GE 's new J624 gas engine with 2-stage turbocharging

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ABSTRACT

GE Energy's gas engine business is a manufacturer of gas-fueled engines, generator sets, CHP modules, ORC systems and auxiliaries. The type 6 engine family was introduced in 1988 and is currently the largest series in GE's Jenbacher gas engine product portfolio. With 190 mm bore and 220 mm stroke it is available as 12-, 16-, 20- and 24- cylinder version.

The new J624 gas engine now has 4.4 MW output and is the world's first gas engine with 2-stage turbocharging. All of GE's gas engines are high-speed engines running at 1,500 rpm and therefore have higher power density compared to medium and low speed engines. Today GE has delivered more than 2,600 type 6 units worldwide running on all types of gaseous fuels from pipeline gas to low BTU gas as well as high hydrogen gas. With the new 2-stage turbocharger the output of the J624 is increased by 10% with room for further growth. Two stage turbocharging is the enabling technology to increase the specific output and efficiency of the gas engine.

This new technology offers significant output and efficiency advantages under hot environment conditions and it offers a higher total efficiency for combined heat and power applications. This paper discusses the features of 2-stage turbocharging on the J624 gas engine as well as the advantages this new technology offers for typical applications.

Lengths …................12.0 m

Width …...................2.5 m

Height …..................2.9 m

Engine + turbo ....30 t

Generator ....15 t

4.4 MW el. Output 46.5% el. Efficiency

@ ISO3046, PF=1, NOx=500 mg/Nm³ (@5%O2), MN>80, LHV

Figure 1: The new J624 2-stage turbocharged

INTRODUCTION

For years gas engines have been gaining importance within the global energy mix. One reason for that is the comparatively good, long term availability of natural gas combined with achieving a high level of electrical and thermal efficiency. A total efficiency (electrical and thermal) of 90% and above can be achieved using the new advanced 2-stage turbocharging technology. In addition GE's gas engines can meet the most stringent emission standards. This makes gas engines a comparable cleaner technology for supplying electricity and heat around the globe as part of a decentralized structure.

The ambient conditions, ranging from temperate latitudes of arctic areas to hot and humid tropical climates require a robust engine design and operating flexibility. Annual operating hours can be more than 8,000 hours with an availability of over 95 % under full load conditions. Jenbacher gas engines fulfil these requirements along with the most severe emission standards despite varying gas quality and gas composition. In accordance with TA Luft 2002 an engine emission level of ≤500 mg/Nm³ of NOx and an even more severe of ≤250 mg/Nm³ (at 5 % O2 in the exhaust gas) can be achieved, if required.

For more than 60 years GE's Jenbacher gas engines have been developing solutions for the never-ending list of new technological challenges to stationary gas engines and is thus driving technology forward. One of the latest products is the 2-stage turbocharged 24-cylinder lean burn engine J624 - Figure 1. It produces 4.4 MW of electric power and reaches an electrical efficiency of 46.5 % by combining a set of new technology blocks.

