Extraction Turbine Power and Heat Balance

Power of an extraction (pass-out) steam turbine from inlet steam, extraction pressure and flow, exhaust pressure and section efficiencies, with the extraction steam state.

Method: IAPWS R7-97(2012) IF97; first law of thermodynamics

Input parameters

Unit system: SI

Parameter	Value	Unit
Inlet steam flow	60,000	kg/h
Inlet steam pressure (absolute)	66.000	bar
Inlet steam condition	Superheated at the temperature below	
Inlet steam temperature (superheated only)	485.00	°C
Extraction pressure (absolute)	4.0000	bar
Extraction steam flow	20,000	kg/h
Exhaust pressure (absolute)	10.000	kPa
Isentropic efficiency, inlet to extraction	80.000	%
Isentropic efficiency, extraction to exhaust	78.000	%
Gearbox and generator efficiency	95.000	%

Calculated results

Parameter	Value	Unit
Electrical power	13,479	kW
Shaft power, inlet to extraction	9,173.7	kW
Shaft power, extraction to exhaust	5,014.5	kW
Extraction steam temperature	185.00	°C
Extraction steam enthalpy	2,829.3	kJ/kg
Exhaust steam flow	40,000	kg/h
Exhaust dryness (1 = dry or superheated)	91.393	%
Exhaust enthalpy	2,378.0	kJ/kg

Formula and method

$$h_x = h_1 - \eta_{HP}\left[h_1 - h(p_x, s_1)\right] \qquad h_2 = h_x - \eta_{LP}\left[h_x - h(p_2, s_x)\right]$$

$$P_{HP} = \dot{m}_1 (h_1 - h_x) \qquad P_{LP} = (\dot{m}_1 - \dot{m}_x)(h_x - h_2) \qquad P_{el} = \eta_g (P_{HP} + P_{LP})$$

Variables

$\dot{m}_1$	inlet steam flow	kg/s
p_1	inlet pressure, absolute	Pa
state	dry saturated or superheated inlet	–
T_1	inlet temperature (superheated)	K
p_x	extraction pressure, absolute	Pa
$\dot{m}_x$	extraction flow	kg/s
p_2	exhaust pressure, absolute	Pa
η_{HP}	isentropic efficiency, inlet to extraction	–

η_{LP}	isentropic efficiency, extraction to exhaust	–
η_g	gearbox and generator efficiency	–
P_{el}	electrical power	W
P_{HP}	shaft power of the first section	W
P_{LP}	shaft power of the second section	W
T_x	extraction steam temperature	K
h_x	extraction steam enthalpy	J/kg
$\dot{m}_2$	exhaust steam flow	kg/s
x_2	exhaust dryness	–
$h_1\$, \$h_2$	inlet and exhaust enthalpy	J/kg
$s_1\$, \$s_x$	entropy at inlet and at extraction	J/(kg·K)

Method and standards

Two expansions in series, each with its own isentropic efficiency, and a mass balance at the extraction; states by FireCAD's IAPWS-IF97.

Assumptions and limits

- One extraction; steady flow; section efficiencies constant.
- With all the steam extracted the LP section carries no flow: its exhaust state is not shown, and a note recalls the minimum LP cooling flow, which is the turbine maker's figure and is not checked here.

References

- IAPWS R7-97(2012) IF97
- first law of thermodynamics

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/extraction-turbine-balance

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Reopens the calculator with the inputs of this report.