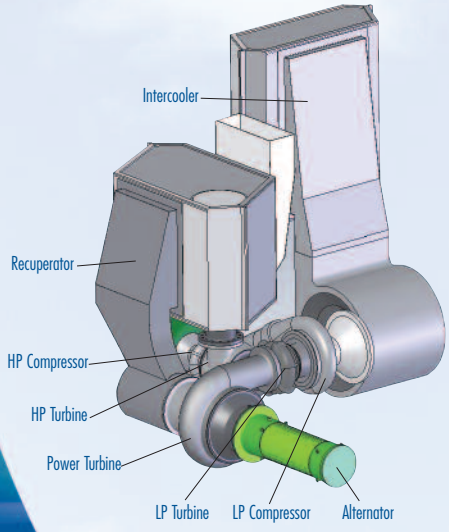
The ICR 225 Vehicle Engine

Gas turbines dominate aircraft propulsion. Major attributes include light weight, high efficiency, high reliability, low maintenance, reasonable cost and low emissions. Yet vehicular gas turbines have only made it into serious production for the military. The challenges have been low efficiency at low power, slow response time and high cost.

Efficiency at high power can be achieved using the Inter-Cooled Recuperated (ICR) cycle. Ceramic turbine wheels have been in high production for turbochargers and can further enhance efficiency. However, the majority of vehicles operate most of the time in traffic or at steady-state highway speeds where power requirements are low. Therefore, efficiency at low power is critical to reduce overall fuel consumption.

The ICR 225 patented cycle gives high efficiency at high power and even higher efficiency at low power. The 225 kW gas turbine operates as a 75 kW gas turbine for low fuel consumption. But it still has all 225 kW available immediately, for rapid acceleration, passing, hill climbing and sustained heavy loads.

The preferred version of the ICR 225 gas turbine drives a generator although a mechanical output can also be used. Electric drives are well proven and the trend is to power auxiliary loads electrically. The system is scalable and can be designed to meet higher horsepower requirements for specific applications.



Performance Specifications

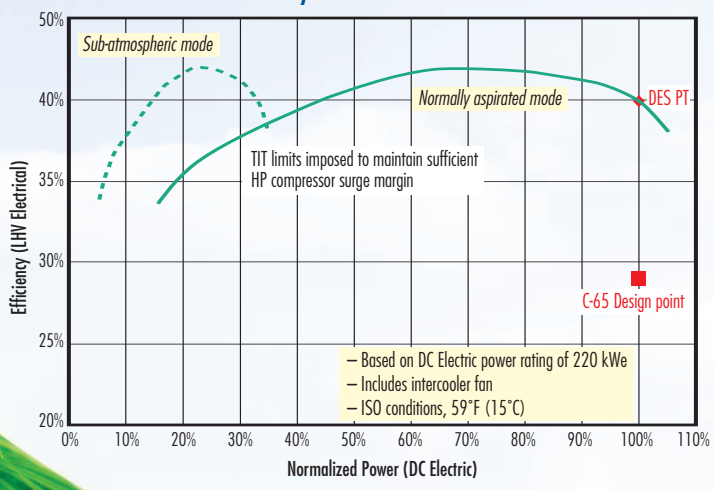
- **High Efficiency**
  - Up to 42% *(see Efficiency Curve below.)*
- **Low Emissions**
  - (Without after treatment)
  - NOx: 0.05 to 0.10 g/hp/hr
  - Particulates: negligible

Status

Basic design & performance analysis are complete. Detail design, prototype fabrication & test unit delivery will take approximately 18 months ARO. Design can be optimized for specific applications.

