Steam Turbine Extraction and Backpressure Evaluation — Report

DOCUMENT

Plant / project	**Example Plant**
Equipment tag / system	**Steam turbine generator**
Calculation / document no.	**CALC-STX-001**
Revision	**0**
Prepared by	**Your name**
Checked by	**—**
Date	**07-Nov-2026**
Calculation basis	Back-pressure turbine, 2 extraction points · 60.0 bar a / 480 °C · exhaust 3.50 bar a (header) or 0.100 bar a (condenser) · flow given at the inlet · section efficiencies as entered or from the PlantCalcKit screening curve · IAPWS-IF97 steam properties · comparison: back-pressure, condensing, PRV letdown
Status	**✓ Inputs OK · ℹ️ 9 default value(s) in use: isentropic efficiency, section 1, isentropic efficiency, section 2, isentropic efficiency, last section to the header, isentropic efficiency, last section to the condenser, mechanical efficiency of the turbine, generator efficiency, boiler efficiency, feedwater temperature, operating hours per year**

KEY INPUTS

Input	Unit	Value used
Inlet pressure (stop-valve inlet)	bar a	60.00
Inlet temperature	°C	480.0
Steam flow	kg/h	80,000
Extraction 1 pressure	bar a	20.00
Extraction 1 flow	kg/h	12,000
Extraction 2 pressure	bar a	8.00
Extraction 2 flow	kg/h	18,000
Back-pressure header pressure	bar a	3.500
Condenser pressure	bar a	0.1000
Isentropic efficiency, section 1 (inlet to extraction 1)	%	81.3
Isentropic efficiency, section 2 (extraction 1 to 2)	%	75.3
Isentropic efficiency, last section to the header	%	67.2
Isentropic efficiency, last section to the condenser	%	77.3
Mechanical efficiency of the turbine	%	98.5
Generator efficiency	%	97.0
Boiler efficiency (on fuel heating value)	%	85.0
Feedwater temperature	°C	105.0
Operating hours per year	h/yr	8,000
Value of electricity	per MWh	80.00
Fuel price (on fuel heating value)	per GJ	6.00

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RESULTS — BALANCE, POWER, MARGINAL COSTS

Result	Unit	Value
Turbine inlet flow	kg/h	80,000
Exhaust-section flow	kg/h	50,000
Internal (blade) power, all sections	kW	10,636.4
Shaft (coupling) power	kW	10,476.8
Generator output	kW	10,162.5
Steam rate (inlet steam per kWh at the generator)	kg/kWh	7.872
Process heat delivered to the headers (to saturated liquid)	kW	49,619
Heat-to-power ratio (process heat per kW of electricity)	-	4.88
Overall efficiency (power + process heat) on fuel	%	78.0
Power not generated if the header steam goes through a PRV	kW	10,162.5
Energy not generated per year	MWh/yr	81,300
Value of that electricity per year	per yr	6,504,018
Incremental heat rate of back-pressure power (versus letdown	kJ/kWh	3,768
Marginal cost of back-pressure power	per MWh	26.60
Extra power if the last section exhausts to the condenser	kW	+5,803.2
Incremental heat rate of that extra power	kJ/kWh	20,527
Marginal cost of that extra power	per MWh	144.90

SECTION BY SECTION

Result	Unit	Section 1	Section 2	Last section to header	Last section to condenser
Steam flow through the section	kg/h	80,000	68,000	50,000	50,000
Inlet pressure	bar a	60.00	20.00	8.00	8.00
Outlet pressure	bar a	20.000	8.000	3.500	0.100
Isentropic enthalpy drop	kJ/kg	321.2	224.7	175.4	718.1
Isentropic efficiency used	%	81.3	75.3	67.2	77.3
Actual enthalpy drop	kJ/kg	261.2	169.2	117.9	555.2
Internal power of the section	kW	5,803.4	3,195.1	1,637.8	7,711.6
Outlet temperature	°C	339.5	247.4	182.5	45.8
Outlet dryness (100 % = superheated)	%	100.0	100.0	100.0	91.9

THREE WAYS TO SUPPLY THE SAME HEADER STEAM

Result	Unit	Back-pressure	Condensing	PRV letdown
Turbine as operated		◄ as operated	—	—
Exhaust pressure of the last section	bar a	3.500	0.100	—
Generator output	kW	10,162.5	15,965.7	0.0
Condenser duty (heat to cooling water)	kW	—	30,526	—
Boiler heat above feedwater, to give the same header steam	kW	65,125	98,214	54,489
Fuel heat input	kW	76,618	115,546	64,105
Fuel cost per year	per yr	13,239,604	19,966,410	11,077,291
Value of the electricity per year	per yr	6,504,018	10,218,048	0
Net energy cost per year (fuel less electricity)	per yr	6,735,586	9,748,363	11,077,291
Net cost against back-pressure (+ = costs more)	per yr	—	+3,012,777	+4,341,705