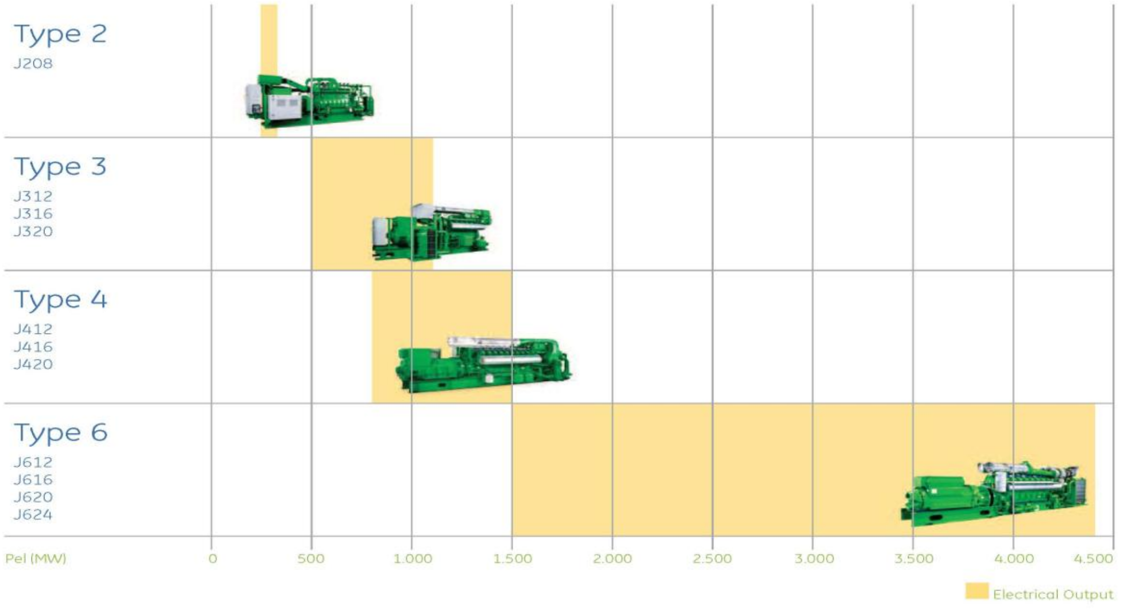

Figure 2: GE's Jenbacher gas engine portfolio

The new J624 gas engine builds on almost 20 years of experience with the type 6 engine family and an installed fleet of more than 2,600 units. Compared to the previous version it offers 10% more power output and about 1% point higher electrical efficiency, and due to 2-stage turbocharging this engine achieves a total efficiency of 90% and more.

INNOVATIVE TECHNOLOGY

In order to achieve the highest customer value, the type 6 gas engine was developed by focusing on high electrical efficiency and high specific output. The design concept is based on a pre-chamber ignition system, favourable combustion geometry, reasonable piston speed with 11 m/s, separation of the cool mixture intake section from the hot exhaust gas flow (cross flow cylinder head) and a four-valve cylinder head design. This concept allows continuous performance improvements over time. The electrical efficiency could be increased from 38 % in 1994 (at 12 bar BMEP) to 45.6 % in 2009 (at 22 bar BMEP) while always meeting TA Luft emission requirements. The new J624 with 2-stage turbocharging, portrayed in this paper, has a maximum electrical efficiency of 46.5 % and produces 4.4 MW (at 24 bar BMEP). It follows the same general path of development.

New technology blocks are combined to achieve advanced performance. The road to more advanced Miller valve timing and the optimized lean-burn combustion process, enabling higher efficiency levels, is achieved with 2-stage turbocharging. Combined with the optimized MORIS high energy ignition system along with refined control strategies and algorithms, these technology blocks facilitate a sufficiently wide operating band between the knock and misfire limits. In particular they make operation possible at high altitudes and under tropical hot conditions without compromising efficiency.

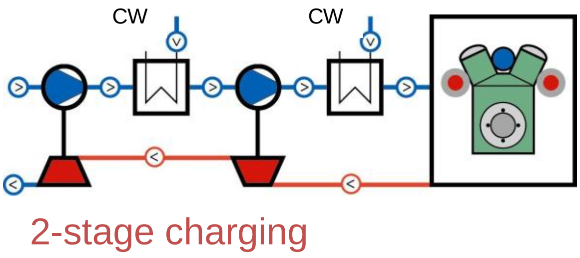

Figure 3: 2-stage turbocharging concept

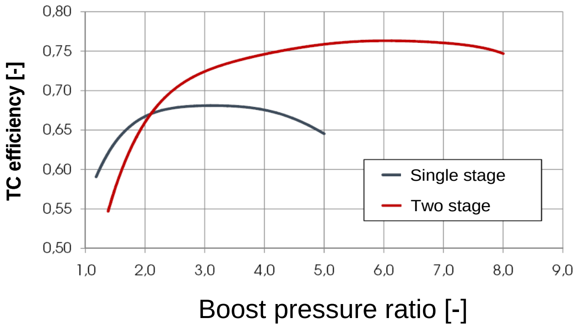

Figure 4: Charging Efficiency improvement

Far advanced Miller valve timing reduces the knock tendency; however, it also increases the required charging pressure. To meet the required charging pressure, the required boost pressure ratio >6 can be achieved only by using special turbocharger features, and then the charging efficiency would drop dramatically to a value below 60%. Therefore 2-stage turbocharging is used, which offers a charging efficiency of more than 75% (Figure 4). The newly developed charger module consists of a low-pressure compressor, intercooler, a high-pressure compressor, and aftercooler (blue line in Figure 3) with the corresponding high- and low-pressure turbocharger turbines on the exhaust side (red line in Figure 3). Due to the split into a low pressure and a high pressure turbocharger and an intercooler in between, the thermo-mechanical stress on the components is lower.

