gas turbine package to evaluate different design alternatives from an access and service perspective. It is important to have a good model of the complete gas turbine and the package for simulation of access. All interfaces within the gas turbine and also between the core engine and the baseframe with its auxiliaries must also be optimized. All 3D studio sessions always involve designers, assembly shop representatives and service engineers to ensure that that site experience is fed back to the development process. A large number of sessions have been spent in the 3D stereo studio to study the total layout of the package.

Good serviceability must be built in to the design concepts from the very beginning. During this process different design alternatives, from inlet to outlet, have been evaluated for better access and all foreseen service situations have been simulated to reduce service time. As a result the location of many components and the design of many features have been improved from an assembly, access and service perspective. In the end this will improve the uptime for the end user.

Installation

The SGT-750 installation (Figure 2) meets stringent requirements for compactness, short installation and commissioning times and ease of maintenance. The gas turbine is skid-mounted, with the auxiliaries grouped in self-contained 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 auxiliaries are located in front of the gas turbine in the auxiliary room. The gas turbine skid is then bolted to the generator skid and the whole package thus forms a single lift unit. The air intake and exhaust stack are supported by separate external beam structures. A two-stage disposable air filter is supplied as standard, but other options are also available, depending on customer requirements. In the standard version, the electrical and control module containing MDS:s (Motor Drive System), batteries and unit control

cubicles stands on its own support adjacent to the gas turbine/generator skid on the air intake side.

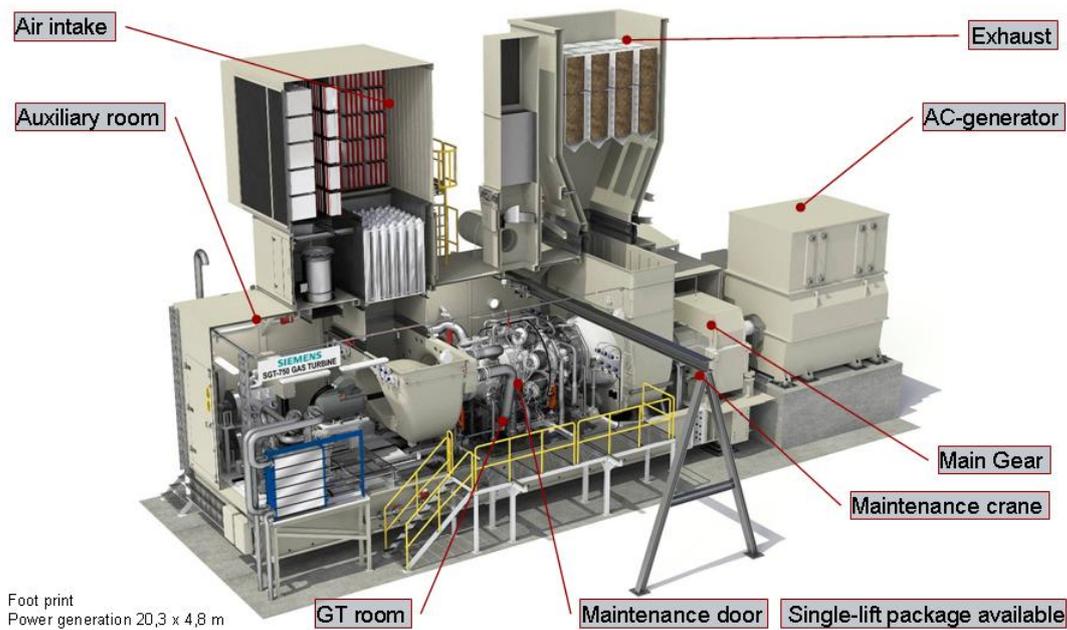


Figure 2 Package layout

Compressor

The compressor design benefits from the latest experience and tools. All compressor blades are designed with CDA airfoils (Controlled Diffusion Airfoils). They are axially attached to the rotor disks for easy maintenance. The guide vanes are assembled as segments with inner shrouds for minimum leakage and maximum performance. All blades can easily be accessed from outside through borescope inspection holes. In the event of need to replace blades or vanes in the front part of the compressor, an extra split plane in the casing has been introduced after stage 3. The compressor has 13 stages and a pressure ratio 24:1 (figure 3). Two variable guide vane rows and three compressor bleeds located after stage 3, 6 and 9 are used during start-up and part load operation. This configuration was chosen for maximum reliability, highest possible compressor performance and for rapid engine swap.