COST OF STEAM AT EACH POINT

Result	Unit	Inlet steam	Extraction 1	Extraction 2	Exhaust header
Steam flow at the point	kg/h	80,000	12,000	18,000	50,000
Work taken from each kg before it gets there	kJ/kg	0.0	261.2	430.3	548.2
Power credit per unit of steam	per t	0.00	5.54	9.14	11.64
Net cost of the steam at the point	per t	20.69	15.14	11.55	9.05

FINDINGS AND RECOMMENDATIONS

◆ **Opportunity**

Back-pressure operation is the lowest-cost option: passing the header steam through the turbine instead of a PRV makes 10,163 kW (81,300 MWh per year, worth USD 6,504,018) for an extra fuel cost of USD 2,162,313: net saving USD 4,341,705 per year. Marginal cost of this power 26.60 per MWh against 80.00.

ℹ️ **Note**

Condensing the last section would add 5,803 kW but needs 33,089 kW more boiler heat to replace the header steam: incremental heat rate 20,527 kJ/kWh, marginal cost 144.90 per MWh, above the electricity value of 80.00. Back-pressure is cheaper by USD 3,012,777 per year while the header needs the steam.

ℹ️ **Note**

The back-pressure exhaust is superheated by 44 K. If the process needs saturated steam, a desuperheater will spray about 2,077 kg/h of feedwater, adding that much steam to the header.

ℹ️ **Note**

Section efficiencies from the PlantCalcKit screening curve are in use (generator output 10,163 kW). Replace them with the maker's heat-balance values before using the result for a decision or a guarantee.

ℹ️ **Note**

A 10 % lower exhaust pressure would give about 178 kW more power at the same flows (1,427 MWh per year, about USD 114,186 per year).

ℹ️ **Note**

Sensitivity: drawing 10 % more steam at extraction 1 (and less to the exhaust) changes the power by -91 kW.

ℹ️ **Note**

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WHAT-IF — EXHAUST PRESSURE (same flows and efficiencies)

Case	Pressure	Power	Change	Dryness, %	Exhaust T
Exhaust pressure × 0.60	2.100	10,993.0	+830.5	100.0	148.1
Exhaust pressure × 0.70	2.450	10,749.8	+587.3	100.0	158.2
Exhaust pressure × 0.80	2.800	10,535.2	+372.6	100.0	167.1
Exhaust pressure × 0.90	3.150	10,340.9	+178.4	100.0	175.1
Exhaust pressure × 1.00	3.500	10,162.5	0.0	100.0	182.5
Exhaust pressure × 1.10	3.850	9,997.2	-165.3	100.0	189.4
Exhaust pressure × 1.25	4.375	9,769.6	-393.0	100.0	198.8
Exhaust pressure × 1.50	5.250	9,432.8	-729.8	100.0	212.8
Exhaust pressure × 2.00	7.000	8,871.3	-1,291.2	100.0	236.0