The allowable mixture temperature to the engine is higher and therefore the required cooling water (CW) temperature to the mixture coolers can be up to 70°C, a significant increase compared to previous versions.

APPLICATIONS

The trend to de-centralized power generation with smaller units and multiple unit installations is in favour for gas engines. Because gas engines offer high simple cycle efficiency, many installations are operated in simple cycle mode thus reducing investment costs. Due to low derating at high ambient conditions and the availability of low grade heat, gas engines are best suitable for installations with tropical climate conditions as well as Combined Heat and Power (CHP) applications.

Hot and tropical ambient conditions:

The biggest benefit of the new J624 with 2-stage turbocharging is the 10% higher output and the electrical efficiency improvement by 1 % pt. The second benefit is the much better performance at higher ambients. The higher charging pressure provided by 2-stage turbocharging is the enabler to improve the output of the engine. At the same time 2-stage turbocharging is providing a higher charging efficiency which is a strong contributor to increasing the electrical efficiency of the engine by about 1 % pt at ISO conditions. The efficiency improvement with 2-stage turbocharging is even better in a hot country, here the electrical efficiency increase is 1.7 % pts – see figure 5.

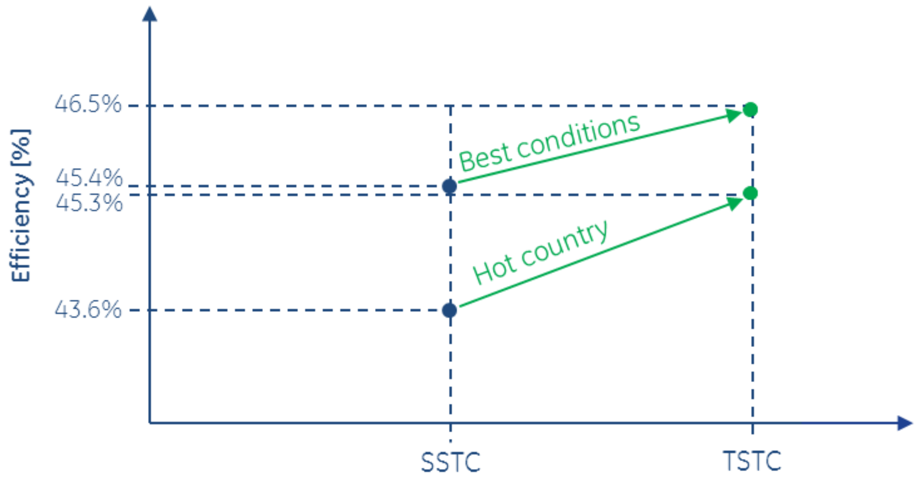

Figure 5: J624 el. efficiency with single stage (SSTC) and two stage (TSTC) turbocharging

The higher allowable cooling water temperature is a benefit if the engine runs under hot ambient conditions because under this climate the available cooling water temperatures are typically higher. 2-stage turbocharging is also the enabler to run the engine with full output at higher ambient temperatures. That allows more power and efficiency at high ambient temperatures when power demand typically peaks.

For installations in hot and tropical environments, the higher allowable mixture temperature of 70°C avoids mixture condensation, because the cooling water temperature can be up to 70°C. And due to this higher allowable cooling water temperature, the heat from the mixture cooler can be dumped by much smaller horizontal air coolers.