The compressor rotor disks and shafts are joined together by the use of electron-beam welding, the same technology as used on other Siemens gas turbines. Field-balancing possibilities are provided for, as well as access from the outside to the standard instrumentation at the bearings, which facilitates easy exchange of vibration probes if necessary. All materials have been selected to suit hot and cold ambient conditions. Protective coating against corrosion is also available for customers requiring this.

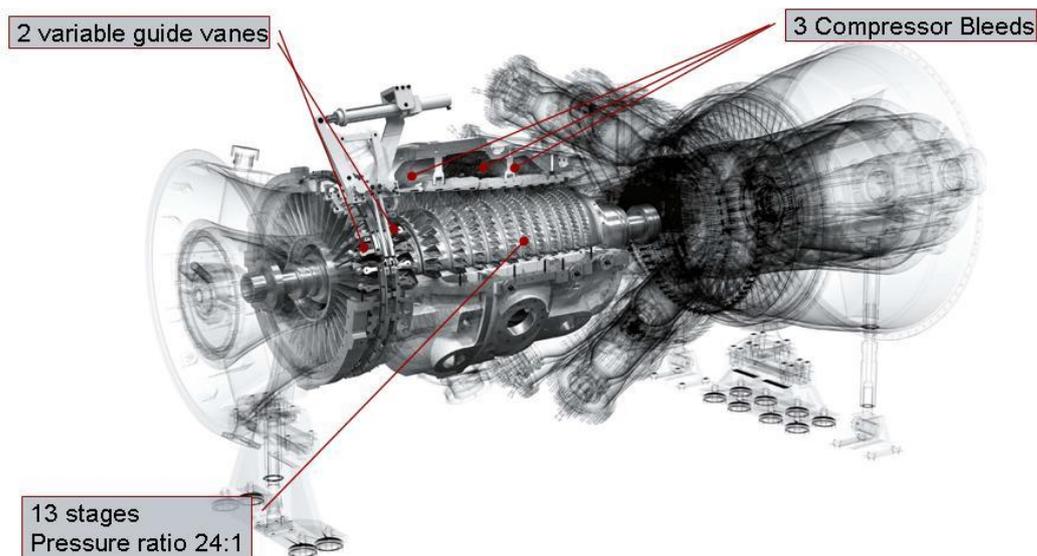


Figure 3. Compressor section

4th generation DLE Combustion System

The 4th generation DLE burner is designed for extremely low emissions over a wide operating range. A compressor discharge air bleed is available to further reduce the emissions at very low loads. We have utilized the world leading knowledge available within Siemens as a foundation for the development of the 4th generation DLE burner used in the SGT-750, and further developed the burner to achieve optimized aerodynamics and excellent fuel/air mixing. This was made possible by using state of the art unsteady combustion modeling alongside extensive testing at atmospheric as well as at full pressure operating conditions.

The SGT-750 combustion system is a can combustor system with 8 cans (figure 4). The design concept has been used in Siemens gas turbines for many years. The design has been developed with focus on high reliability and easy maintenance to ensure highest possible uptime. It is possible to replace individual combustion chambers from the compressor side without disassembling the turbine module, thus helping to keep maintenance time down to a minimum. The dual-fuel option has DLE capability on gas. Water injection can be used for NO_x emission reduction during liquid operation. The system is designed for smooth switchover between liquid and gaseous fuels during operation.

