Combined Cycle Efficiency and Power Split

Steam turbine power, total output, efficiency and heat rate of a gas turbine combined cycle from the gas turbine efficiency, HRSG heat recovery and steam cycle efficiency.

Method: Combined cycle energy balance (Kehlhofer, Hannemann, Stirnimann and Rukes, Combined-Cycle Gas & Steam Turbine Power Plants, 3rd ed., PennWell, 2009)

Input parameters

Unit system: SI

Parameter	Value	Unit
Gas turbine power	100.00	MW
Gas turbine efficiency (on fuel heat) Gas turbine ratings are usually on the lower heating value (LHV); the fuel heat, efficiencies and heat rate come out on the same basis.	36.000	%
Share of the exhaust heat the HRSG recovers	80.000	%
Steam cycle efficiency (power ÷ heat absorbed in the HRSG)	33.000	%
Auxiliary power, share of gross output	2.0000	%

Calculated results

Parameter	Value	Unit
Fuel heat input	277.78	MW
Heat in the gas turbine exhaust	177.78	MW
Heat recovered in the HRSG	142.22	MW
Steam turbine power	46.933	MW
Gross combined cycle output	146.93	MW
Net output	143.99	MW
Gross combined cycle efficiency	52.896	%
Net efficiency	51.838	%
Net heat rate	6,944.7	kJ/kWh

Notes for this case

- No supplementary firing; the gas turbine's own heat losses (casing, lube oil, generator) are counted as exhaust heat, which slightly overstates the steam power.

Formula and method

$$Q_F = \frac{P_{GT}}{\eta_{GT}}, \quad Q_{ex} = Q_F - P_{GT}, \quad Q_R = \eta_R Q_{ex}, \quad P_{ST} = \eta_{ST} Q_R$$

$$\eta_{CC} = \eta_{GT} + (1 - \eta_{GT})\,\eta_R\,\eta_{ST}$$

$$P_n = (P_{GT} + P_{ST})(1 - a), \quad \eta_n = P_n / Q_F, \quad HR_n = Q_F / P_n$$

Variables

P_{GT}	Gas turbine power	W
η_{GT}	Gas turbine efficiency (on fuel heat)	-
η_R	Share of the exhaust heat the HRSG recovers	-
η_{ST}	Steam cycle efficiency (power ÷ heat absorbed in the HRSG)	-
a	Auxiliary power, share of gross output	-
Q_F	Fuel heat input	W

Q_{ex}	Heat in the gas turbine exhaust	W
Q_R	Heat recovered in the HRSG	W
P_{ST}	Steam turbine power	W
P_g	Gross combined cycle output	W
P_n	Net output	W
η_{CC}	Gross combined cycle efficiency	-
η_n	Net efficiency	-
HR_n	Net heat rate	J/J

Method and standards

An energy balance of the topping and bottoming cycles: the gas turbine's fuel heat less its power is the exhaust heat; the HRSG recovers a share of it; the steam cycle converts that share at its own efficiency.

Assumptions and limits

- Steady full load; no supplementary firing.
- Gas turbine losses other than exhaust are counted as exhaust heat.
- Heating value basis follows the gas turbine efficiency entered, usually LHV; efficiencies and heat rate are on that basis.

References

• Combined cycle energy balance (Kehlhofer, Hannemann, Stirnimann and Rukes, Combined-Cycle Gas & Steam Turbine Power Plants, 3rd ed., PennWell, 2009)

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/turbines-cycles/combined-cycle-efficiency

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Reopens the calculator with the inputs of this report.