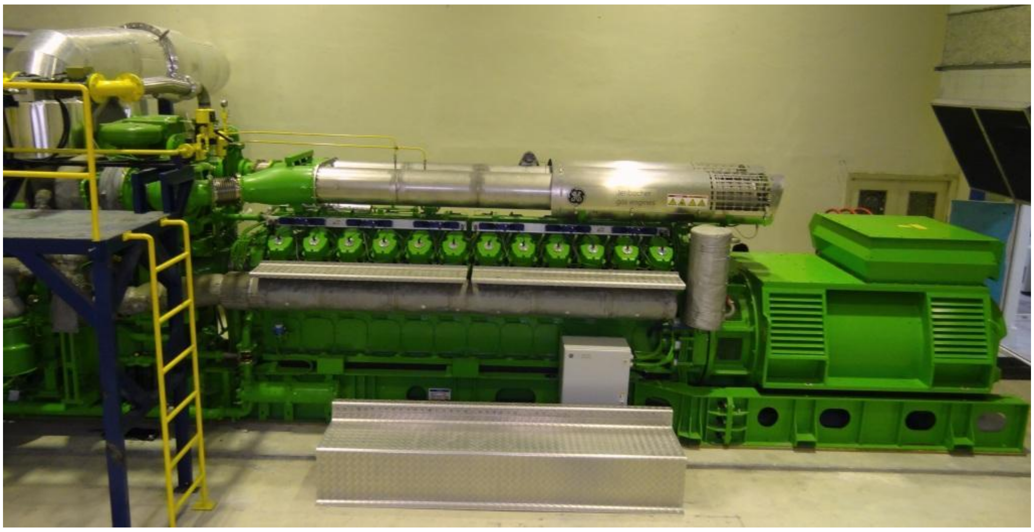

Figure 6: First 2-stage turbocharging gas engine in Asia

The first new J624 was placed into commercial operation in the Netherlands in September 2010. Figure 6 shows the first J624 installed in Asia in mid-2011 at Batam Island, Indonesia. This engine is supplying onsite power to a nearby Industrial Estate.

Combined Heat and Power:

2-stage turbocharging allows the potential to achieve 90% total efficiency – about 3 to 4 % pts higher than a gas engine with a single stage turbocharging. Figure 7 shows how all the heat from the engine and engine exhaust can be utilized in a combined heat and power plant. A water return temperature of up to 70°C is allowed and cold enough for cooling all the heat exchangers on the engine.

Gas engine power plants for CHP are running with constant high electrical efficiency, independent if heat is extracted or not. Only one additional gas/water heat exchanger is needed at the gas engine exhaust, all other heat exchangers are available on the engine frame. Together with the use of simple water circuits and a straight forward power plant design makes gas engines very attractive for combined heat and power solutions.

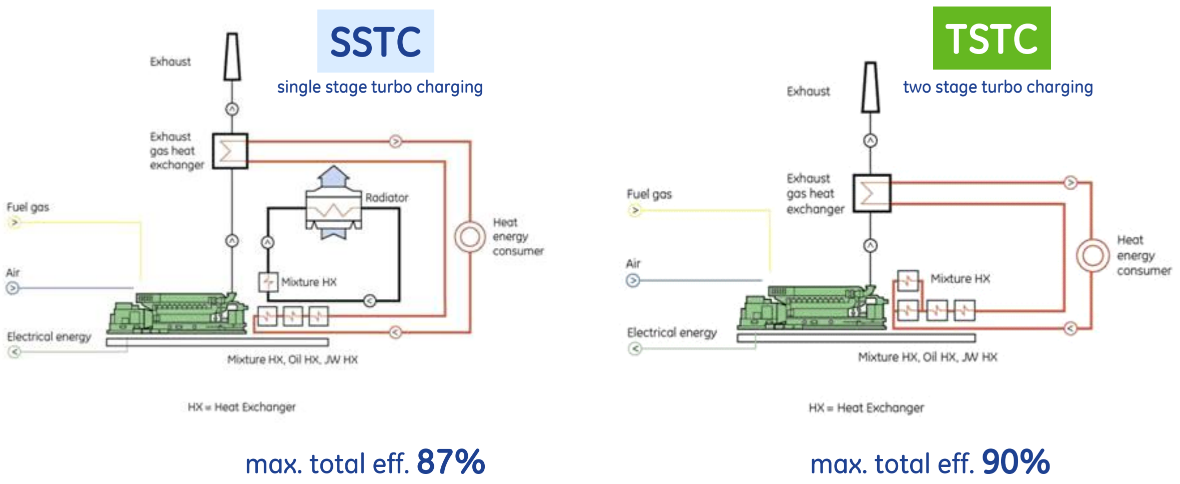

Figure 7: CHP Concept with single stage (SSTC) and two stage (TSTC) turbocharging and 70/90°C water temp

Greenhouse Concepts:

The greenhouse concept based on Jenbacher gas engines is a very attractive concept providing power, heat and CO_2 as fertilizer for greenhouse crop production. Using the CO_2 from the exhaust of the gas engine the CO_2 concentration inside the greenhouse can be increased from around 350 ppm to approx. 1,000 ppm. With this higher CO_2 concentration the productivity of the crops can be increased by 20-30%. This kind of CO_2 augmentation is used to grow vegetables like peppers, tomatoes or cucumber. Today most of our greenhouse applications can be found in the Netherlands where GE's Jenbacher gas engines have installed more than 1.5 GW, representing more than 10 % of the installed capacity on the Dutch grid.

