IAGT Symposium 2011

Gas Turbine Basics

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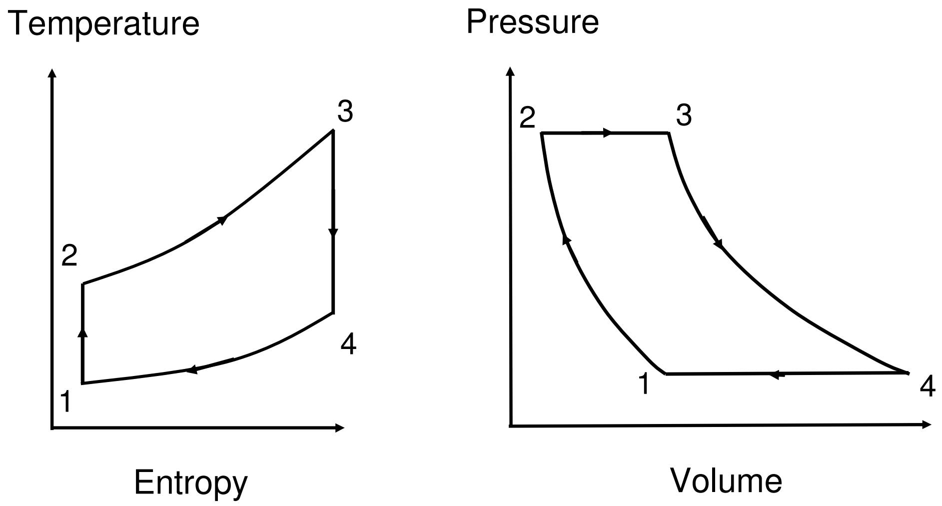
Contents

Rolls-Royce

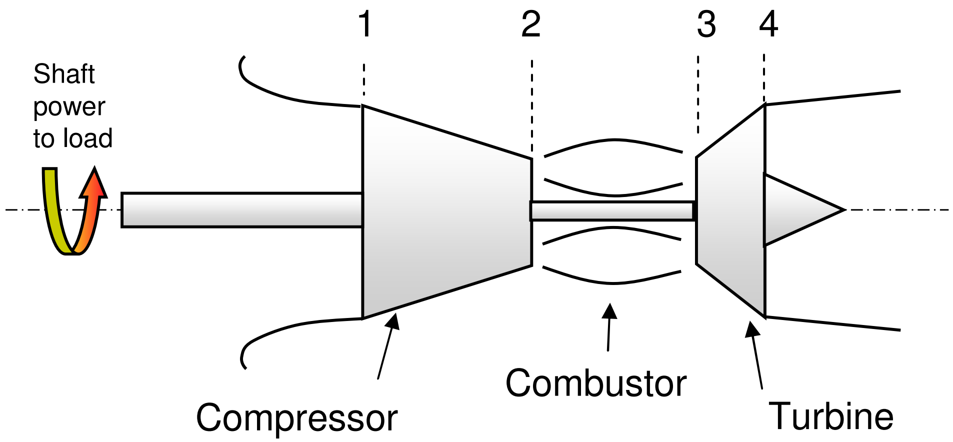
Performance Theory

Simple Cycle Gas Turbine

•Brayton Cycle:
Compression
Constant Pressure Combustion
Expansion



•Characteristics:
High power-to-weight ratio
Simple
Reliable
Low vibration
Low oil consumption



Performance Parameters

Thermal Efficiency

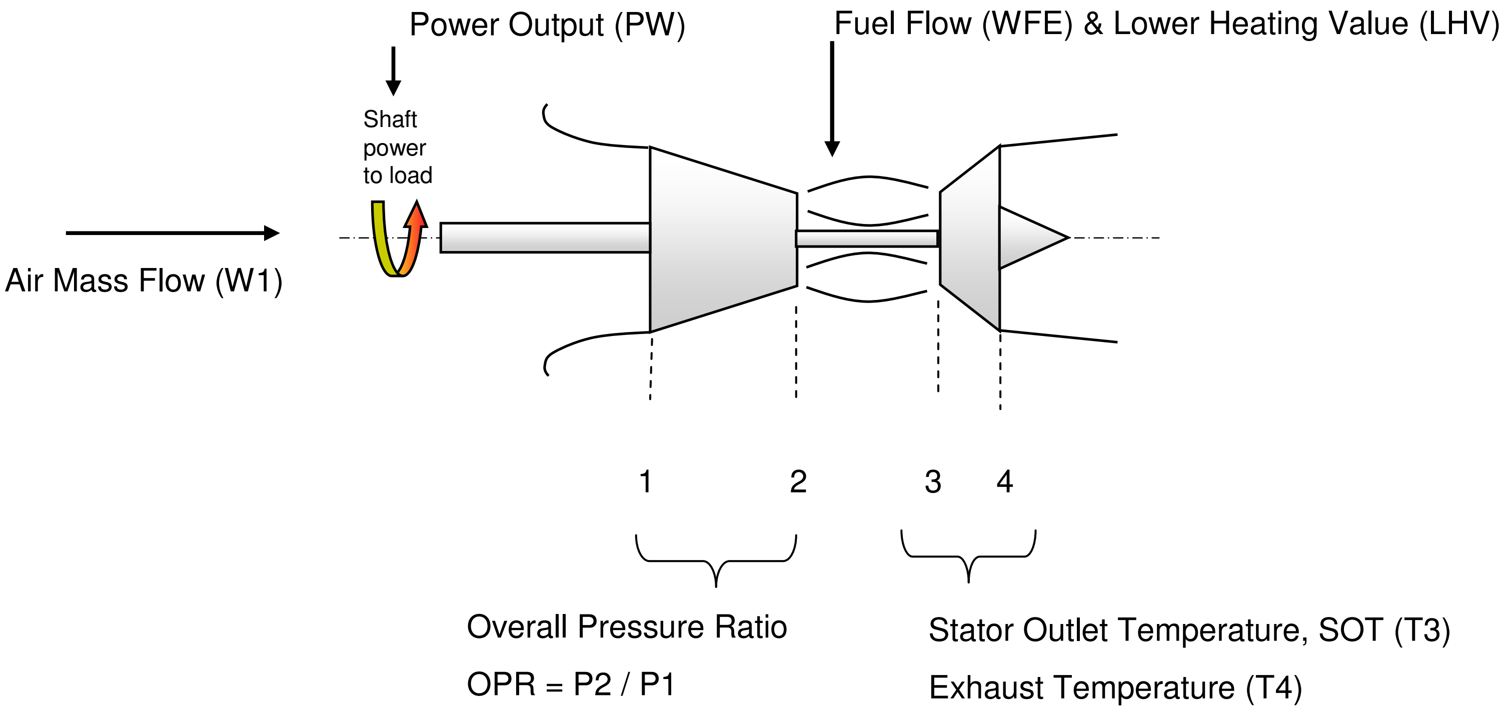
= power output / rate of energy input

= PW / (WFE * LHV)

Specific Power

= power output / air mass flow

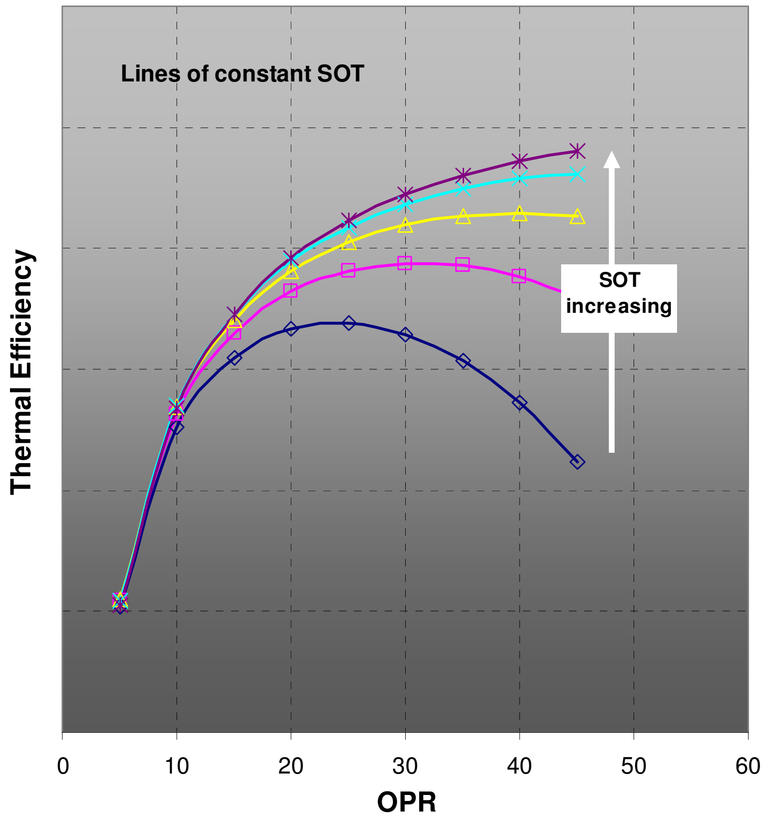
= PW / W1

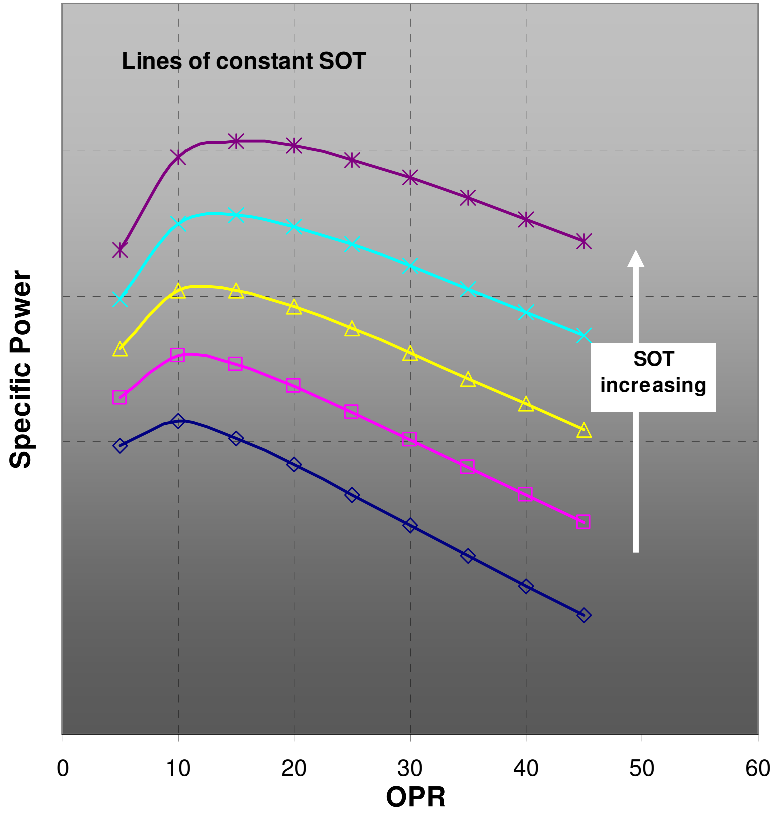


Performance Parameters (2)