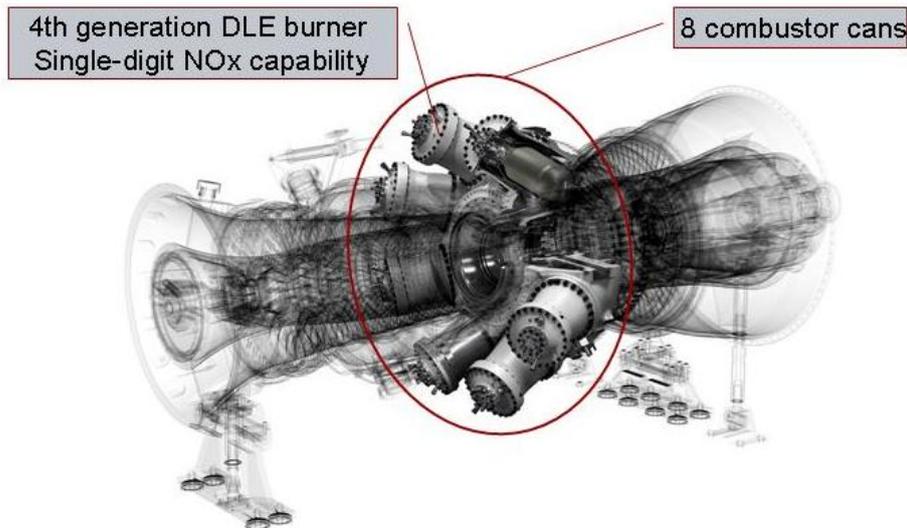


Figure 4 Combustor design

SGT-750 turbine section

The turbine section of the SGT-750 consists of the two-stage air-cooled compressor turbine and the two-stage uncooled counter-rotating power turbine.(figure 5)

Compressor turbine

In the development of the SGT-750, focus of the design work has from the very beginning been on reliability and uptime. All materials in the turbine are well proven in the Siemens gas turbine fleet. The relatively low TIT (turbine inlet temperature) is selected for robustness. As a comparison the TIT is 56°C lower than SGT-800.

The stage 1 vanes and blades have both film and convection cooling with compressor discharge air. These blades and vanes have a thermal barrier coating for reduced cooling-air consumption. The stage 2 vane and blade are convectionally cooled with cooling air from compressor stage 9. For high reliability the cooling technology is based on proven components in the Siemens gas turbine fleet and only proven materials are used. The layout of the CT-PT (compressor turbine-power turbine) gas path is made with a minimal increase in hub radius from CT to PT. This avoids using a turbine intermediate duct and thus reduces aerodynamic duct losses, also reducing the size of the engine and the hot surfaces.

The CT blades are unshrouded and rub into an abradable coating in the shroud segments for minimized over-tip leakage. The gas path at blade 1 and 2 is cylindrical for stable tip clearance during axial thermal movements in transient operation.

The compressor turbine casing is also cooled with cooling air from compressor stage 9. This reduces the temperature of the casing by 100° compared to full-pressure air and thus reduces thermal expansion and improves the blade tip leakage for increased efficiency.

At overhaul the compressor turbine hot section is handled as a single module for increased uptime. The module comprises the two bladed disks and the turbine stator. The disks are bolted to the rotor with 12 tie-bolts. The torque is transferred from the disks to the rotor with a curvic coupling. Curvic couplings have proven balancing behavior and low assembly time. The second disk has a balancing plane accessible from outside without stripping the engine.

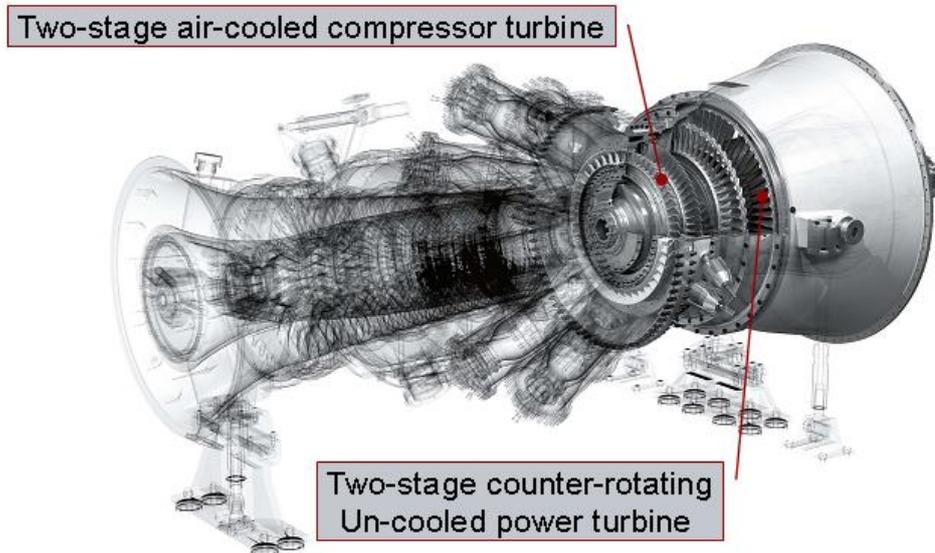


Figure 5. Turbine

Power turbine

The free power turbine can be used for power generation at a nominal speed of 6100 rpm or used as a variable-speed mechanical driver with a speed range of 50-105% of the nominal speed. Blade 3 and 4 are shrouded for dynamic damping. The shrouds have two seal fins each and cover the throat area for improved efficiency.