The greenhouse application goes together with Ultra-low emissions on NOx, CO, C2H4. Before the exhaust gas is used in the greenhouse, a special exhaust cleaning system is reducing NOx emissions to less than 25 ppm (based on 5% O_2) and reducing CO emissions by more than 99% - Figure 8.

With a simultaneous supply of heat, electricity and CO_2, a very high fuel efficiency of up to 95% is achieved. Due to the use of heat storage tanks the application allows more independent power and heat production, which makes the greenhouse concept even more attractive when operating in a liberalized energy market.

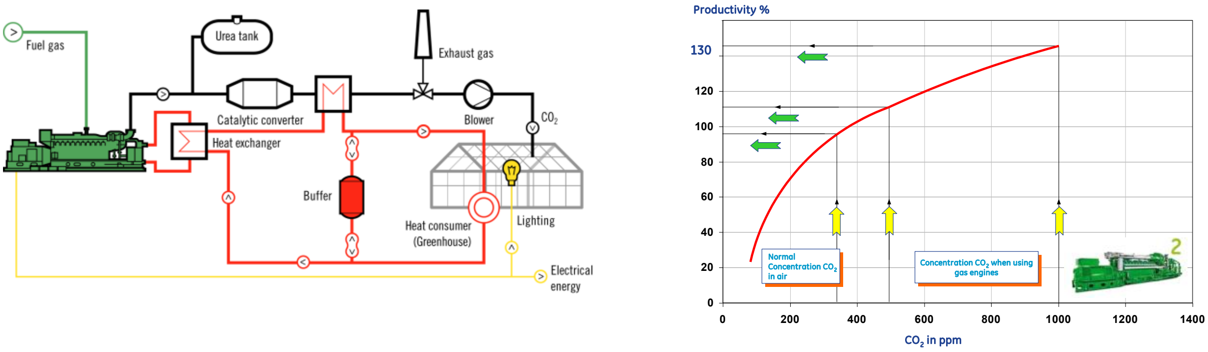

Figure 8: GE's Jenbacher gas engine greenhouse concept

Multiple gas engine power plants:

Either for combined heat and power or power generation only, multiple gas engines offer several customer advantages. Due to multiple installed generating units, higher plant availability is achieved and plant output is reduced only by the incremental output - depending on the number of engines installed – in case one engine is down for maintenance. The J624 with multiple units installed offers a very compact power plant design (Figure 9). The centreline distance between engines is only 4.5 m and radiators can be placed on the rooftop of the building to reduce the required land. If the plant is a combined heat and power plant, only an additional exhaust heat exchanger is required and can be placed aside the engine or on a second floor of the engine room.

Starting from a pre-heated engine, the J624 offers a 5 minutes start-up time from initial to start to full load. Multiple engines can be started in parallel. The short start-up time makes gas engine power plants a preferable solution for frequent start stop operations and offers best in class load following capability.

Additional advantage of a multiple gas engine power plant is the high plant part load efficiency. Starting from a high simple cycle gas engine efficiency, the efficiency stays high in part load operation due to incremental engine shut-down. Only the number of engines are online and running that are required to meet the target plant output, and those engines are running at full load, hence at maximum efficiency (Figure 10).