- High Thermal Efficiency
  - Reduces fuel consumption
  - Reduces emissions of carbon dioxide
- High Specific Power
  - Requires a smaller engine
- High Exhaust Temperature
  - Important for combined cycle / combined heat & power
- OPR & SOT
  - Engine performance depends on these

Effect of OPR and SOT on Thermal Efficiency and Specific Power

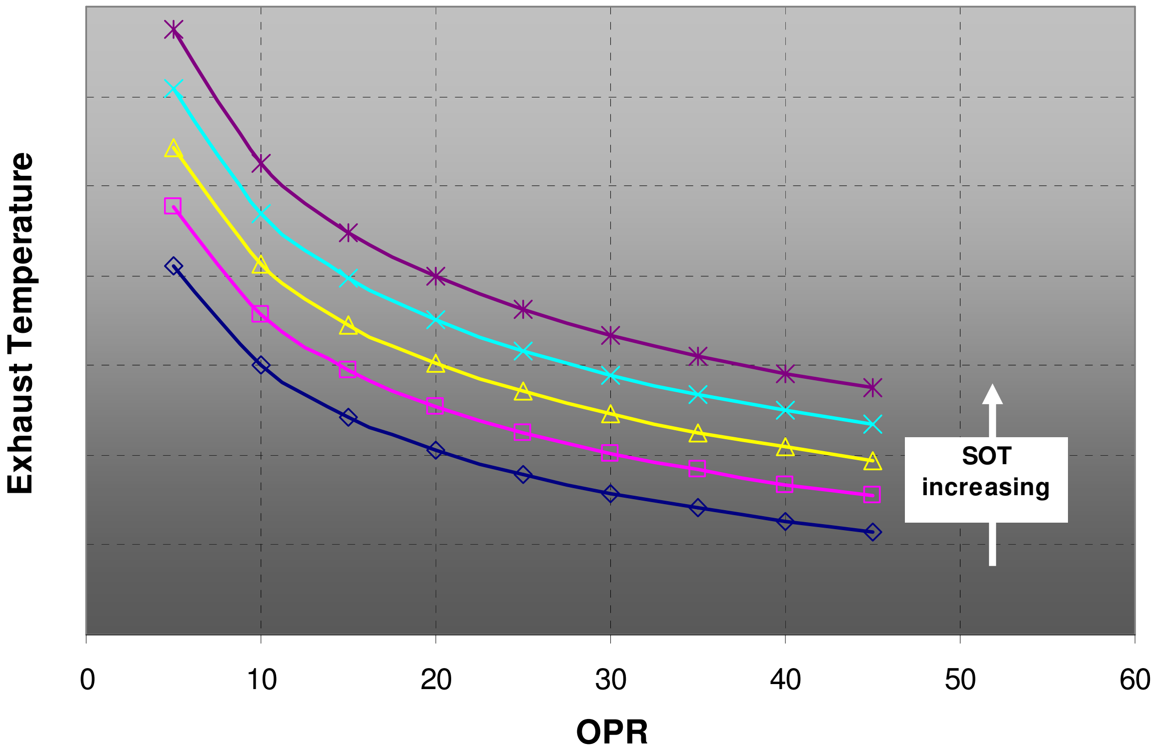




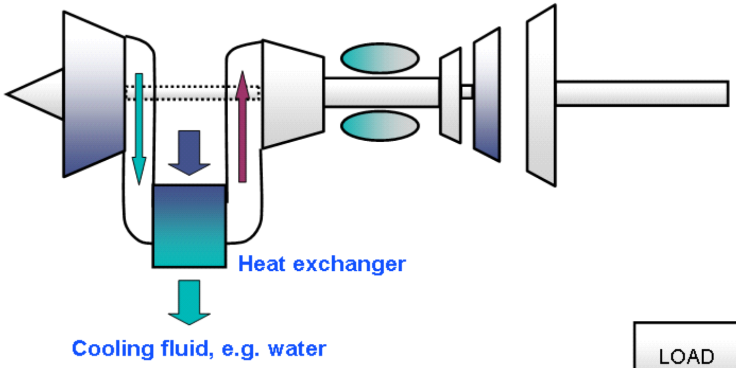
The optimum OPR for efficiency differs from that for specific power - choice of cycle depends on relative importance of each

Rolls-Royce

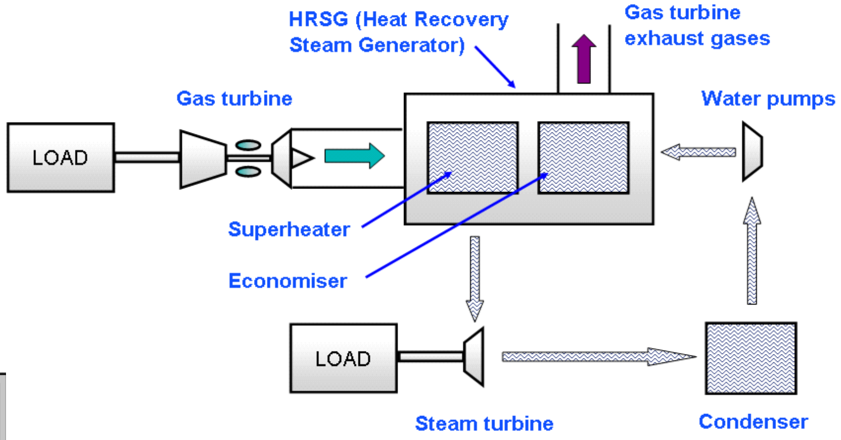
Effect of OPR and SOT on Exhaust Temperature



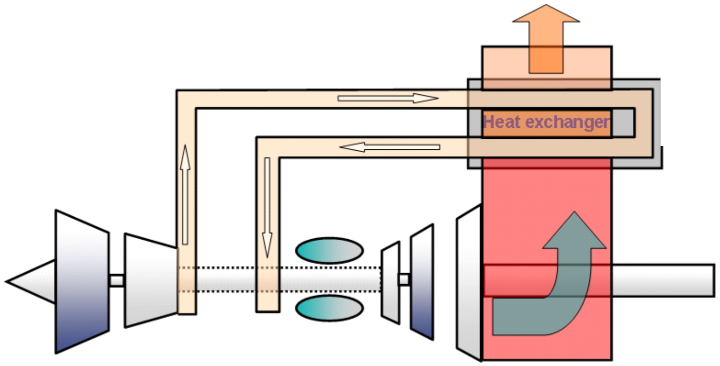
Enhanced Cycles



Intercooled



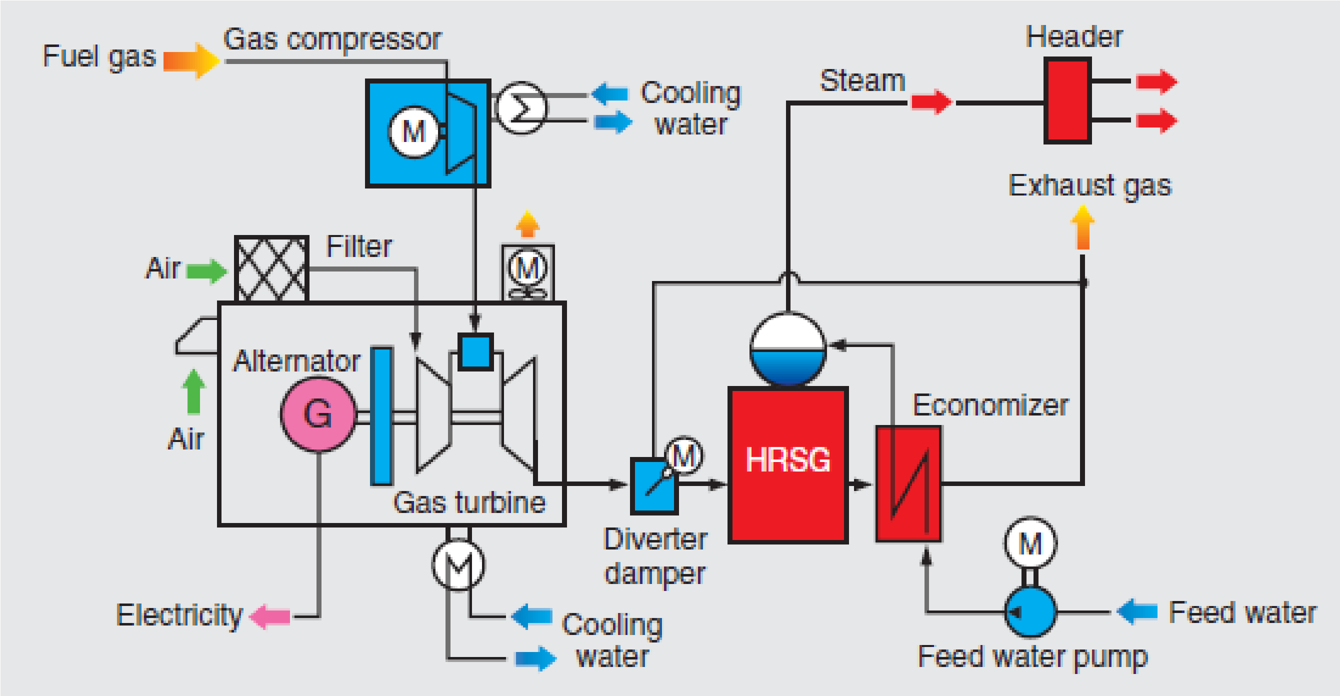
Combined Cycle



Recuperated

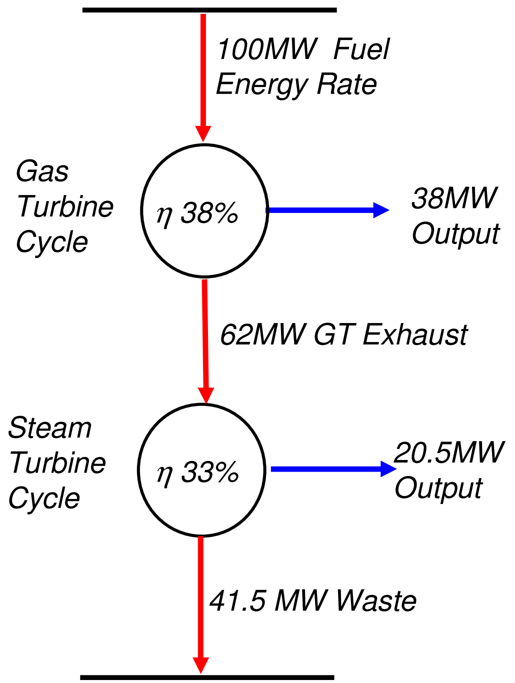
Source – Gas Turbine Performance, Walsh & Fletcher

