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## 25MW Class Modern Industrial Gas Turbine Suitable for Wide Range of Applications in CoGen/CC Power Plants

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### Abstract

The GT10 25MW class industrial gas turbine from ABB has seen a rapid success in power as well as heat generation for utilities, district heating plants, refineries, communities, universities, paper & food, cement and petrochemical industries.

This broad application attests to the versatility of a modern gas turbine benefiting from advanced technology concepts in combustion, as well as turbine component efficiencies. The paper will review these developments and some interesting applications that could benefit dispersed industrial power plants in the fast developing economies of South East Asia.

### GT10 Improvements

The GT10B at current rating of 24,630kW at ISO conditions with simple cycle efficiency of 34.5% is a result of some important technology adaptations in 1990 and in 1992. The GT10 was the first small industrial gas turbine to have the dry low NO<sub>x</sub> (DLN) lean pre-mix EV burner incorporated in a compact annular combustor. Fig 1.

### EV Burner

The EV double cone low NO<sub>x</sub> burner proven in larger silo combustors was specially adapted to the annular combustor and forms an integral part of the combustor.

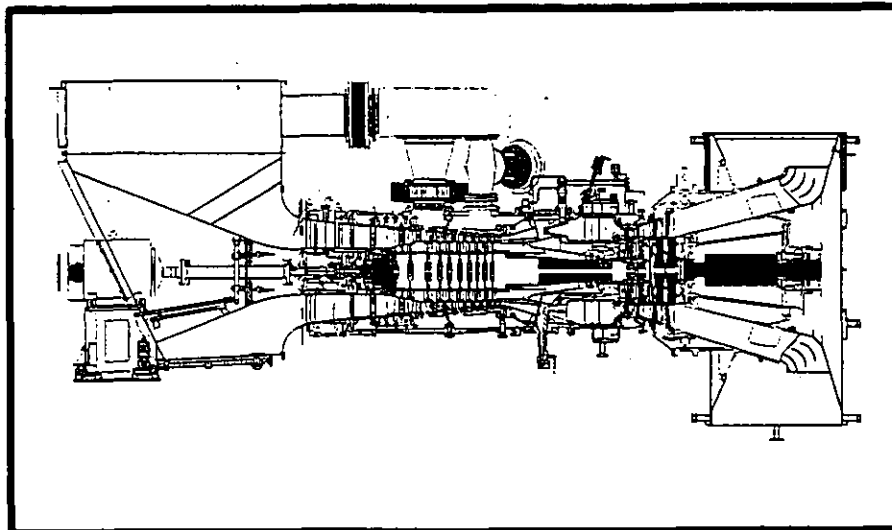
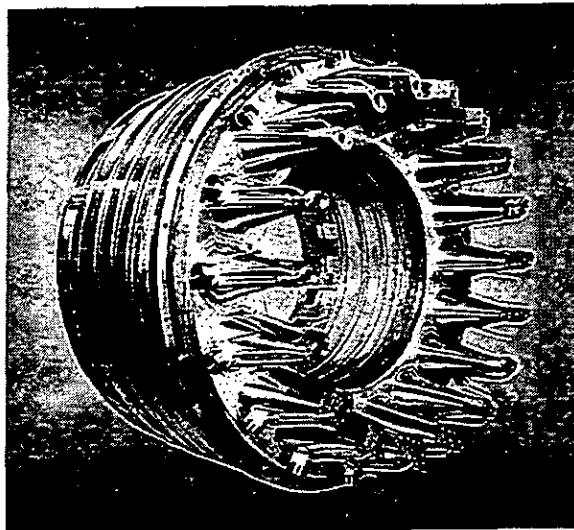


Fig. 1: GT10B. Modern Industrial Gas Turbine

Fig 2 shows the combustor assembly with the integrated EV Burners (18). For the compact combustor the EV burner was modified to incorporate a pilot burner nozzle to enrich the fuel mixture for start - up and lower power ranges. As most of the air passes thru the EV double cone, the very lean mixture under these circumstances require a pilot flame. The cooler flame core temperature which results in low  $\text{NO}_x$  emissions, also extends the combustor life. The first units installed in Sweden at Angelholm and Lund were tested at 15 vppm at commissioning and verified during service by official measurements.



