Steam Turbine Power with up to Four Extractions and Condensing Exhaust

Shaft and generator power of an extraction-condensing turbine from inlet steam, up to four extractions (flow, pressure, temperature) and the exhaust (IAPWS-IF97).

Input parameters

Unit system: SI

Parameter	Value	Unit
Inlet (throttle) steam flow	120.00	t/h
Inlet steam pressure (absolute)	105.00	bar
Inlet steam temperature	535.00	°C
Extraction 1: data	Measured temperature (superheated)	
Extraction 1: steam flow	8.0000	t/h
Extraction 1: pressure (absolute)	32.000	bar
Extraction 1: measured temperature	371.12	°C
Extraction 2: data	Measured temperature (superheated)	
Extraction 2: steam flow	25.000	t/h
Extraction 2: pressure (absolute)	12.000	bar
Extraction 2: measured temperature	258.77	°C
Extraction 3: data	Measured temperature (superheated)	
Extraction 3: steam flow	15.000	t/h
Extraction 3: pressure (absolute)	4.5000	bar
Extraction 3: measured temperature	166.57	°C
Extraction 4: data	Wet or not measured: from section efficiency	
Extraction 4: steam flow	5.0000	t/h
Extraction 4: pressure (absolute)	1.5000	bar
Extraction 4: measured temperature	111.37	°C
Section efficiency for extractions without a measured temperature	82.000	%
Exhaust (condenser) pressure (absolute)	0.10000	bar
Exhaust state from	Last-section efficiency	
Last-section isentropic efficiency	78.000	%
Exhaust dryness	92.000	%
Measured exhaust temperature	150.00	°C
Gearbox and generator efficiency	96.500	%

Calculated results

Parameter	Value	Unit
Inlet enthalpy	3,459.0	kJ/kg

Parameter	Value	Unit
Extraction 1: enthalpy	3,161.4	kJ/kg
Extraction 1: temperature	371.12	°C
Extraction 1: dryness (1 = dry or superheated)	1.0000	
Section 1: isentropic efficiency (to extraction 1)	82.002	%
Section 1: shaft power (to extraction 1)	9,919.1	kW
Extraction 2: enthalpy	2,955.5	kJ/kg
Extraction 2: temperature	258.77	°C
Extraction 2: dryness (1 = dry or superheated)	1.0000	
Section 2: isentropic efficiency (to extraction 2)	82.995	%
Section 2: shaft power (to extraction 2)	6,405.2	kW
Extraction 3: enthalpy	2,786.1	kJ/kg
Extraction 3: temperature	166.57	°C
Extraction 3: dryness (1 = dry or superheated)	1.0000	
Section 3: isentropic efficiency (to extraction 3)	82.000	%
Section 3: shaft power (to extraction 3)	4,094.4	kW
Extraction 4: enthalpy	2,625.4	kJ/kg
Extraction 4: temperature	111.35	°C
Extraction 4: dryness (1 = dry or superheated)	0.96959	
Section 4: isentropic efficiency (to extraction 4)	82.000	%
Section 4: shaft power (to extraction 4)	3,213.0	kW
Exhaust (condensing) steam flow	67.000	t/h
Exhaust enthalpy	2,318.9	kJ/kg
Exhaust dryness (1 = dry or superheated)	0.88921	
Exhaust temperature	45.808	°C
Last-section isentropic efficiency	78.000	%
Last-section shaft power	5,705.4	kW
Total shaft power	29,337	kW
Generator output	28,310	kW
Specific steam consumption (inlet flow per generator output)	4.2387	kg/kWh
Condenser heat load	39,587	kW

Notes for this case

- Each section carries the inlet flow less the extractions above it. Gland leakage, balance-drum leak-off and extractions used to heat feedwater are treated as ordinary extractions; enter them as extractions if significant.