Combined Heat & Power



Source – Kawasaki, GPB series brochure, Kawasakigasturbines.com

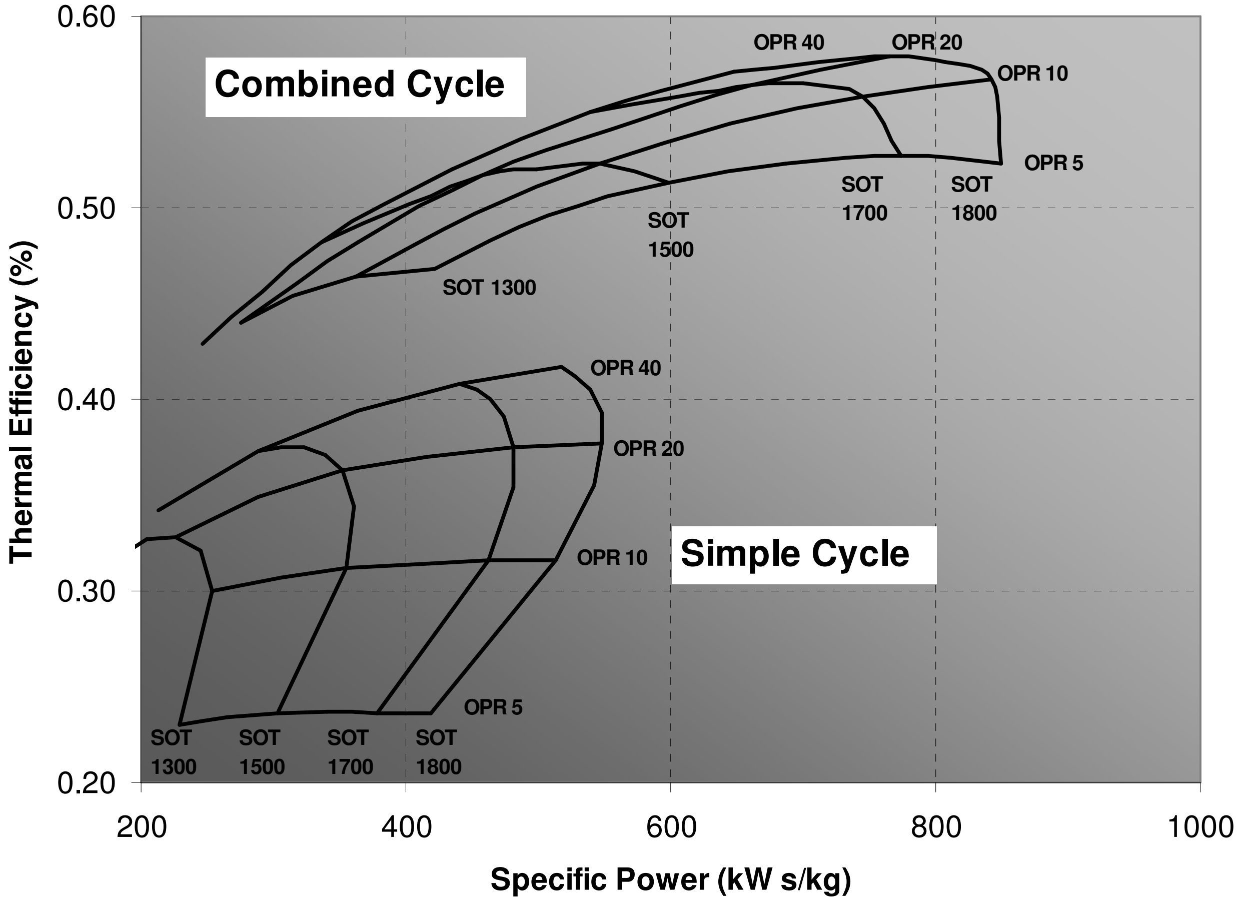
Combined Cycle Efficiency



Overall η *= 58.5%*

Adapted from Encyclopaedia of Energy, Volume 6, Turbines, Gas

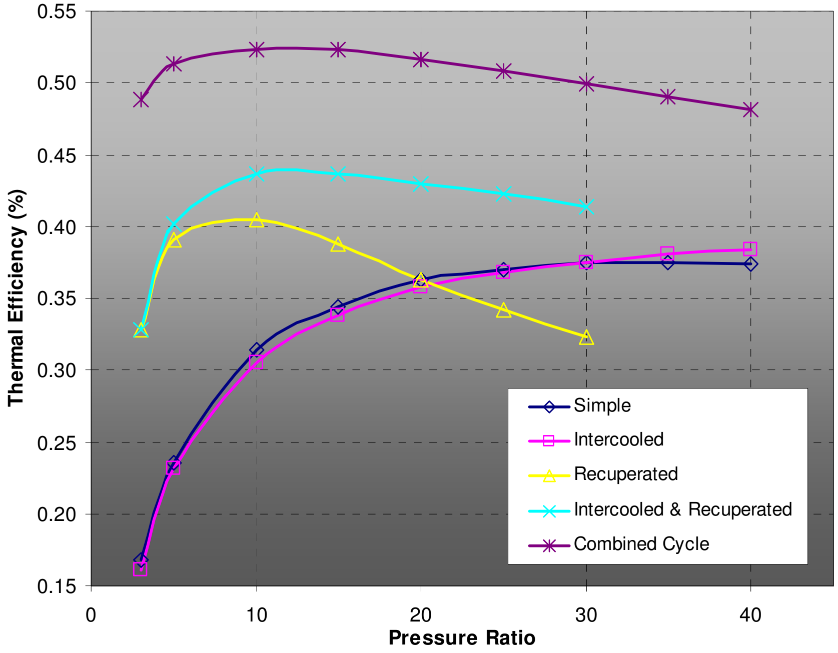
Effect of OPR & SOT on Simple and Combined Cycle Efficiency

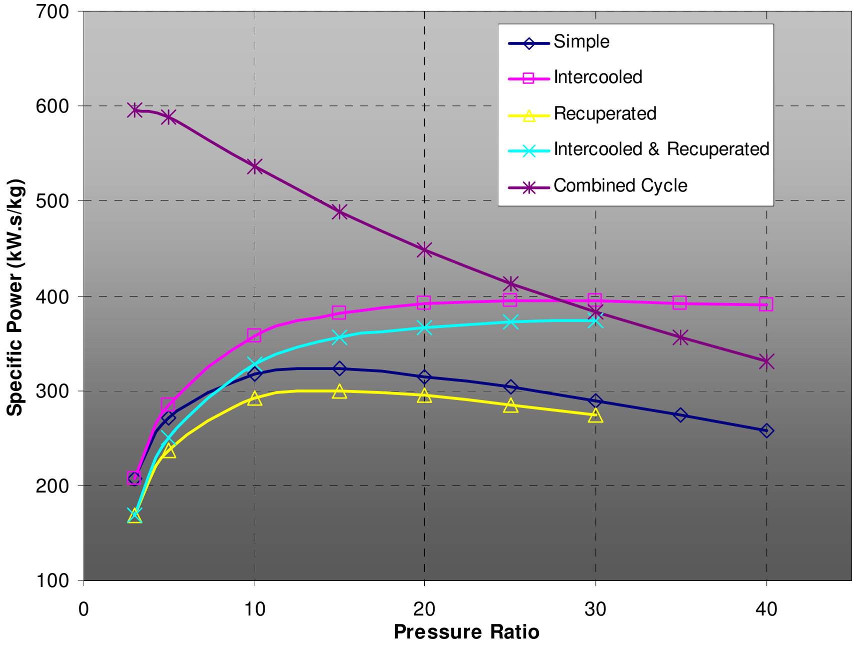


Optimum OPR for combined cycle efficiency is lower than for simple cycle

Adapted from Gas Turbine Performance, Walsh & Fletcher

Enhanced Cycle Performance



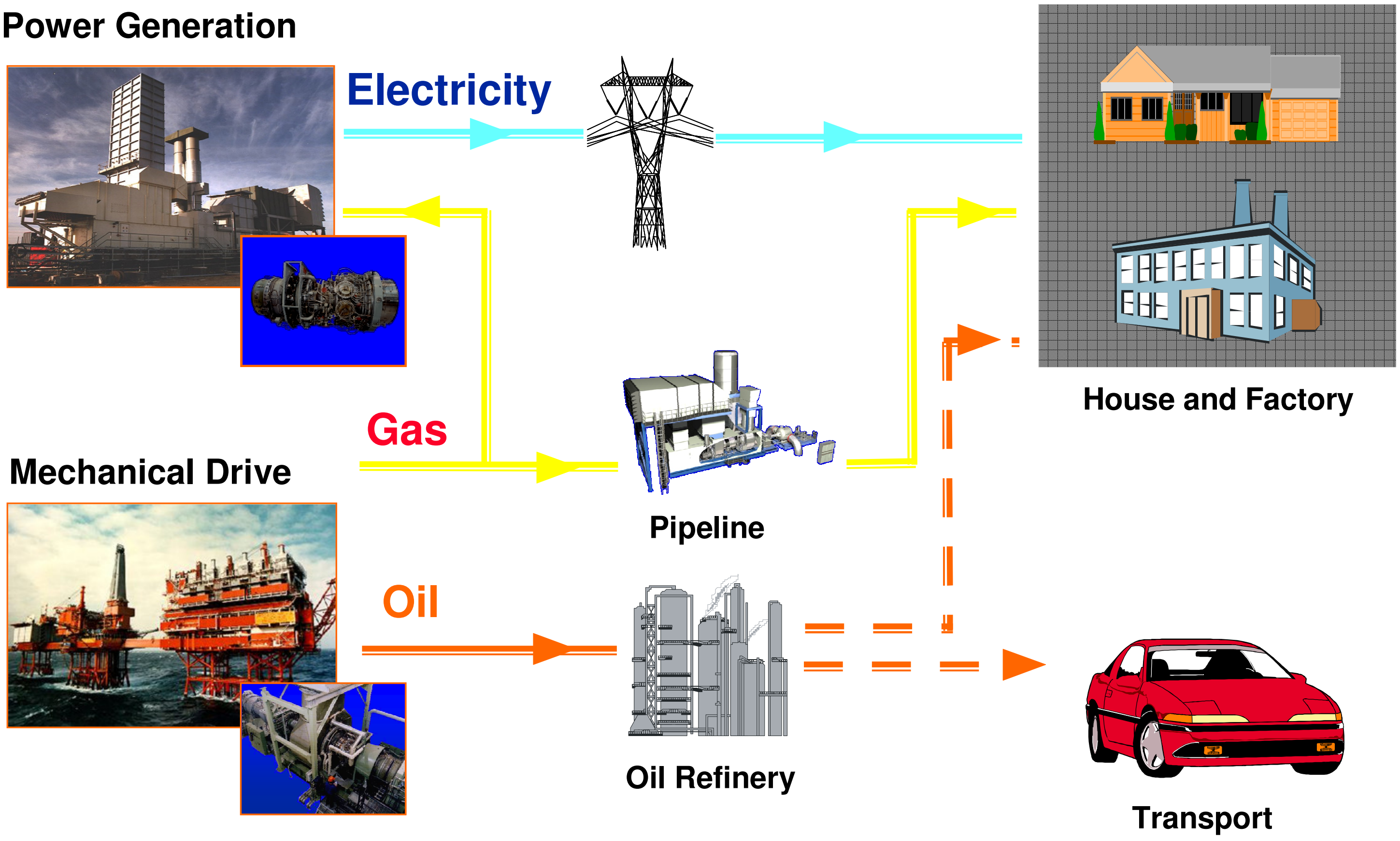


Some significant gains relative to the simple cycle but at expense of complexity and size, especially for combined cycles