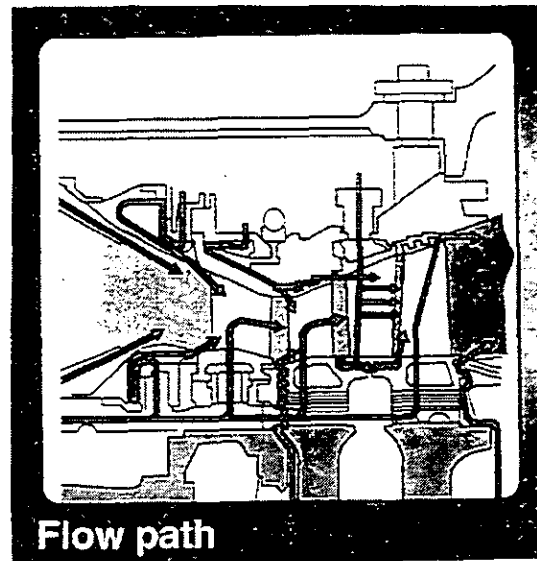
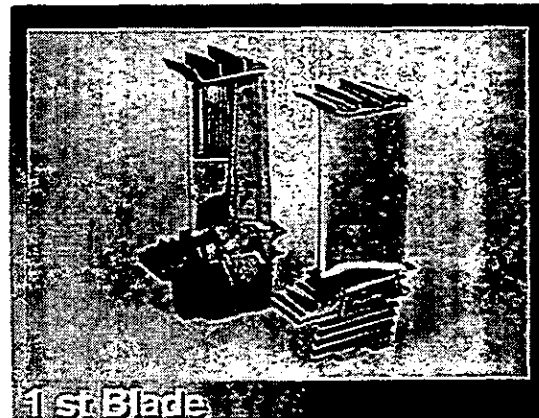
**Fig. 2: Dry Low  $\text{NO}_x$  (DLN) EV Combustor Assembly**

This break-through in combustion technology on a 22MW Gas Turbine was remarkable and set the stage for further improvements now possible in the turbine section. With only 7% of the air passing into the combustor as dilution air vs 35% before, increasing the turbine inlet temperature was the next logical stage.

#### Turbine Modifications

The upgraded engine, the GT10B was introduced in 1992 for a CHP plant in Antwerp to be operational in May of 1993. The turbine inlet temperature (TIT) was increased from  $1062^\circ\text{C}$  ( $1944^\circ\text{F}$ ) to  $1112^\circ\text{C}$  ( $2033^\circ\text{F}$ ), through the use of advanced materials, in the compressor and HP turbine, as well as coatings on the rotating blades and stationary vanes for

oxidation protection. Fig. 3 is an illustration of the two stage HP turbine, with air-cooled vanes and blades.



**Fig. 3: Air Cooling of Blades & Vanes of GT10B Compressor Turbine**

To optimize the unit performance, the two stage 7700 rpm overhung design power turbine, was equipped with new blades with advanced profiles scaled from ABBs larger units. The objective was to improve the gas flow, i.e. lower losses. This also required replacing the wire lacing blade design with integral shrouded blades and honey - comb seals. This reduced tip leakage as well. The combined benefits resulted in a modern machine of 24,630kW rating and efficiency improvement to 34.2% from previous 33.0%. More importantly with the exhaust temp

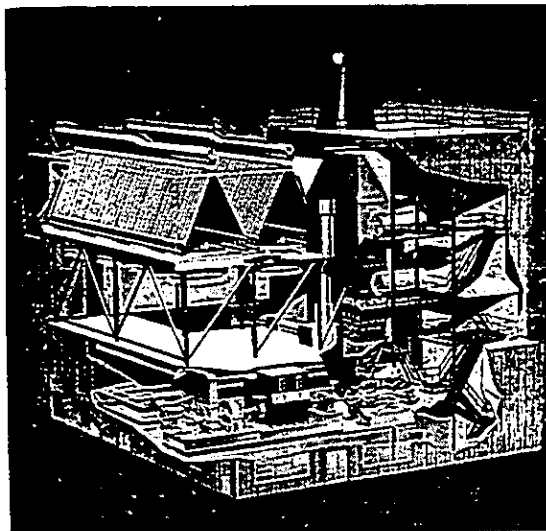
(TEX) now at 534°C (993°F) from 506°C (943°F), improved CC small power plants for co-generation application could be planned.