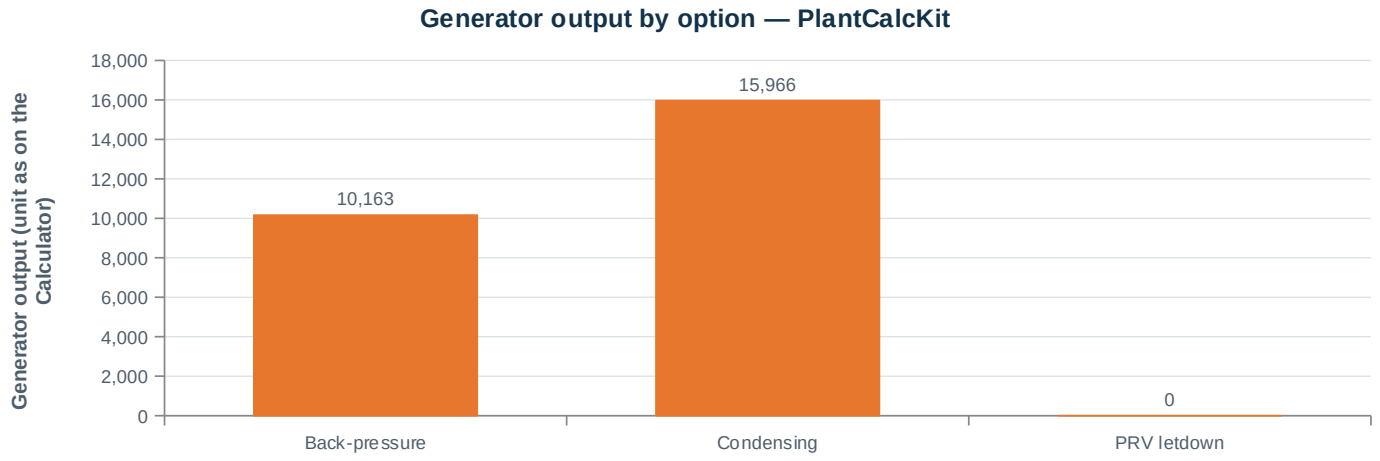
WHAT-IF — EXTRACTION 1 PRESSURE

Case	Pressure	Power	Change	Dryness, %	Exhaust T
Extraction 1 pressure × 0.60	12.00	10,558.0	+395.5	100.0	180.7
Extraction 1 pressure × 0.75	15.00	10,400.8	+238.3	100.0	181.2
Extraction 1 pressure × 0.90	18.00	10,254.5	+92.0	100.0	182.0
Extraction 1 pressure × 1.00	20.00	10,162.5	0.0	100.0	182.5
Extraction 1 pressure × 1.10	22.00	10,074.6	-87.9	100.0	183.1
Extraction 1 pressure × 1.25	25.00	9,949.6	-212.9	100.0	184.1
Extraction 1 pressure × 1.50	30.00	9,757.1	-405.4	100.0	185.6

WHAT-IF — EXTRACTION 1 FLOW (same inlet flow)

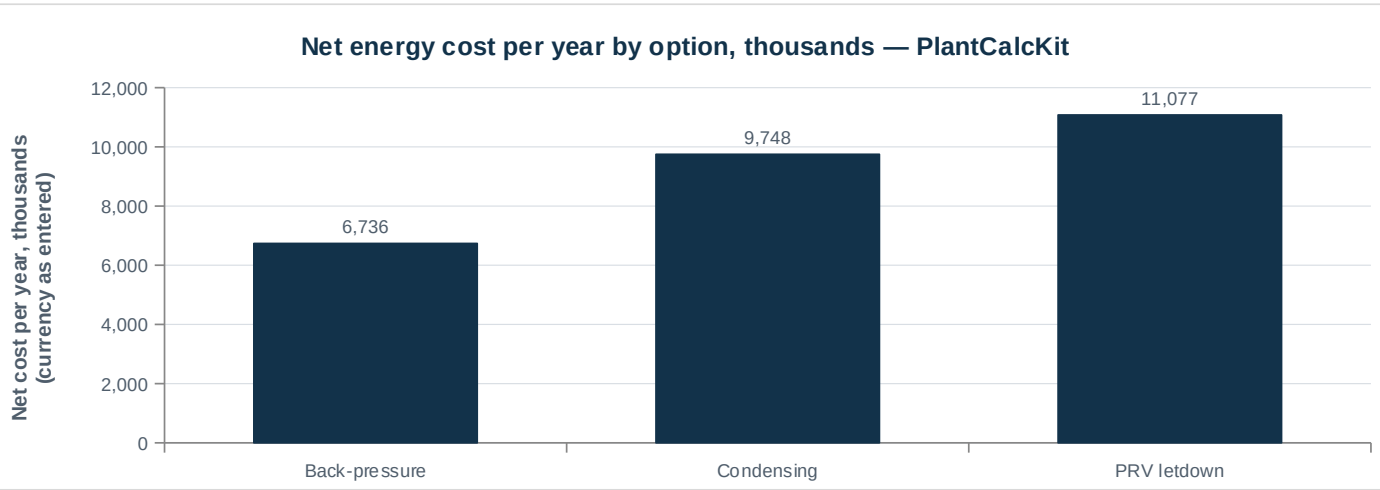
Case	Extraction flow	Exhaust flow	Power	Change	Minimum flow
Extraction 1 flow × 0.00	0	62,000	11,076.8	+914.3	no minimum set
Extraction 1 flow × 0.50	6,000	56,000	10,619.7	+457.1	no minimum set
Extraction 1 flow × 0.75	9,000	53,000	10,391.1	+228.6	no minimum set
Extraction 1 flow × 1.00	12,000	50,000	10,162.5	0.0	no minimum set
Extraction 1 flow × 1.25	15,000	47,000	9,934.0	-228.6	no minimum set
Extraction 1 flow × 1.50	18,000	44,000	9,705.4	-457.1	no minimum set
Extraction 1 flow × 2.00	24,000	38,000	9,248.2	-914.3	no minimum set