Source – Gas Turbine Performance, Walsh & Fletcher

Applications

Power Generation & Mechanical Drive



Adapted from Jet Engines in Energy, Paul Fletcher

Power Generation Applications

Plant type	Examples of applications	Power per engine (MW)
Standby generator	Emergency power supply for office block, hospital	0.25 - 1.5
small scale CHP	Power & heating for hospital, small process factory	0.5 - 10
large scale CHP	Power & heating for town of up to 25000 people or large process factory, exporting electrical power	10 - 60
Peak lopping	Supply to grid during periods of peak demand	20 - 60
Mid merit power station	Supply to grid during seasonal periods of higher demand	30 - 60
Base load power station	Continuous supply to grid	50 - 500+

Source – Gas Turbine Performance, Walsh & Fletcher

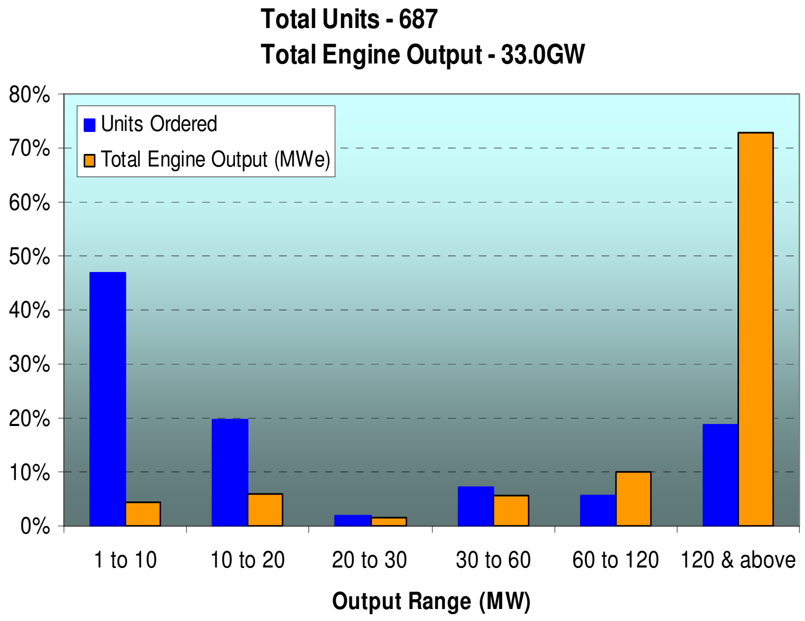
Ratings Definitions

Class	Power Rating	Hours / year	Starts / year
A	Reserve peak	Up to 500	
B	Peak	Up to 2000	
B	ISO standard peak load	2000	500 average
C	Semi-base	Up to 6000	
D	Base	Up to 8760	
D	ISO standard base load	8760	25 average

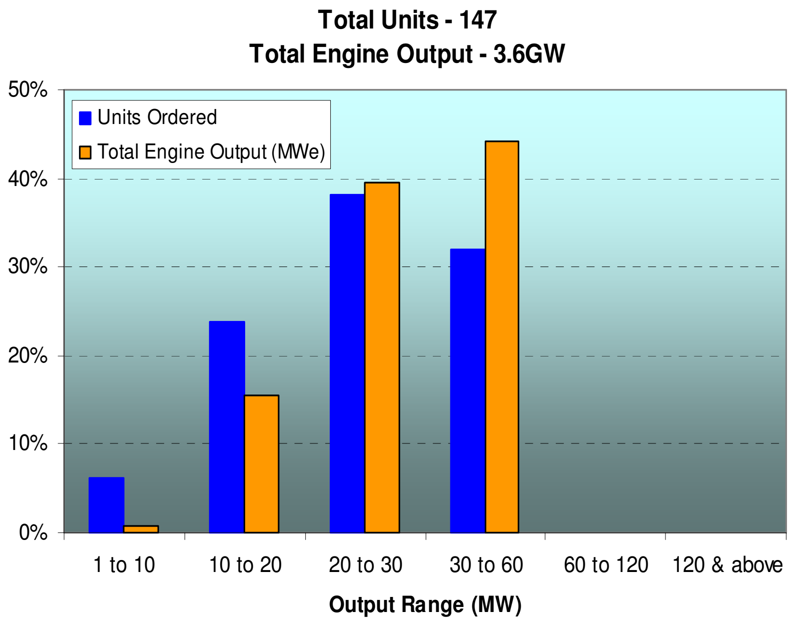
Source – Gas Turbine Performance, Walsh & Fletcher

Gas Turbine Orders - 2010

Power Generation Market



Mechanical Drive Market

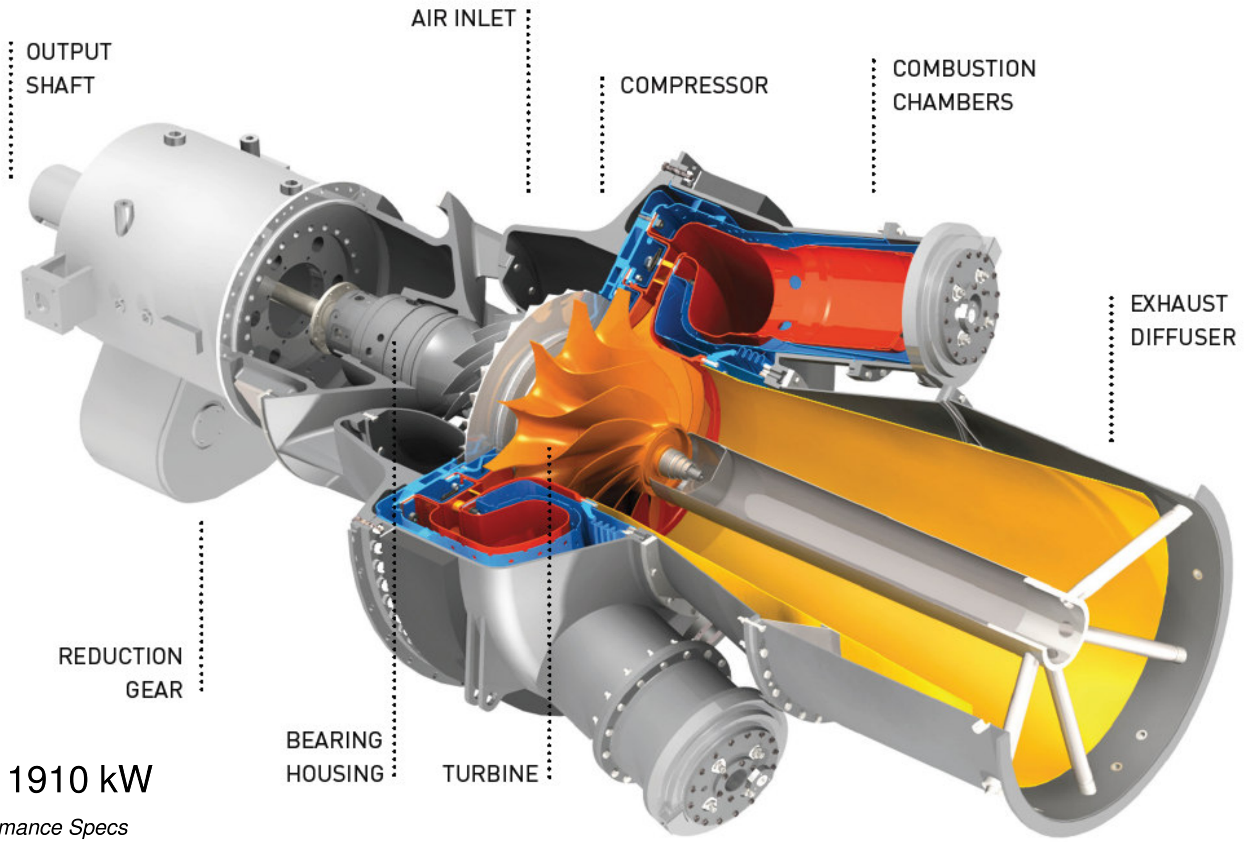


Power generation market is larger and more diverse, in terms of range of power

Source – 2010 Order Surveys, Diesel & Gas Turbine Worldwide

Engine Examples

OPRA OP16 Small Scale CHP Gas Turbine

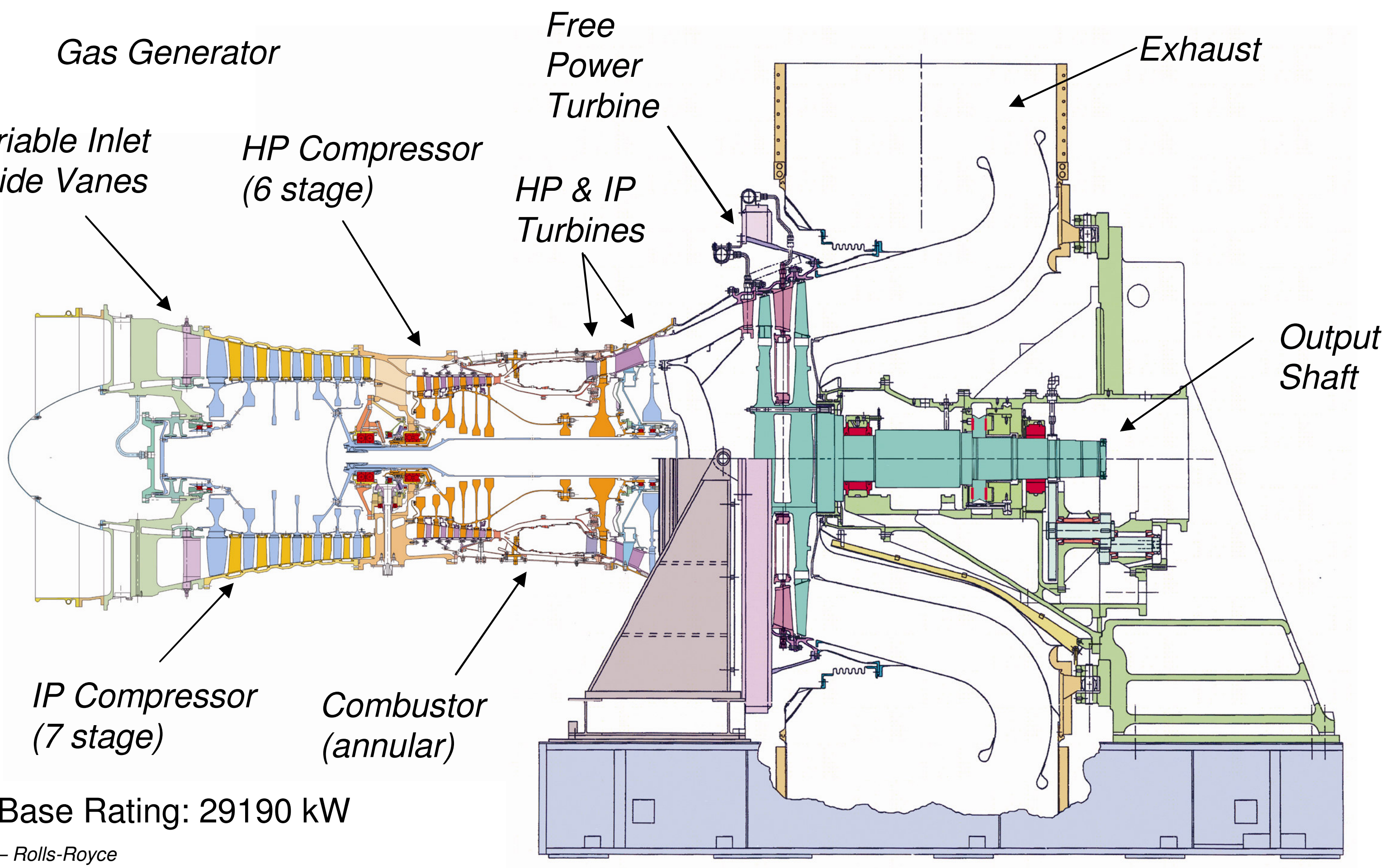


ISO Base Rating: 1910 kW

Source: GT World 2009 Performance Specs

Compact, robust machine, low OPR (6.7) results in relatively high exhaust temperature – suitable for combined heat & power applications