**Single Shaft GT & ST CC Co-generation Power Plant**

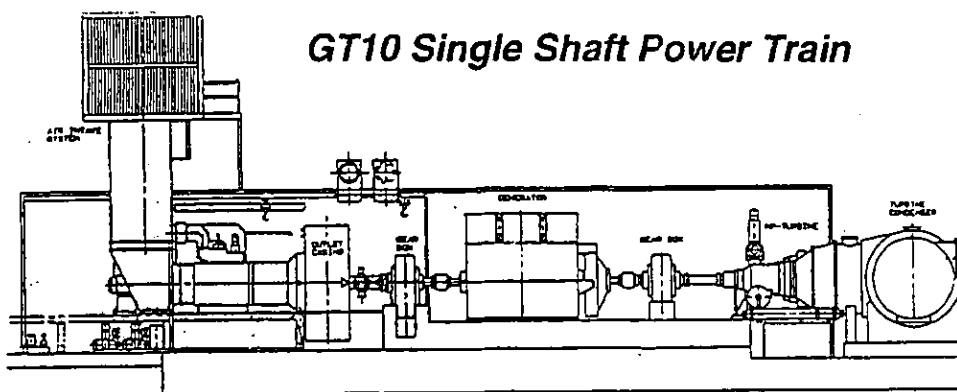
With the improvements of the GT10B, the first to go in operation in the Spring 1993 more than 20 of the GT10 single shaft combined cycle co-generation plants were committed in under two years. One of the more attractive innovations introduced, was to install the machinery train on a common floor level concrete foundation. The single common generator is mounted in the center with the GT10B driver at one end via a speed reduction gear, and the other end steam turbine driven via a reduction gear and a self-shifting synchronizing - clutch (SSS). Fig 4 The generator speed is 1500 rpm (50HZ) while the GT and ST are 7700 rpm & 8400 rpm respectively.

The first units of this Single Shaft (SS) compact arrangement were selected by the Netherlands Utility PNEM to operate as CC co-generation units to deliver power to the public electrical network, as well as co-generate process steam to the respective factories at Den Bosch (Heineken

as well as CO<sub>2</sub>, being one of the National Environmental objectives, there is also a benefit of low water consumption with the use of Air-Cooled Condensers, which are designed to take the full HRSG steam flow with steam HP & LP bypass/reducing stations, so that the plant could operate with the GT only, no process steam, and the ST disconnected via the SSS clutch. Fig. 5



**Fig. 5: SS GT & ST CC Cogeneration Power Plant at Den Bosch**



**Fig. 4: Single Shaft GT & ST Power Train**

Brewery) and at Helmond (Prumest Works). These units required no steam or water injection for NO<sub>x</sub> reductions, provided overall thermal efficiencies of 70% and electric efficiency as high as 48%. The emissions reduction of NO<sub>x</sub>

The flow schematic Fig. 6 of the water/steam cycle, shows a 2 pressure boiler providing 54 & 5 bar (760 psi) and (71.0 psi) steam at 500°C and 200°C (932°F) and (372°F) respectively, process steam from the ST LP section could vary

from 0 to 9.7 kg/sec (21.4 lb/sec) at 13.5 bar (192 psi) i.e. up to 90% of the HRSG steam flow. The ST is capable of 10MW in the full condensing mode, achieving 48.5% net cycle efficiency.