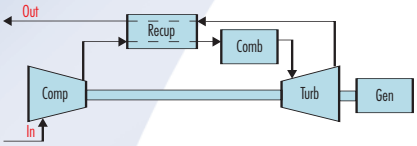
- **Low Cost**
  - Turbocharger-based rotor groups
  - Compact generator
  - Small recuperator
- **Light Weight**
  - Generator set: 1200 lb. (545 kg)
  - Energy storage: lighter & smaller
- **Fuel Flexibility**
  - Diesel, gasoline, methanol, ethanol, bio- fuels, natural gas, propane, hydrogen

Efficiency vs Normalized Power



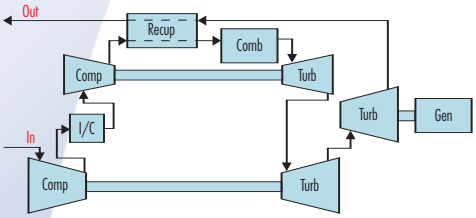
What Makes the ICR 225 Gas Turbine Unique?

The ICR 225 gas turbine generator set provides 225 kW (300 hp) for rapid acceleration, passing, hill climbing and sustained high power. Very efficient in this mode, it uses a patented process to achieve equally high efficiency at 75 kW (100 hp) when the vehicle is in traffic or cruising on highways. The low emissions characteristics of the turbine are well suited to meet 2010 emission requirements.



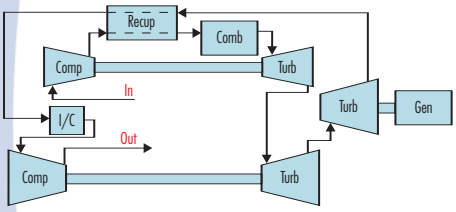
Conventional Microturbine

In a typical microturbine, air is compressed, preheated in a recuperator and heated further in a combustor. The hot gas expands through the turbine wheel that drives the compressor and the generator. The turbine discharge gas then enters the recuperator and preheats the air entering the combustor to reduce the input fuel required.



ICR 225 Gas Turbine at High Power

The ICR 225 gas turbine uses two stages of compression to increase the cycle pressure. An intercooler is employed to reduce compressor temperatures and increase power density. The high pressure ratio increases the temperature drop across the turbine wheels which allows much higher turbine inlet temperatures. Ceramic turbine wheels similar to those that have been mass-produced for turbochargers are used. Variable turbine nozzles control the pressure ratio and mass flow to increase efficiency at part load. The free-floating turbine generator handles step loads through momentum while the two turbine/compressor rotors accelerate.



The ICR 225 Gas Turbine at Low Power

When operating in the critical low power mode, the 225 kW generator set becomes a 75 kW generator set affording exceptionally high efficiencies by reducing the mass flow and keeping the turbine inlet temperature high Air now enters the high-pressure compressor instead of the low-pressure compressor. The mass flow and therefore the power are reduced by a factor of three. The steady state temperatures and shaft speed at 75 kW are the same as at 225 kW, thereby minimizing thermal and mechanical shock. The result is outstanding high efficiency at low power with transition to high power in less than one second. Lower mass flow also reduces pressure drop in the flow path increasing power and efficiency.

Cost

Over ten million turbochargers are produced each year at very low cost. The ICR concept is to use commercially available parts to capture the benefit of the quantity scales that currently exist in the market place. Additionally Capstone microturbines have proven performance with millions of operating hours. When both technologies are coupled together a very highly reliable and cost effective turbine engine is the result.

The ICR Team:

The ICR team includes Agile Turbine Technology, Brayton Energy, and Capstone Turbine Corporation.

Agile Turbine Technology, LLC

Agile Turbine Technology designs advanced vehicle engines. The microturbine-based engines use patented technology to achieve high efficiency at both full load and part load with very fast throttle response. The Agile engines represent the most cost-effective means for meeting efficiency and emission goals on either liquid or gaseous fuels.

Brayton Energy, LLC

Brayton Energy is a research and development firm specializing in turbomachinery, high temperature heat exchangers, and advanced combustion systems. Brayton's experienced engineering team has pioneered many advancements related to microturbines and gas turbines.

Capstone Turbine Corporation

Capstone Turbine Corporation is the world's leading producer of low-emission microturbine systems, and was first to market with commercially viable microturbine energy products. Capstone Turbine has shipped thousands of Capstone MicroTurbine systems to customers worldwide. These award winning systems have logged millions of documented operating hours.

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Capstone® Microturbine Solutions

Agile Turbine Technology, LLC.