Vane 3 (first power turbine vane) can be selected with different flow capacities optimized for normal or hot climate. By alternating the flow capacity of vane 3, the speed of the gas generator is optimized to improve performance at the dedicated site.

The exhaust diffuser structure is cast as a solid single component in a creep-resisting steel for high temperature. The diffuser and blade 4 are aerodynamically designed together for optimal total performance of blade and diffuser recovery by optimizing the pressure profile at blade 4 outlet. Not only to achieve the highest blade performance but also to achieve highest performance for the whole system by increasing pressure recovery in the diffuser.

The power turbine inner casing is hosting the rotor bearings. All essential instruments are replaceable from outside without stripping the engine, which will increase uptime. By tapering the shaft, a straight line of sight from the port holes in the rear of the engine to bearing #3 was created for reliable assembly of instruments such as vibration and temperature monitoring. During overhaul the power turbine stages 3 and 4 are handled as a single component using a module tool with the same principle as the compressor turbine for reduced downtime

Maintenance

A maintenance plan is a recommendation for the preventive maintenance schedule during the gas turbine's life-cycle which includes parts replacement schemes and activities at different levels. It is designed to optimize cost and availability during the lifetime of the gas turbine. Inspection intervals are based on EOH (Equivalent Operating Hours) or EOC (Equivalent Operating Cycles), whichever comes first. Component life time has been optimized for long service intervals. Based on field experience from the designs in the SGT-600/700 fleet and extensive component testing, time between major overhauls for the SGT-750 could thus be extended to 68,000 Operating Hours.

The maintenance plan for the SGT-750 with corresponding inspection levels for the gas turbine is shown in Figure 6. The program contains 8 level A (borescope), 2 level B (hot section) and 1 level C (overhaul) inspections. Various other activities such as power turbine maintenance, generator or compressor maintenance are included in the different levels. A full maintenance period is reached after 136 000 EOH, i.e. approximately 17 years of continuous operation. After this there will be a service package to continue operation.

There are two options available for performing maintenance on the gas generator, auxiliaries and driven equipment. An industrial type of on-site maintenance where all activities can be performed on the customer's site and an aero-engine type of off-site maintenance featuring a fast core exchange where the maintenance of the core is performed at a local workshop or at the Siemens facilities in Sweden. Total downtime for preventive maintenance in seventeen years of base load operation is 48 days for the on-site option and a stunning 17 days for the off-site option using an exchange engine. This ensures maximized availability and minimized risk for production loss.

