PRDS vs Back-Pressure Turbine (Power Lost)

Power a back-pressure steam turbine would make from steam now reduced through a PRDS valve, and its value per year, with both outlet steam states (IAPWS-IF97).

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

Input parameters

Unit system: SI

Parameter	Value	Unit
Steam flow through the PRDS	20,000	kg/h
Inlet steam pressure (absolute)	45.000	bar
Inlet steam condition	Superheated at the temperature below	
Inlet steam temperature (superheated only)	400.00	°C
Process (reduced) pressure (absolute)	400.00	kPa
Turbine isentropic efficiency	70.000	%
Gearbox and generator efficiency	95.000	%
Operating hours per year	8,000.0	h
Value of electricity per kWh (your currency)	8.0000	

Calculated results

Parameter	Value	Unit
Electrical power a turbine would make	2,017.4	kW
Value of that power per year (your currency)	1.2912e+08	
Steam temperature after the PRDS valve (before spray)	367.17	°C
Steam temperature after the turbine	182.18	°C
Turbine exhaust dryness (1 = dry or superheated)	100.00	%
Turbine exhaust enthalpy	2,823.3	kJ/kg

Notes for this case

- The turbine exhaust carries 382 kJ/kg less than PRDS steam (the difference became power): the process gets less heat per kg, so a little more steam is needed for the same duty. That extra steam is not computed here.

Formula and method

$$h_2 = h_1 - \eta_i \left[h_1 - h(p_2, s_1)\right] \qquad P_{el} = \eta_g \dot{m}_s (h_1 - h_2)$$

$$V = P_{el}\, t_{op}\, c_e \qquad T_{PRDS} = T(p_2, h_1)$$

Variables

$\dot{m}_s$	steam flow through the PRDS	kg/s
p_1	supply pressure, absolute	Pa
state	dry saturated or superheated supply	–
T_1	supply temperature (superheated)	K
p_2	process (reduced) pressure, absolute	Pa
η_i	turbine isentropic efficiency	–
η_g	gearbox and generator efficiency	–
t_{op}	operating hours per year	s

c_e	value of electricity per kWh	–
P_{el}	electrical power a turbine would make	W
V	value of that power per year	–
T_{PRDS}	steam temperature after the valve, before spray	K
T_2	steam temperature after the turbine	K
x_2	turbine exhaust dryness	–
h_2	turbine exhaust enthalpy	J/kg
$h_1$$, $$s_1$	supply enthalpy and entropy	J/kg, J/(kg·K)

Method and standards

The PRDS valve is isenthalpic (throttling); the turbine follows the isentropic-efficiency expansion. States by FireCAD's IAPWS-IF97. Energy in kWh for the value.

Assumptions and limits

- Same steam flow through the turbine as through the PRDS; constant efficiencies; desuperheating not modelled.
- The extra boiler steam needed to give the process the same heat is not computed; the note gives the enthalpy deficit per kg.
- x_2 follows the property library: 1 for dry or superheated exhaust.

References

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

Report details

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Release checks	3 reference cases of this calculator, computed independently, are checked on every release

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/prds-versus-turbine

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.