Formula and method

$$P_{sh} = \sum_{j=1}^{n+1} (\dot{m}_0 - \sum_{k<j} \dot{m}_k)(h_{j-1} - h_j), \quad \dot{m}_{ex} = \dot{m}_0 - \sum_{k=1}^{n} \dot{m}_k$$

$$h_j = h(p_j, T_j) \text{ (measured) or } h_j = h_{j-1} - \eta_w \left[h_{j-1} - h(p_j, s_{j-1})\right], \quad \eta_j = \frac{h_{j-1} - h_j}{h_{j-1} - h(p_j, s_{j-1})}, \quad P_{el} = \eta_g P_{sh}$$

Variables

$\dot{m}_0$	Inlet (throttle) steam flow	kg/s
p_0	Inlet steam pressure (absolute)	Pa
T_0	Inlet steam temperature	K
mode_1	Extraction 1: data	-
$\dot{m}_1$	Extraction 1: steam flow	kg/s
p_1	Extraction 1: pressure (absolute)	Pa
T_1	Extraction 1: measured temperature	K
mode_2	Extraction 2: data	-
$\dot{m}_2$	Extraction 2: steam flow	kg/s
p_2	Extraction 2: pressure (absolute)	Pa
T_2	Extraction 2: measured temperature	K
mode_3	Extraction 3: data	-
$\dot{m}_3$	Extraction 3: steam flow	kg/s
p_3	Extraction 3: pressure (absolute)	Pa
T_3	Extraction 3: measured temperature	K
mode_4	Extraction 4: data	-
$\dot{m}_4$	Extraction 4: steam flow	kg/s
p_4	Extraction 4: pressure (absolute)	Pa
T_4	Extraction 4: measured temperature	K
η_w	Section efficiency for extractions without a measured temperature	-
p_{ex}	Exhaust (condenser) pressure (absolute)	Pa
mode_{ex}	Exhaust state from	-
η_{ex}	Last-section isentropic efficiency	-
x_{ex}	Exhaust dryness	-
T_{ex}	Measured exhaust temperature	K
η_g	Gearbox and generator efficiency	-
h_0	Inlet enthalpy	J/kg
h_1	Extraction 1: enthalpy	J/kg
$T_1{}'$	Extraction 1: temperature	K
x_1	Extraction 1: dryness (1 = dry or superheated)	-
η_1	Section 1: isentropic efficiency (to extraction 1)	-
P_1	Section 1: shaft power (to extraction 1)	W
h_2	Extraction 2: enthalpy	J/kg
$T_2{}'$	Extraction 2: temperature	K
x_2	Extraction 2: dryness (1 = dry or superheated)	-
η_2	Section 2: isentropic efficiency (to extraction 2)	-
P_2	Section 2: shaft power (to extraction 2)	W
h_3	Extraction 3: enthalpy	J/kg
$T_3{}'$	Extraction 3: temperature	K
x_3	Extraction 3: dryness (1 = dry or superheated)	-
η_3	Section 3: isentropic efficiency (to extraction 3)	-

P_3	Section 3: shaft power (to extraction 3)	W
h_4	Extraction 4: enthalpy	J/kg
$T_4{}'$	Extraction 4: temperature	K
x_4	Extraction 4: dryness (1 = dry or superheated)	-
η_4	Section 4: isentropic efficiency (to extraction 4)	-
P_4	Section 4: shaft power (to extraction 4)	W
$\dot{m}_{ex}$	Exhaust (condensing) steam flow	kg/s
h_{ex}	Exhaust enthalpy	J/kg
$x_{ex}{}'$	Exhaust dryness (1 = dry or superheated)	-
$T_{ex}{}'$	Exhaust temperature	K
$\eta_{ex}{}'$	Last-section isentropic efficiency	-
P_{ex}	Last-section shaft power	W
P_{sh}	Total shaft power	W
P_{el}	Generator output	W
SSC	Specific steam consumption (inlet flow per generator output)	kg/J
Q_c	Condenser heat load	W

Method and standards

Section-by-section heat balance of a multi-extraction steam turbine with IAPWS-IF97 steam properties.

Assumptions and limits

- Steady state; each extraction point is treated as a single state; heat loss from the casing neglected.

Report details

Report reference	FCC-RTCT-PP68 (the same inputs always give the same reference)
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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/steam-turbines/steam-turbine-multi-extraction-power

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Reopens the calculator with the inputs of this report.