Gas Turbine Design-point Cycle: Single Shaft or Free Power Turbine

Specific work, fuel/air ratio, SFC, efficiency and exhaust temperature of a gas turbine with component efficiencies, pressure losses and an optional heat exchanger.

Input parameters

Unit system: SI

Parameter	Value	Unit
Arrangement	Single shaft	
Compressor pressure ratio	16.000	
Turbine inlet temperature	1,226.8	°C
Compressor isentropic efficiency	87.000	%
Turbine isentropic efficiency (each turbine)	90.000	%
Mechanical efficiency (each shaft)	99.000	%
Combustion efficiency	99.500	%
Heat-exchanger effectiveness (0 = none)	0	%
Combustor pressure loss	4.0000	%
Heat-exchanger air-side loss	0	%
Exhaust (and heat-exchanger gas-side) pressure loss	0.050000	bar
Ambient pressure	1.0130	bar
Ambient temperature	29.850	°C
Air specific heat	1.0050	kJ/(kg·K)
Air ratio of specific heats	1.4000	
Gas specific heat	1.1480	kJ/(kg·K)
Gas ratio of specific heats	1.3333	
Fuel net calorific value	43,100	kJ/kg
Fuel H/C atom ratio (kerosene about 1.92, methane 4)	1.9200	
Power required (for the air flow)	10.000	MW

Calculated results

Parameter	Value	Unit
Compressor delivery temperature	723.78	K
Compressor work (per kg air, at the shaft)	427.16	kJ/kg
Turbine inlet pressure	15.560	bar
Turbine exhaust temperature (EGT)	840.19	K
Combustor inlet temperature (after any heat exchanger)	723.78	K
Specific work output	330.31	kJ/kg
Fuel/air ratio	0.022726	
Specific fuel consumption	0.24769	kg/kWh
Cycle efficiency (LHV)	33.722	%
Air flow for the power required	30.275	kg/s

Notes for this case

• Constant mass flow through the machine, no cooling bleeds, constant c_p and γ for air and for gas as in the textbook method. The fuel/air ratio comes from an enthalpy balance with NIST Shomate data for a CH_y fuel; it reproduces the textbook combustion chart to within about 0.5 %.

Formula and method

$$T_{02} - T_{01} = \frac{T_{01}}{\eta_c}\left[r_c^{(\gamma_a - 1)/\gamma_a} - 1\right], \quad \Delta T_t = \eta_t T_{0i}\left[1 - \left(\frac{1}{r_t}\right)^{(\gamma_g - 1)/\gamma_g}\right]$$

$$W = c_{pg}\Delta T_{pt}\eta_m, \quad SFC = \frac{f}{W}, \quad \eta = \frac{W}{fQ_{net}}$$

Variables

$\mathrm{arrangement}$	Arrangement	-
r_c	Compressor pressure ratio	-
T_{03}	Turbine inlet temperature	K
η_c	Compressor isentropic efficiency	-
η_t	Turbine isentropic efficiency (each turbine)	-
η_m	Mechanical efficiency (each shaft)	-
η_b	Combustion efficiency	-
ε	Heat-exchanger effectiveness (0 = none)	-
$\Delta p_b/p_{02}$	Combustor pressure loss	-
$\Delta p_{ha}/p_{02}$	Heat-exchanger air-side loss	-
Δp_{ex}	Exhaust (and heat-exchanger gas-side) pressure loss	Pa
p_a	Ambient pressure	Pa
T_a	Ambient temperature	K
c_{pa}	Air specific heat	J/(kg·K)
γ_a	Air ratio of specific heats	-
c_{pg}	Gas specific heat	J/(kg·K)
γ_g	Gas ratio of specific heats	-
Q_{net}	Fuel net calorific value	J/kg
y	Fuel H/C atom ratio (kerosene about 1.92, methane 4)	-
P	Power required (for the air flow)	W
T_{02}	Compressor delivery temperature	K
W_c	Compressor work (per kg air, at the shaft)	J/kg
p_{03}	Turbine inlet pressure	Pa
p_{04}	Power turbine inlet pressure (free turbine)	Pa
T_{04}	Gas generator turbine exit temperature	K
T_{ex}	Turbine exhaust temperature (EGT)	K
T_{05}	Combustor inlet temperature (after any heat exchanger)	K
W	Specific work output	J/kg
f	Fuel/air ratio	-
SFC	Specific fuel consumption	kg/J
η	Cycle efficiency (LHV)	-
$\dot{m}$	Air flow for the power required	kg/s

Method and standards

Textbook design-point cycle calculation with an enthalpy-balance fuel/air ratio.

Assumptions and limits

- Constant flow; no cooling air; ideal-gas properties with constant c_p.

Report details

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Results are for engineering estimation. Verify critical designs against the referenced standards and your own data.

This calculator online

https://calc.firecad.com/boilers-power-plant/gas-turbines-combined-cycle/gas-turbine-cycle-design-point

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Reopens the calculator with the inputs of this report.