Rolls-Royce RB211-G62 Aeroderivative Gas Turbine

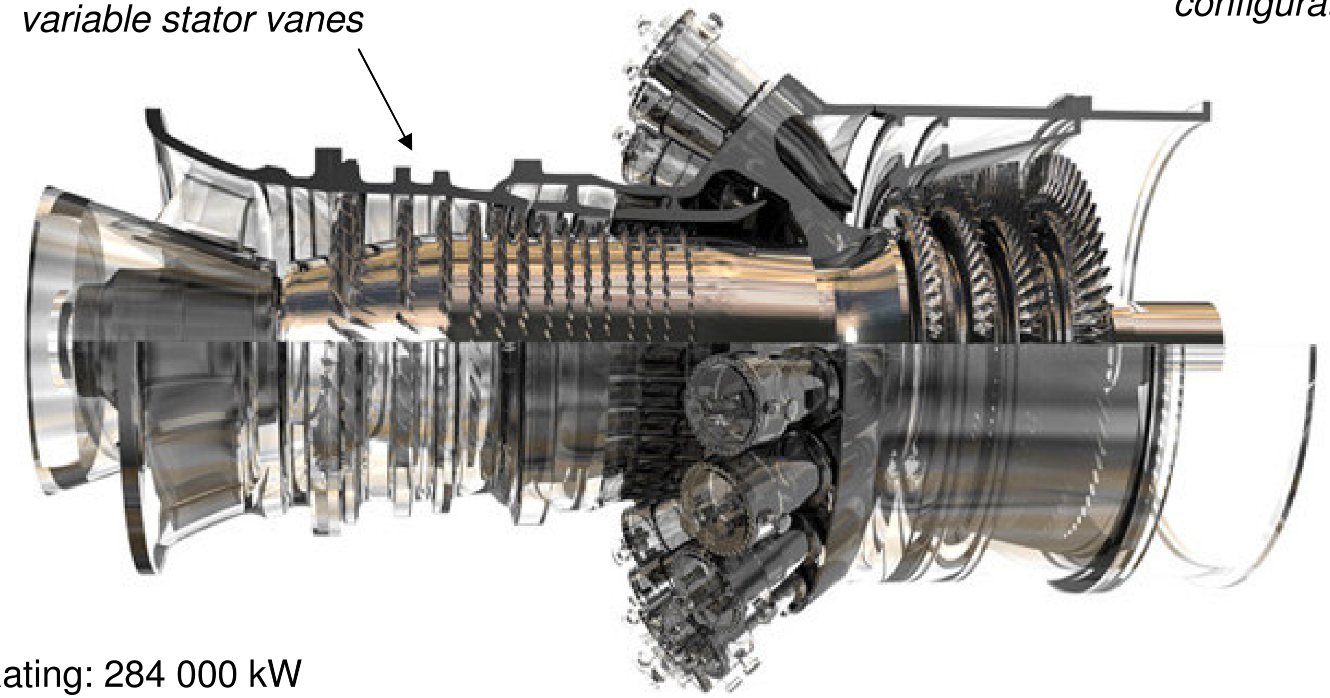


ISO Base Rating: 29190 kW

Source – Rolls-Royce

Flexible operation & high efficiency in simple cycle (OPR ~21), suitable for off-shore power generation, peak lopping & mechanical drive applications

General Electric 9FB Heavy Duty Gas Turbine

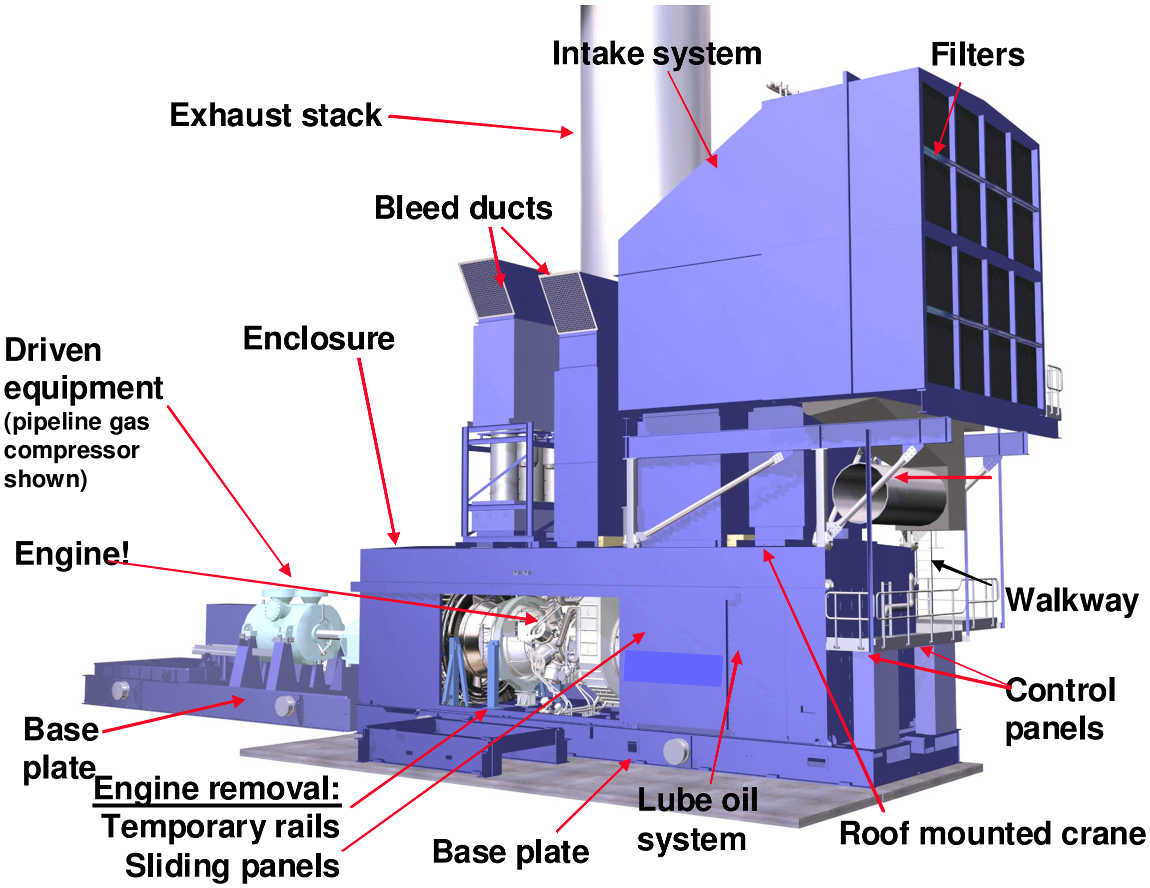


ISO Base Rating: 284 000 kW

Source - GT World 2009 Performance Specs

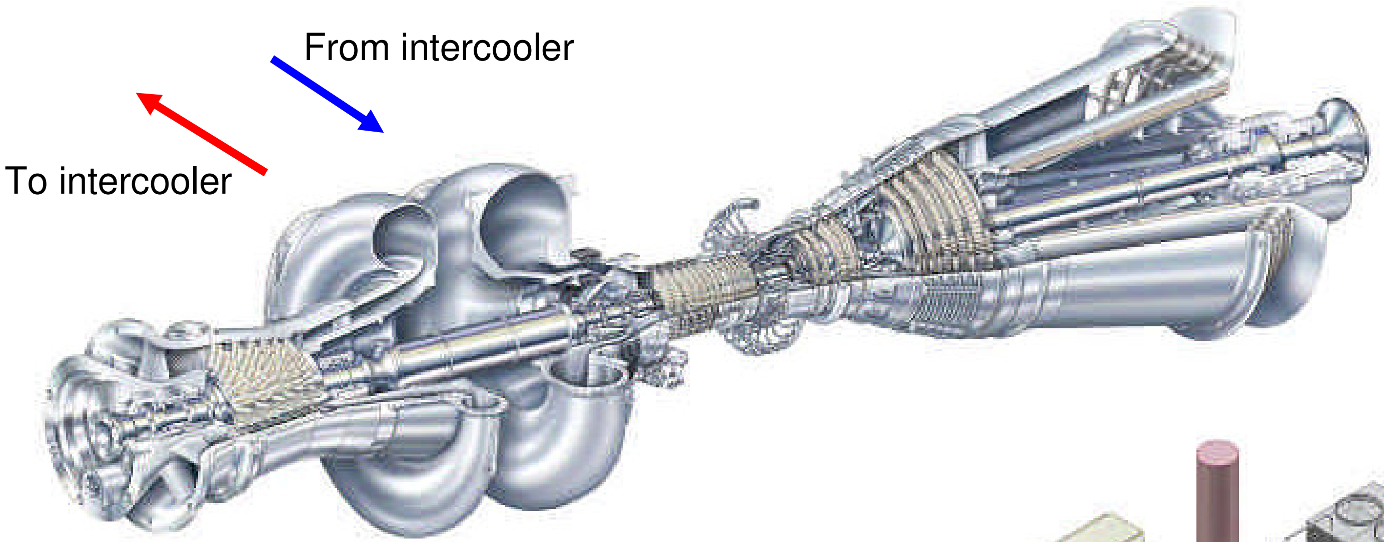
Baseload power generation machine, OPR of 18 - optimised for combined cycle applications

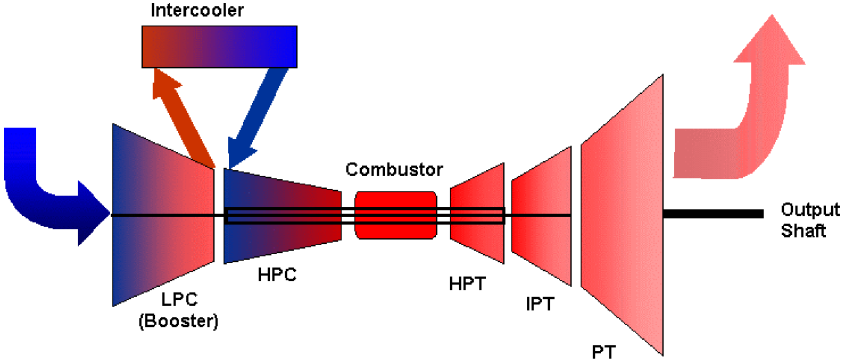
Typical Installation

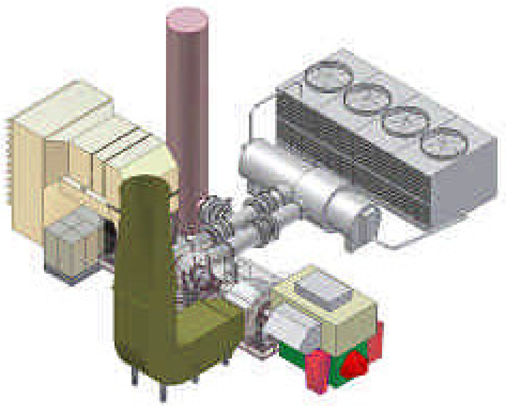


Inlet & exhaust losses are typically 100 / 125 mm water in simple cycle.
Causes about 2-3% loss of power & about 0.5% loss of thermal efficiency.