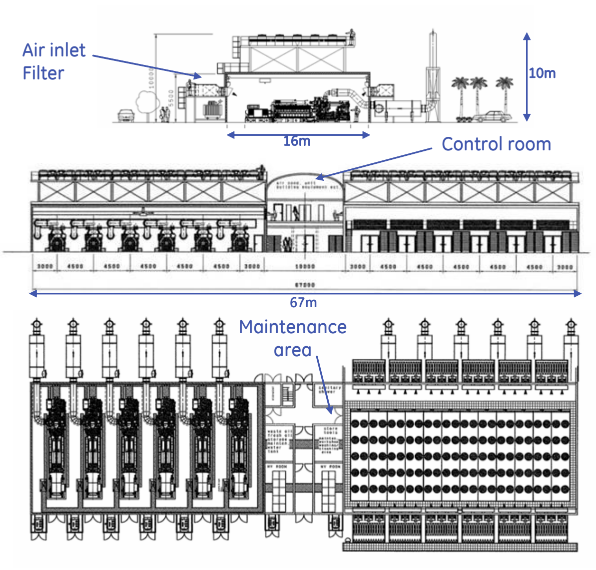

Figure 9: 50 MW multiple gas engine plant example

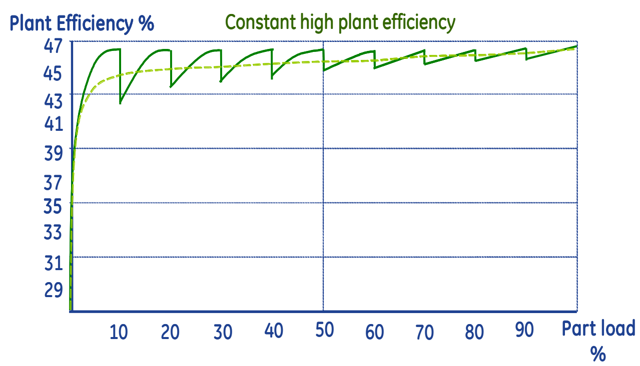

Figure 10: Multiple gas engine plant efficiency

SUMMARY

2-stage turbocharging is the enabling technology for higher specific output, higher efficiency and higher heat output of gas engine power plants. The new J624 underlines this with an electrical efficiency of 46.5 % at 4.4 MW power while meeting TA Luft emission requirements. 2-stage turbocharging implemented in the new J624 makes it the starting point of a new generation of GE gas engines. Testing the engine at a factory test stand and the staged field introduction of the above-mentioned technology allows a reliable field validation of single features and minimizing customer risk.

Combined Heat and Power Plants are typical and very favourable applications for gas engines. The straight forward plant concept and easy installation results in short installation times and reasonable installation costs. The J624 offers another great benefit in regards of transportation and installation. Due to the compact design, the engine can be transported with a standard truck and does not require expensive heavy equipment handling.

Multiple engines offer a big advantage because of redundancy and when the plant needs to achieve part load operation. At plant part load, engines can be shut down as required and can start-up again in 5 minutes, if required. The new J624 is also a very favourable engine for special applications like the greenhouse application.

Improving electrical and total efficiency is important to save the cost of electricity and it is essential to reduce CO_2 emissions in a carbon constrained environment. The new J624 with 2-stage turbocharging meets both requirements.

REFERENCES

[1] Payrhuber K., Chvatal D., Trapp Ch. The new J920 Gas Engine, PowerGen Europe 2011

[2] Payrhuber K., Kramp D., The new Jenbacher J624 gas engine with 2-stage turbocharging, Russia Power 2011

[3] Laiminger S., Trapp Ch., Schaumberger H., Fouquet M., Die nächste Generation von Jenbacher Gasmotoren von GE – die wegweisende Kombination von zweistufiger Aufladung und innovativen Brennverfahren, Dessau Gas Engine Conference 2011

[4] Trapp Ch., Laiminger S., Chvatal D., GE Jenbacher GmbH & Co OHG, Jenbach; ao. Univ.-Prof. Dr. A. Wimmer, Dr. E. Schneßl, Dr. G. Pirker, Technische Universität, Graz, Die neue Gasmotorengeneration von GE Jenbacher – mit zweistufiger Aufladung zu höchsten Wirkungsgraden, Internationales Wiener Motorensymposium 2011

[5] Payrhuber K., Schneider M., Advancements on GE's Jenbacher Type 6 Engines, PowerGen Europe 2010

[6] Payrhuber K., Trapp Ch., Zweistufig Aufgeladener Gasmotor, Energie 2.0-Kompendium 2011

[7] Trapp Ch., Klausner J., Lang J., J624 – der weltweit erste Gasmotor mit zweistufiger Aufladung, MTZ 2011

[8] Trapp Ch., Klausner J., Schaumberger H., Lang J., Haidn M., GE Jenbacher Gas Engines, CIMAC 2010