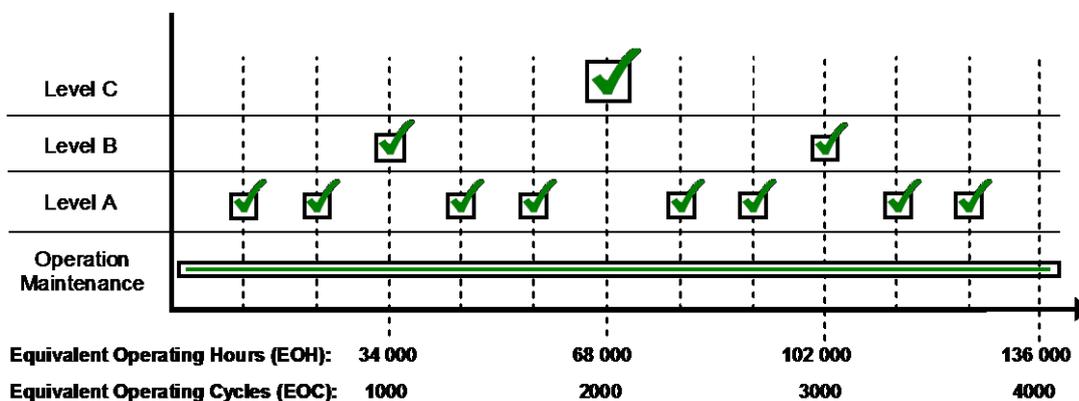


Figure 6 - Inspection levels and intervals for the SGT-750

The maintenance plan also includes an innovative annual on-load performance inspection. This is based on remote diagnostics of operational data by Siemens specialists and does not need any downtime. This performance inspection takes place every calendar year when no A, B or C inspection is planned. Remote diagnostics are also used upfront of the inspections to determine the scope of work.

The unit has a number of features that simplify maintenance and inspection. Borescope ports are available for inspection of five of the compressor stages. At the front of the air inlet chamber, a door is fitted allowing access to the compressor. 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. Exchange of combustor components is enabled within the enclosure.

A core engine exchange can be performed within 24 hours from load to load, which is another important feature for fast maintenance or to maintain availability in the event of a forced outage. For flexibility, the gas generator can be removed from either side (to be selected) of the installation. The gas generator is then disconnected from the air intake and power turbine and removed sideways on a rail assembly, see fig 5 below.

High-speed infrared monitoring system

The SGT-750 uses high-speed on-line infrared monitoring of the hot blades. Turbine blade 1 and turbine blade 2 are equipped with 2 infrared cameras each covering the pressure side, suction side and the platforms. The cameras can detect anomalies before they go to critical events. This system shows high-resolution images of rotating blades in operation, showing the actual surface temperature of the blades.

Before and after each inspection an evaluation of the surface temperature of the turbine blades in the compressor turbine is performed. The gas turbine is started and put on load and the actual material temperature of the blading is measured. This method mitigates risk due to early problem detection by detecting for example temperature disturbances.

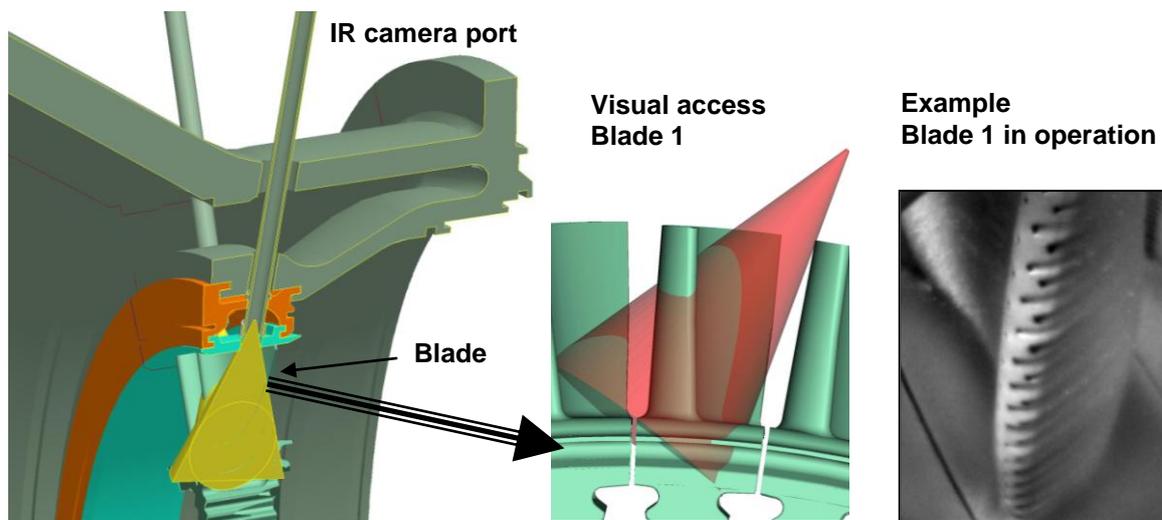


Figure 7 - Compressor turbine blade temperature measurement

Conclusion

There is a constant demand for efficient and clean power generation based on gas turbines. Customers are demanding equipment which offers a high level of performance without sacrificing reliability. The SGT-750 has been developed to meet this demand. The design of the SGT-750 has ensured that it has a very low life-

cycle cost and that it is suitable for a wide range of applications, features which are in line with current and future customer requirements.

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