Inter-cooled Engine, General Electric LMS100



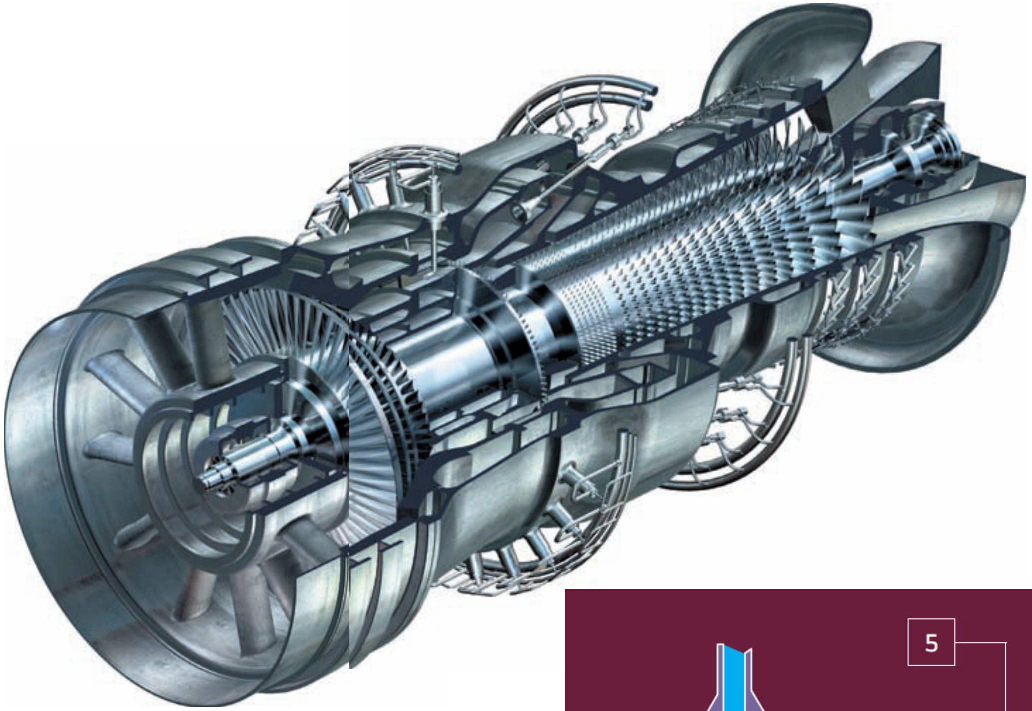


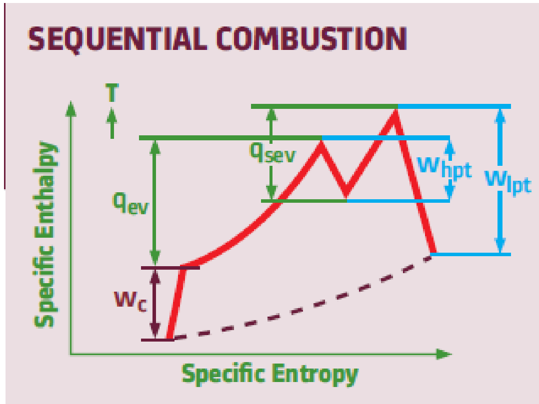


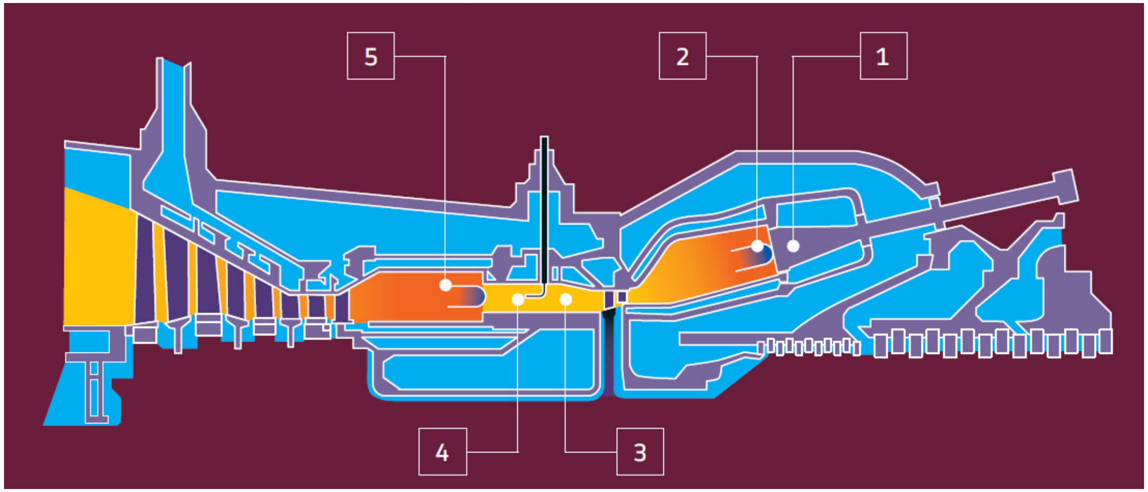
Wet intercooler system

Very high levels of specific power and thermal efficiency (intercooling permits increase in OPR and SOT without increasing HPT blade metal temperature, due to reduced cooling air temp)

Reheated Engine (Sequential Combustion), Alstom GT26

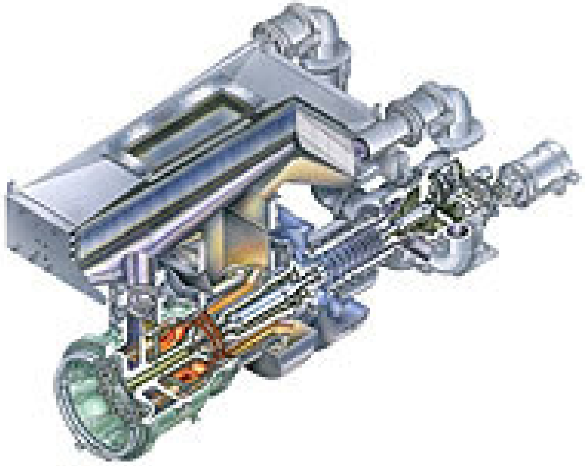






-Higher specific power at a lower SOT than a conventional configuration.
- High exhaust temperature.
- First combustor is fuelled to maintain constant SOT for better part-load efficiency.

Recuperated Engine, Solar Mercury 50



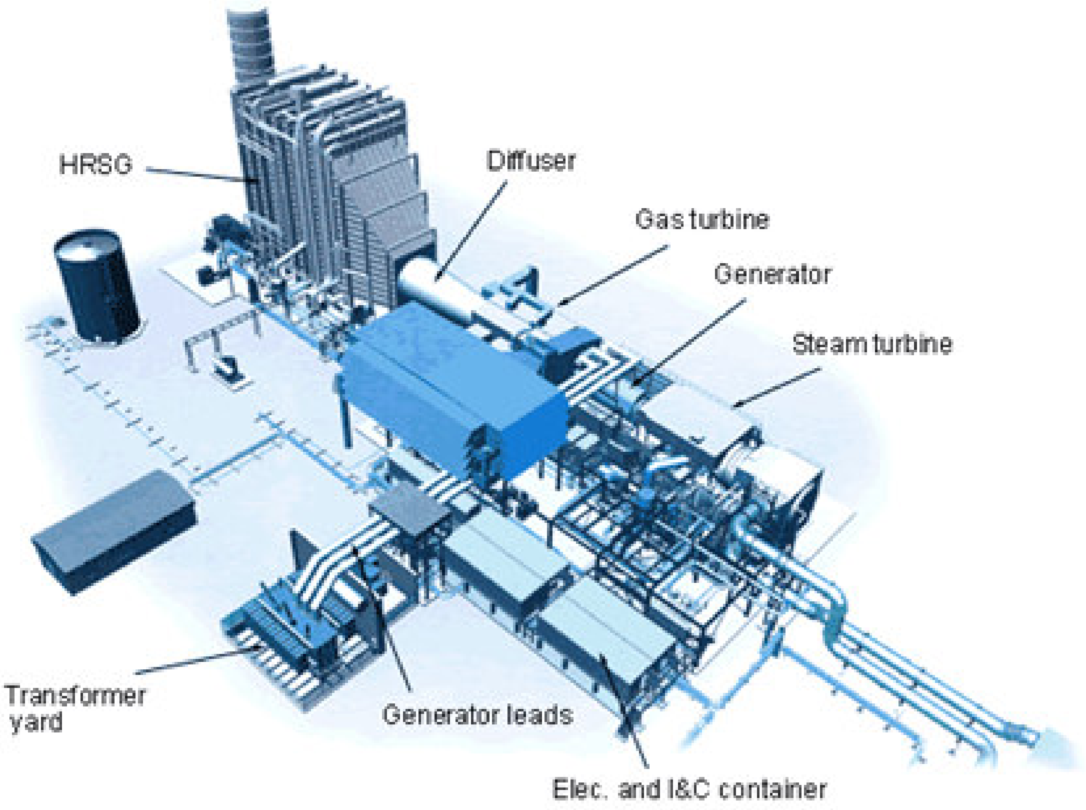
Waste heat from the exhaust heats compressor delivery air, reducing the amount of fuel required to achieve a given SOT.

Very high efficiency is achieved at low OPR (~9).