CHARTS



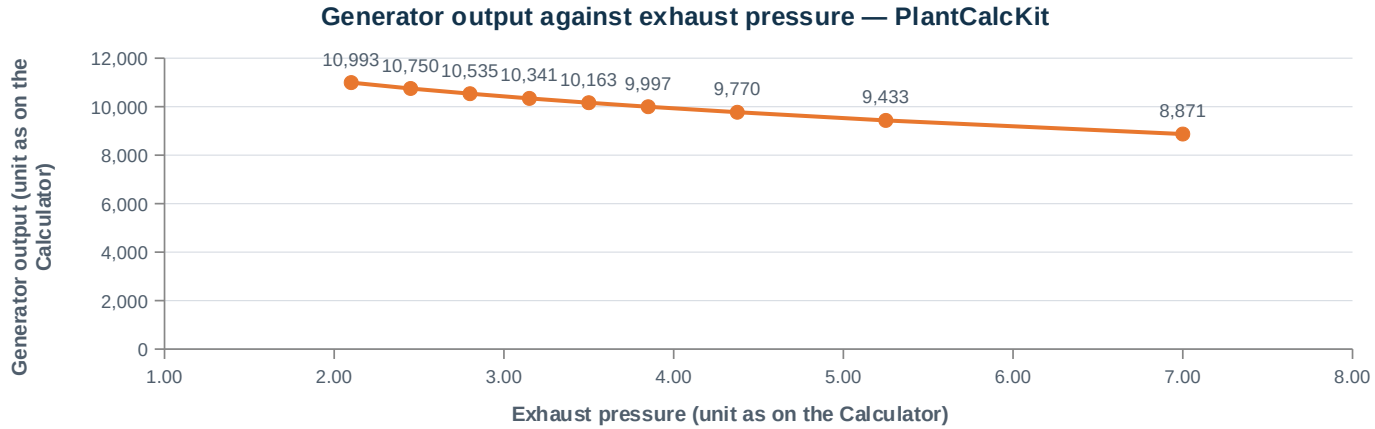
Observations — generator output by option

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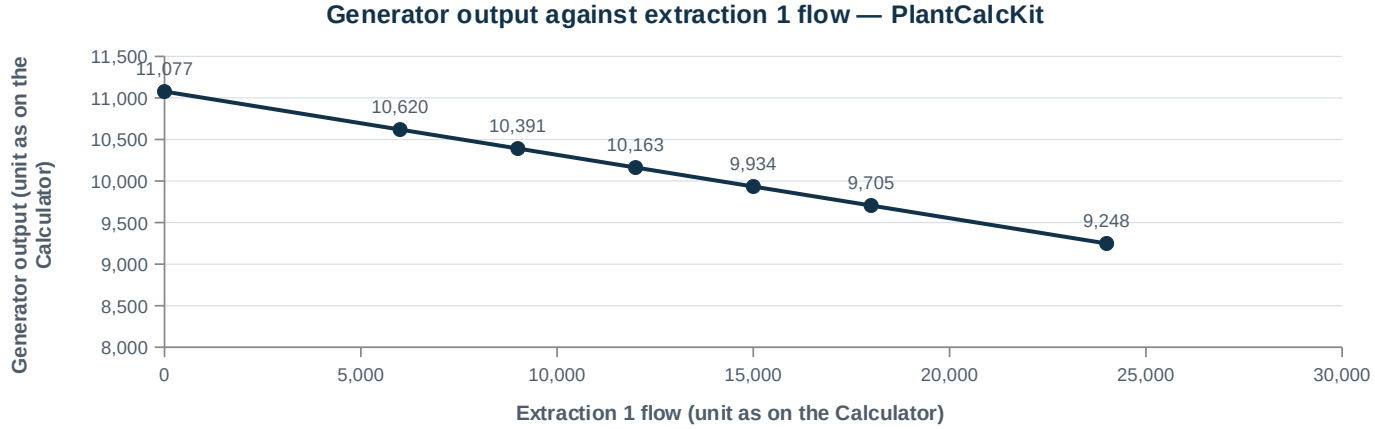
Observations — net energy cost by option

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Observations — exhaust pressure

[Write your observations here]



Observations — extraction flow

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