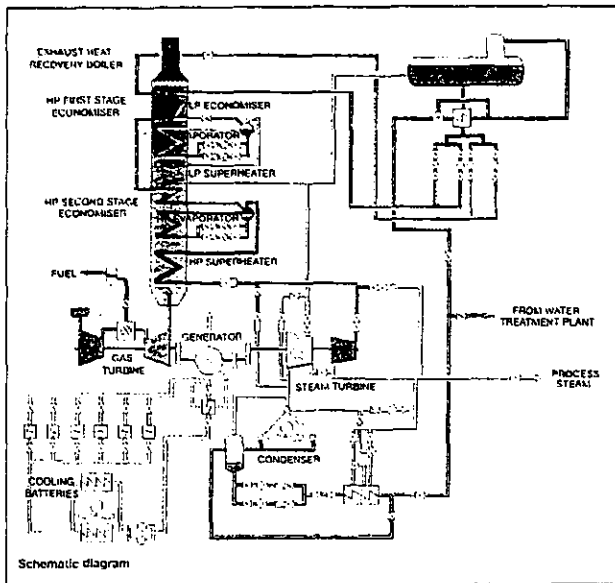


Fig. 6: Flow Schematic Water/Steam Cycle Single Shaft CC Plant

### Benefits in Changing Markets

The specific cycle illustrated is only one example of the flexibility of SS (Single Shaft) - small combined cycle plants where standardization, is blended with cycle optimization for specific projects depending on the process requirements for a wide range of industries such as food, breweries, chemicals, refineries, small town district heating or the heating - requirement of universities, etc.

While several other cycles of interest could be examined, the same benefits will accrue, where technology gains result in compact power plants, with low emission and good fuel utilization. These benefits can be summarized as follows:

### Compact Power Train

- SS Arrangement
- One Generator
- One Electrical system
- Floor Mounting
- Easy access for maintenance

### Compact Power Plant

- HRSG Vertical Mounting Over GT Exhaust Collector
- Air Cooled Condenser Above Machinery Train

### Modern Industrial GT

- DLN Combustion 15 vppm NO<sub>x</sub>
- No Water Consumption 5 vppm CO
- High Efficiency
- Good Exhaust Exergy
- Good Steam Production/Power/Process

### ST - Extraction Condensing

- Single Casing HP & LP
- Full Condensing
- Thermally Flexible/Rapid Start/Load Ramps

### Operational Flexibility

- Simple GT Fuel Input Control
- ST Fixed HP Steam Pressure
- GT/CC Cogen Mode - Process Steam as Needed
- GT/CC Mode (HP & LP Bypass)
- GT only (ST Disconnect Via Clutch)

Different climatic and site specific conditions will define the overall power plant performance, such specifics as type of condenser cooling (cooling tower, once through, dry etc.) will also have some influence, the basic concept of a 30 to 35 MW CC plant as a single shaft machinery train remains unchanged, and can be readily adapted in a variety of industrial power generation applications.

While the larger power plants in South East Asia are being built at a rapid rate to meet the growing capacity needs, there are clear economic opportunities for smaller process industries to benefit from the concepts and example illustrated. One such installation using the GT10B in Singapore at the Petrochemical Corporation of Singapore LTD. The first for this class of low emissions, high efficiency plant, may just pave the way for other similar industries to expand within the large national demand for electric power.

### GT10B Inspection & Maintenance Intervals

Smaller industrial engines such as the 25MW GT10B are subjected to recommended preventive maintenance inspections, these borescope and other routine observations, at 10,000 hr periods, are of short duration 2-3 days. This procedure would result in a required minor overhaul scheduled at 40,000 hrs (10-16 day outage) for the replacement of 1st & 2nd stage turbine blades, which are removed for renovation. Major overhaul will occur at 80,000 hrs for a similar expected down time of 10-16 days. These figures are better than those for large frame machines, and increases the overall availability of these smaller plants. If the down time is considered critical, the gas generator (Compressor & Compressor Turbine) can be changed out by the use of a spare or leased gas generator. This might be the case for critical process plants where it is not desirable to have an outage of 2 weeks.

### Conclusion

Since 1993 the smaller Industrial Single Shaft Combined Cycle units have demonstrated their viability in co-generation and heating plants. This experience with the latest units of this type going commercial in 1995, with demonstrated low emissions, high reliability and availability, a direct benefit from technology investment, provides the assurance to potential users to look at efficient small co-generation power plants to meet their specific needs. Such dispersed generation plants benefit the distribution grid, with the added benefit of economic fuel utilization.

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