Very good part-load efficiency

Specific power not significantly affected

Combined Cycle Plant

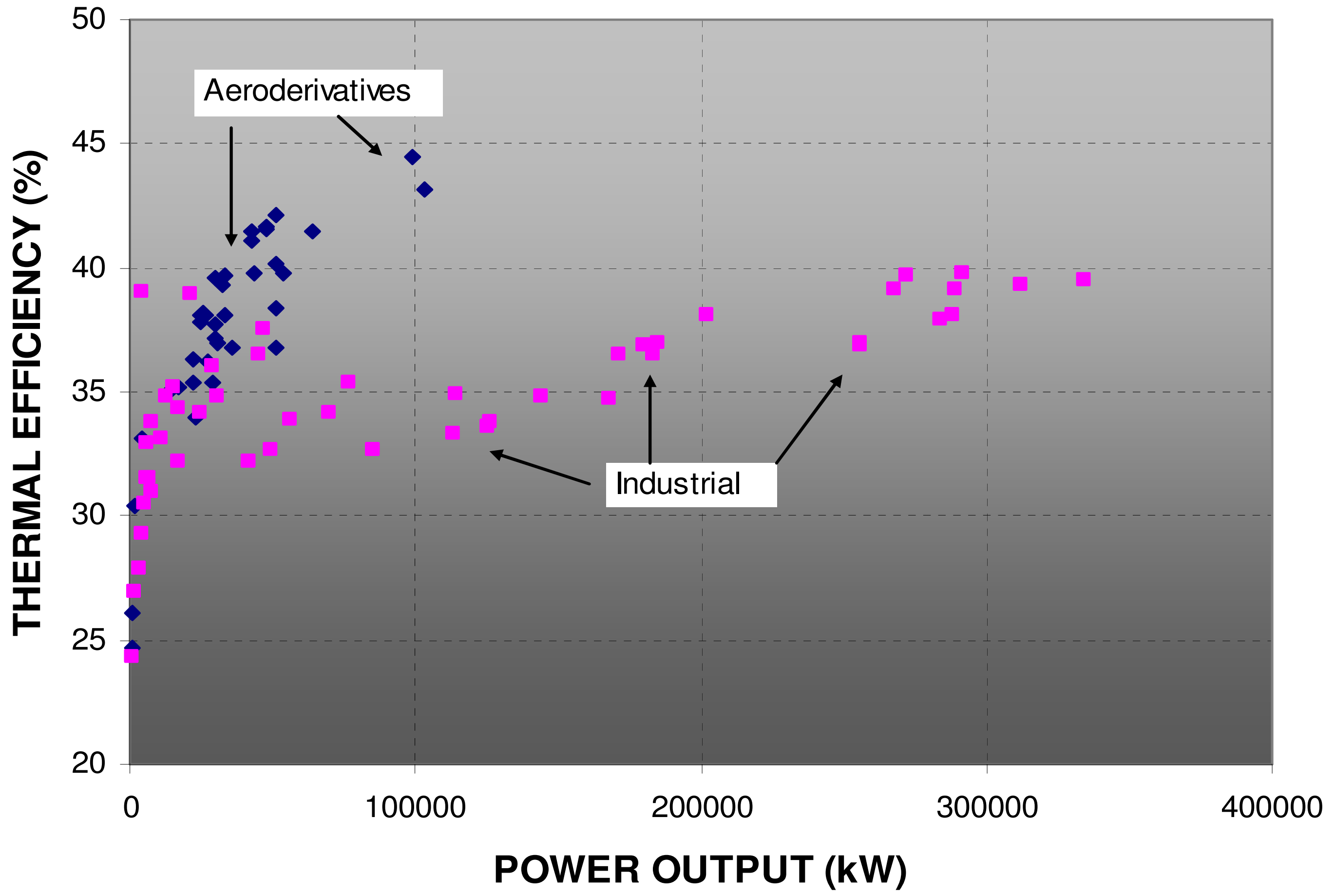


Steam cycle plant is much larger than the gas turbine!

Source - Siemens

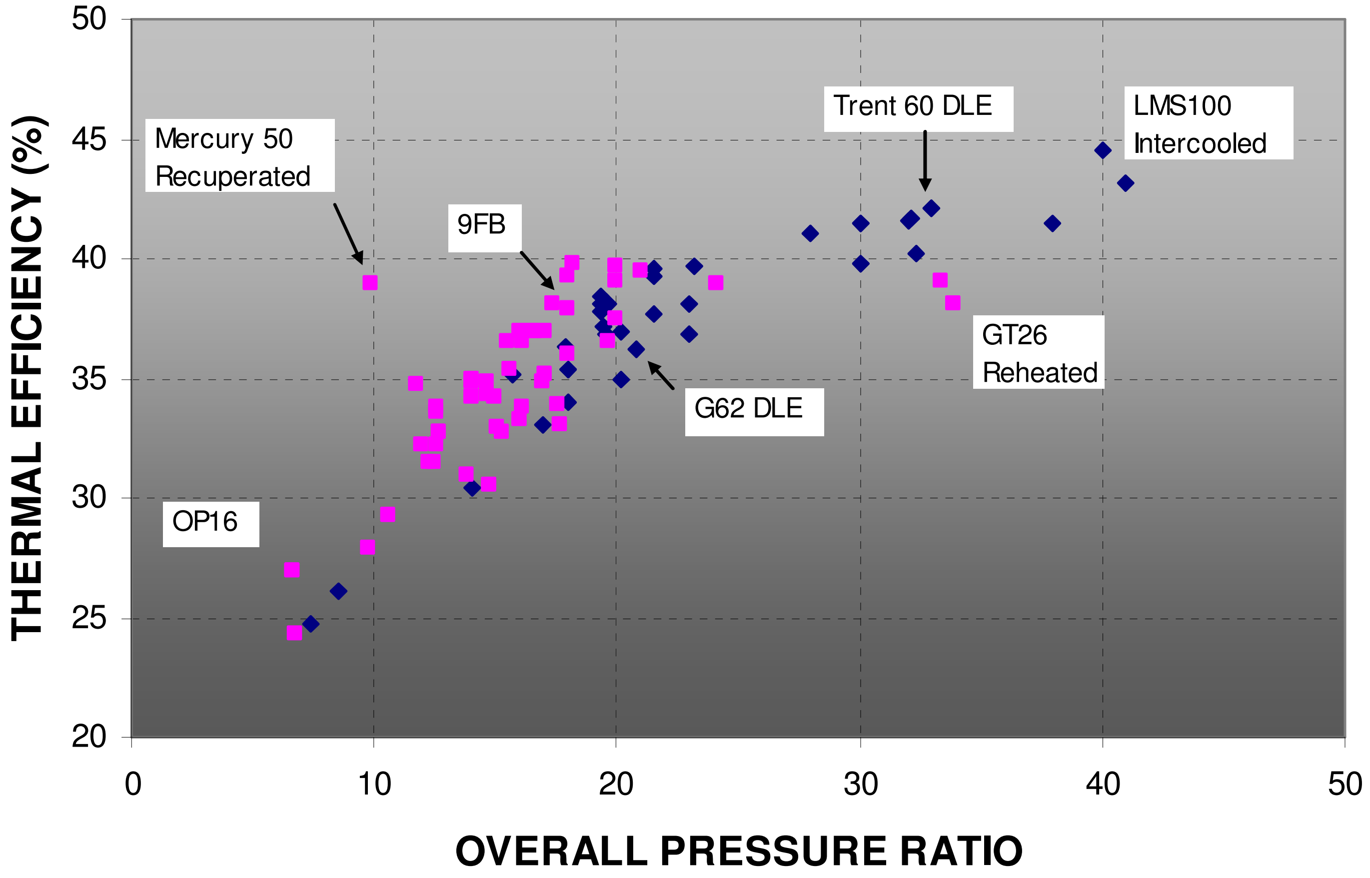
Performance Specifications

Thermal Efficiency versus Power



Data from 2009 Performance Specs, 26th Edition, Gas Turbine World

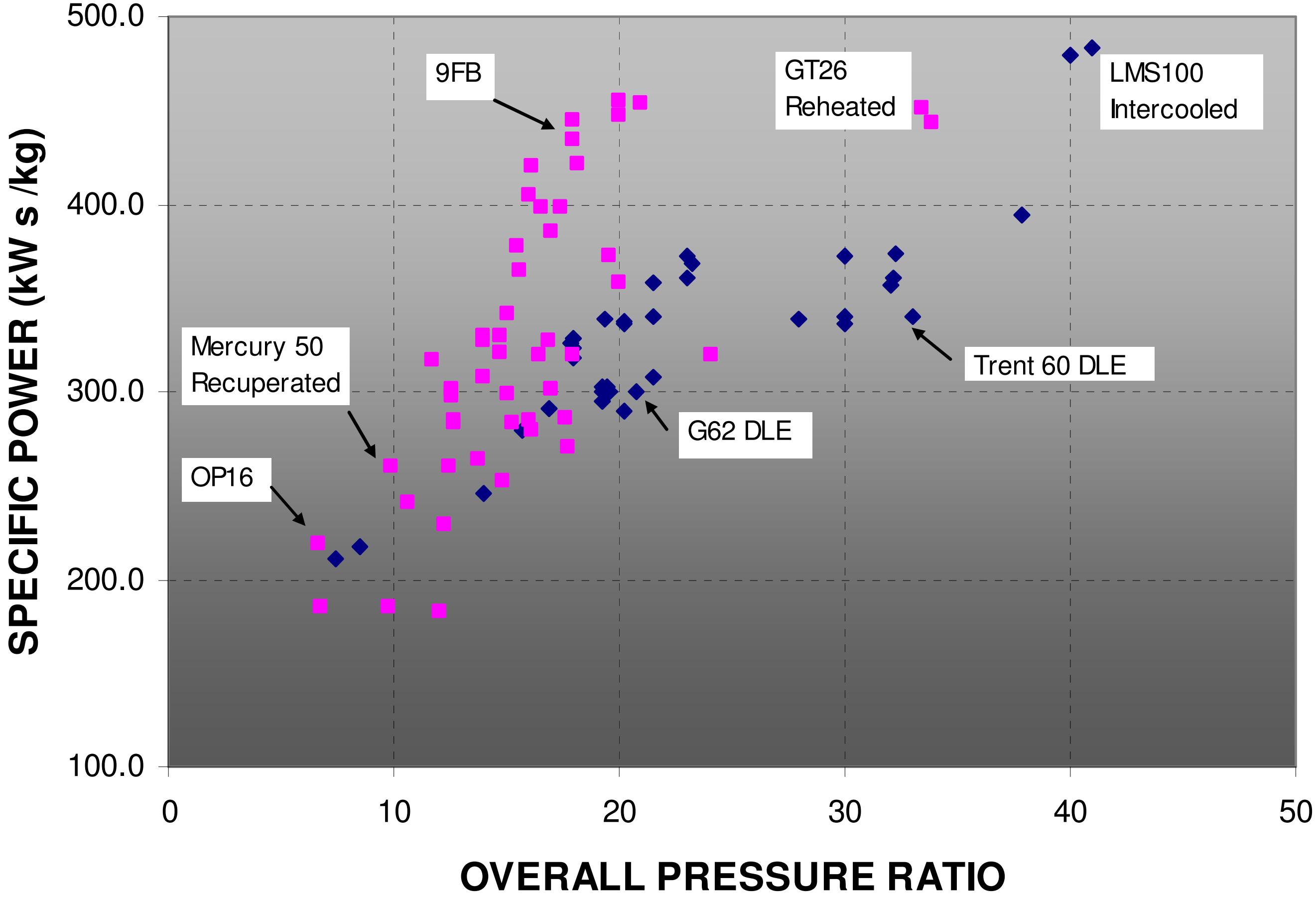
Thermal Efficiency versus OPR



Data from 2009 Performance Specs, 26th Edition, Gas Turbine World

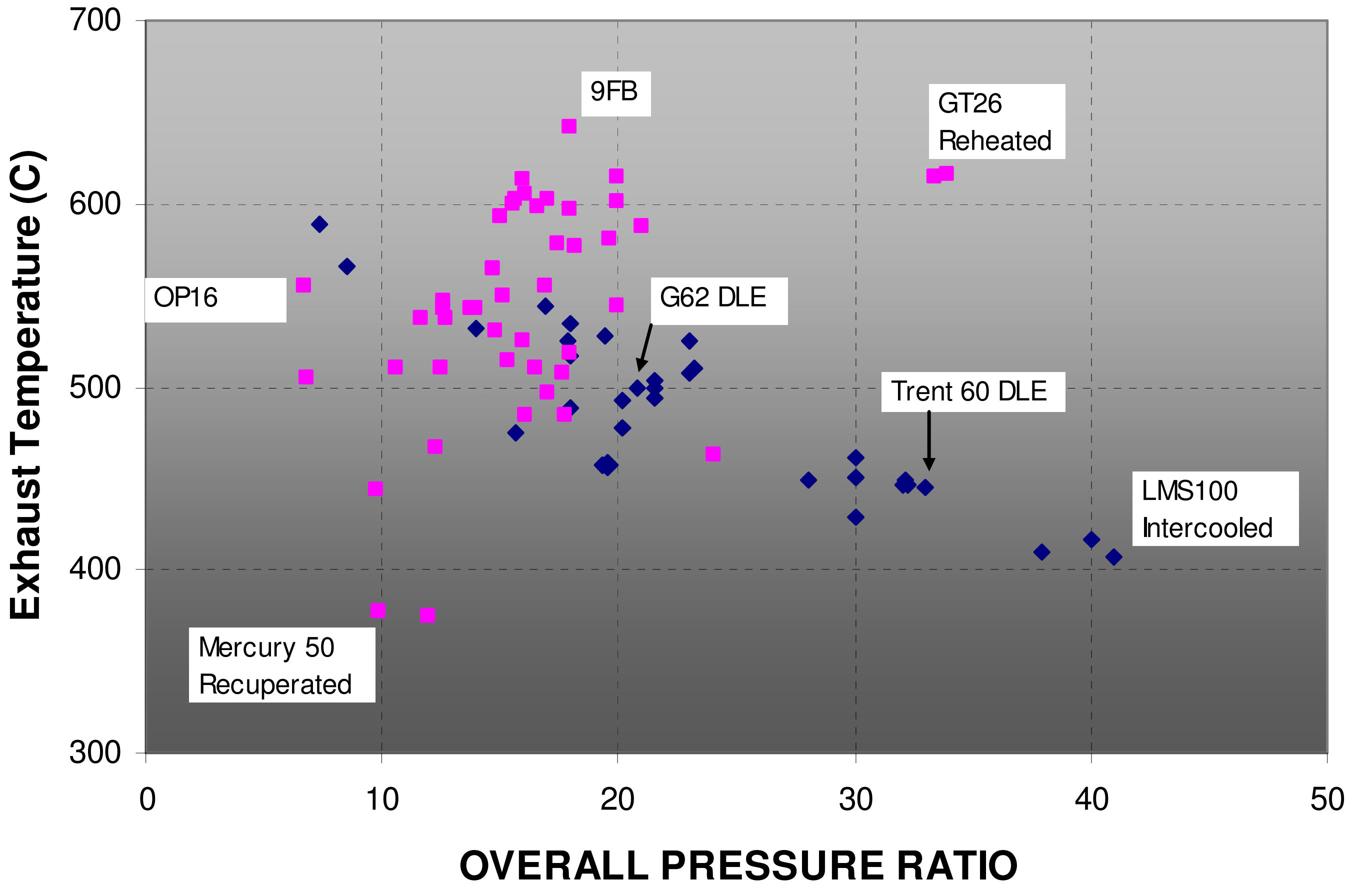
Rolls-Royce

Specific Power versus OPR



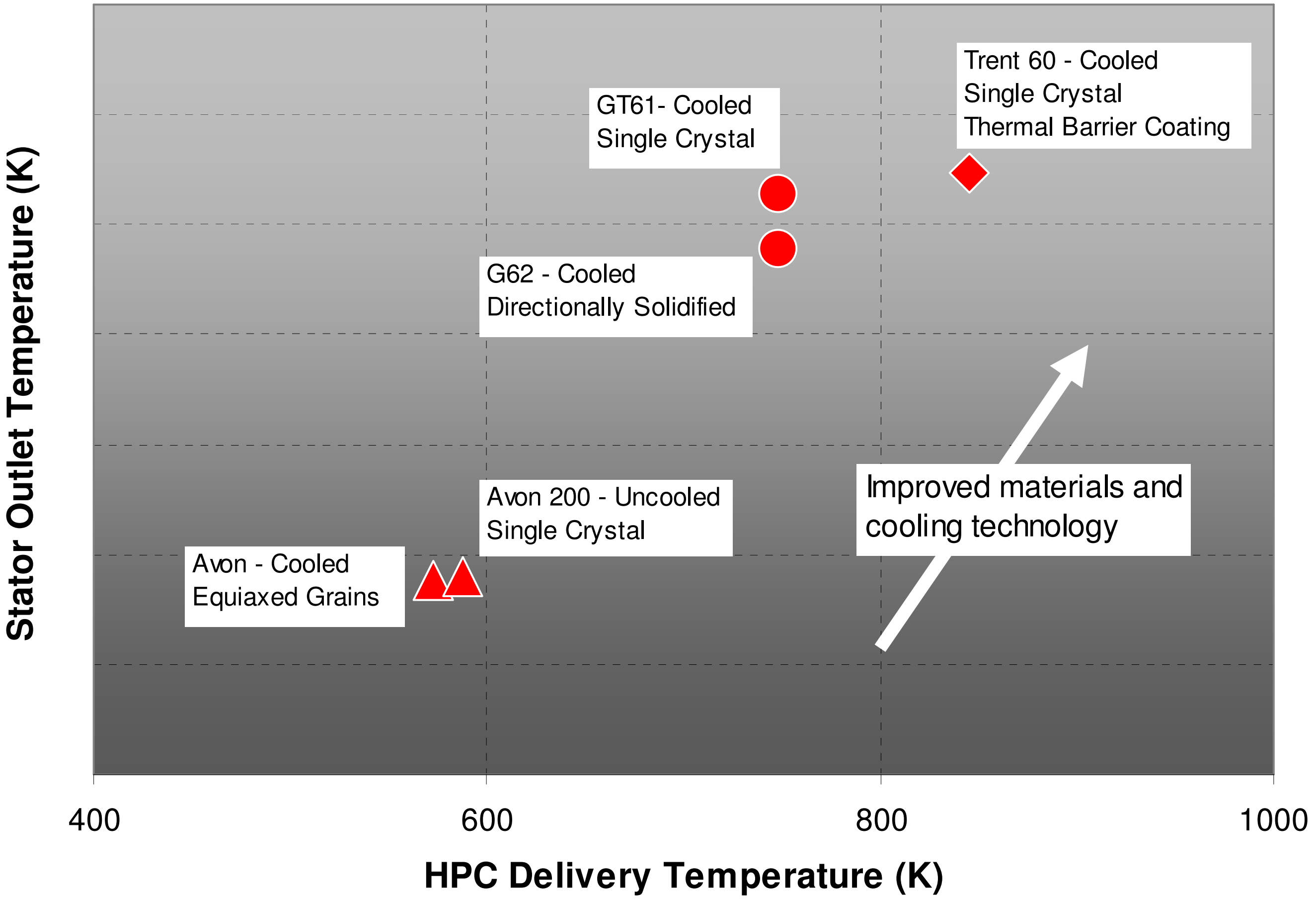
Data from 2009 Performance Specs, 26th Edition, Gas Turbine World

Exhaust Temperature versus OPR



Data from 2009 Performance Specs, 26th Edition, Gas Turbine World

Evolution of HP Turbine Blade Materials

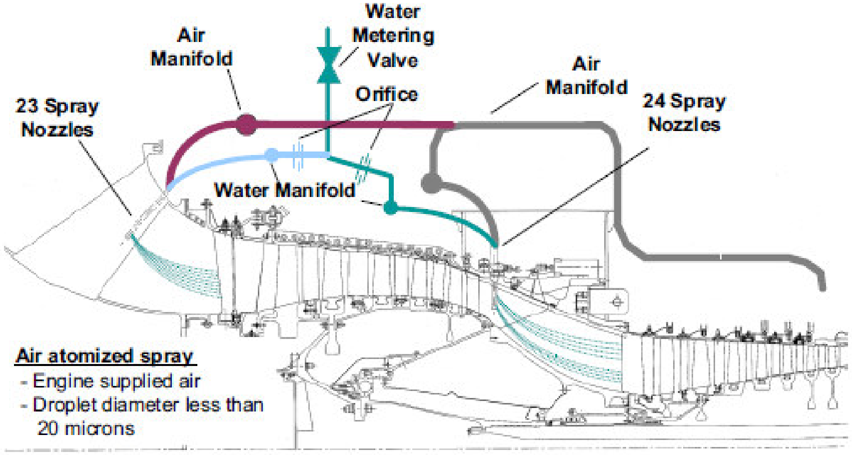


Source – Rolls-Royce Canada

Water Injection

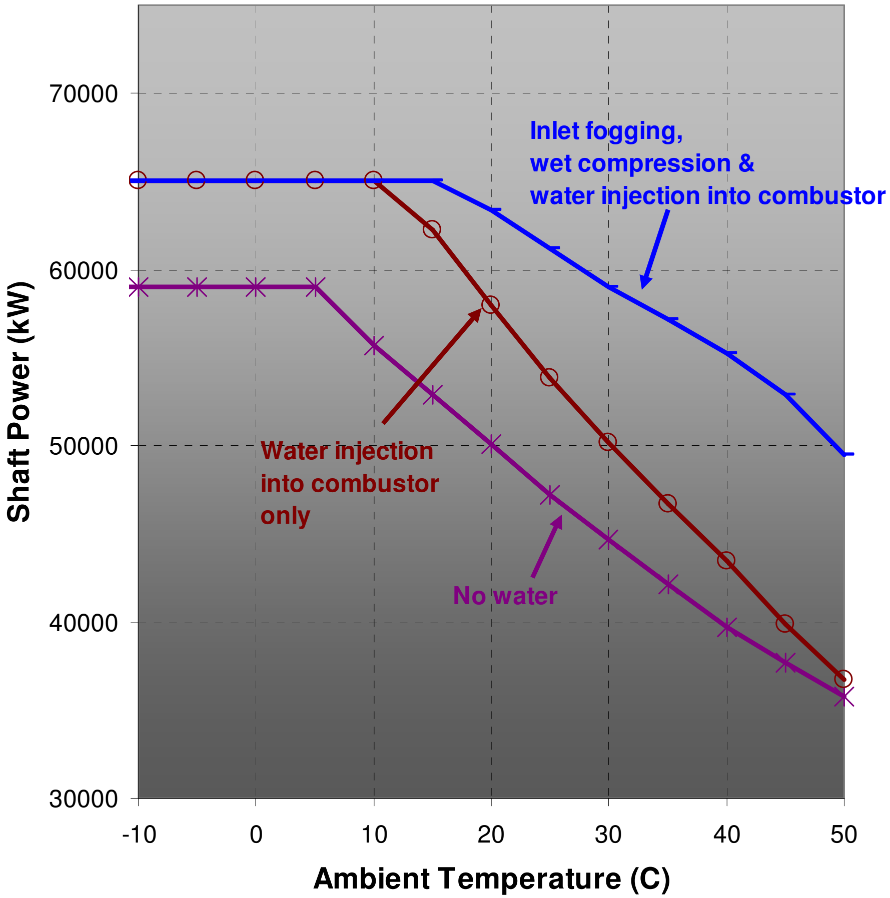
Inlet Chiller

(MEE Industries)



Example of wet compression

(General Electric)



Example of Power Increase *(Rolls-Royce)*