Overview of Power Plant Design

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Dr.-Ing. Ir. Nasruddin, M.Eng

Course: Operators of Geothermal Powerplants

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Dr.-Ing. Ir. Nasruddin, M.Eng – FT UI

2001 - 2005 **RWTH AACHEN – GERMANY**
Mechanical Engineering

1997 - 1999 **K.U. LEUVEN – BELGIUM**
Mechanical Engineering

1990 - 1995 **UNIVERSITY OF INDONESIA**
Mechanical Engineering

nasruddin@eng.ui.ac.id 0815 8593 5355

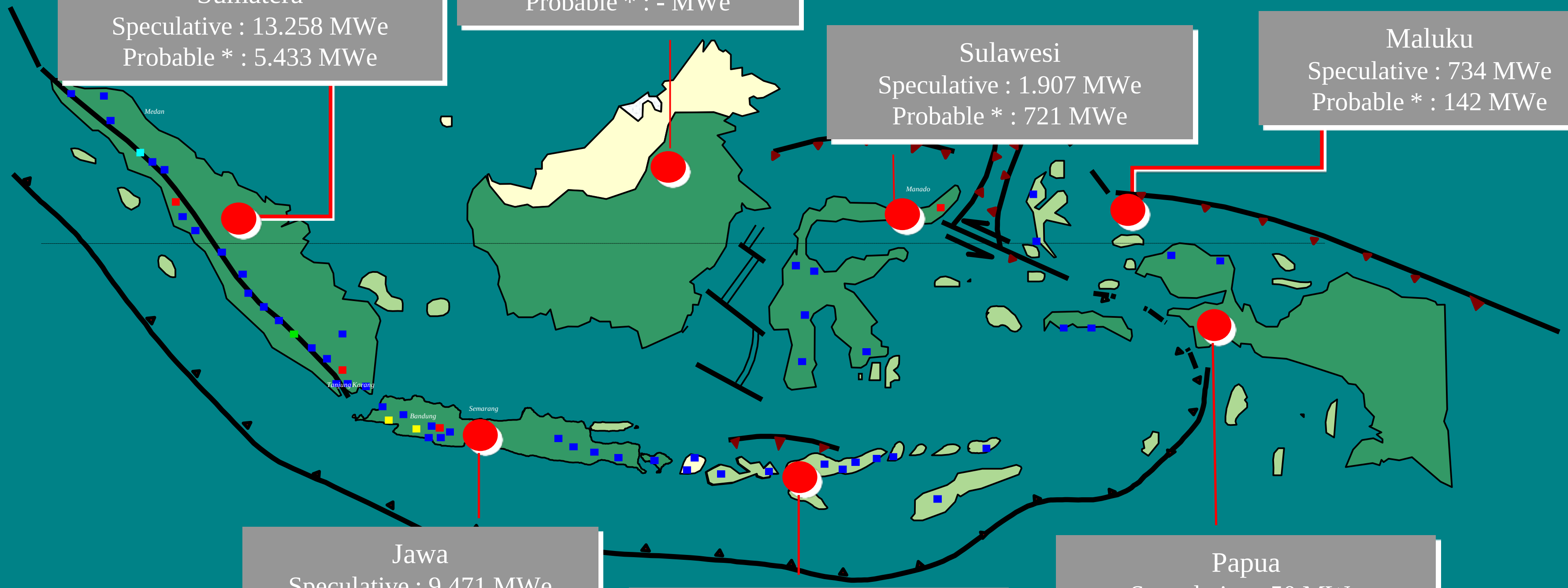
"The First Law of thermodynamics says you can't get something for nothing; the Second Law says you can't even break even."

Anonymous

List of Geothermal Power Plant in Indonesia

Speculative : 27.141 MW
Probable : 10.253 MW

Current Installed Capacity : 1,337 MW



Sumatera
Speculative : 13.258 MWe
Probable * : 5.433 MWe

Borneo
Speculative : 45 MWe
Probable * : - MWe

Sulawesi
Speculative : 1.907 MWe
Probable * : 721 MWe

Maluku
Speculative : 734 MWe
Probable * : 142 MWe

Jawa
Speculative : 9.471 MWe
Probable * : 3.086 MWe

Bali & NTT
Speculative : 1.676 MWe
Probable * : 871 MWe

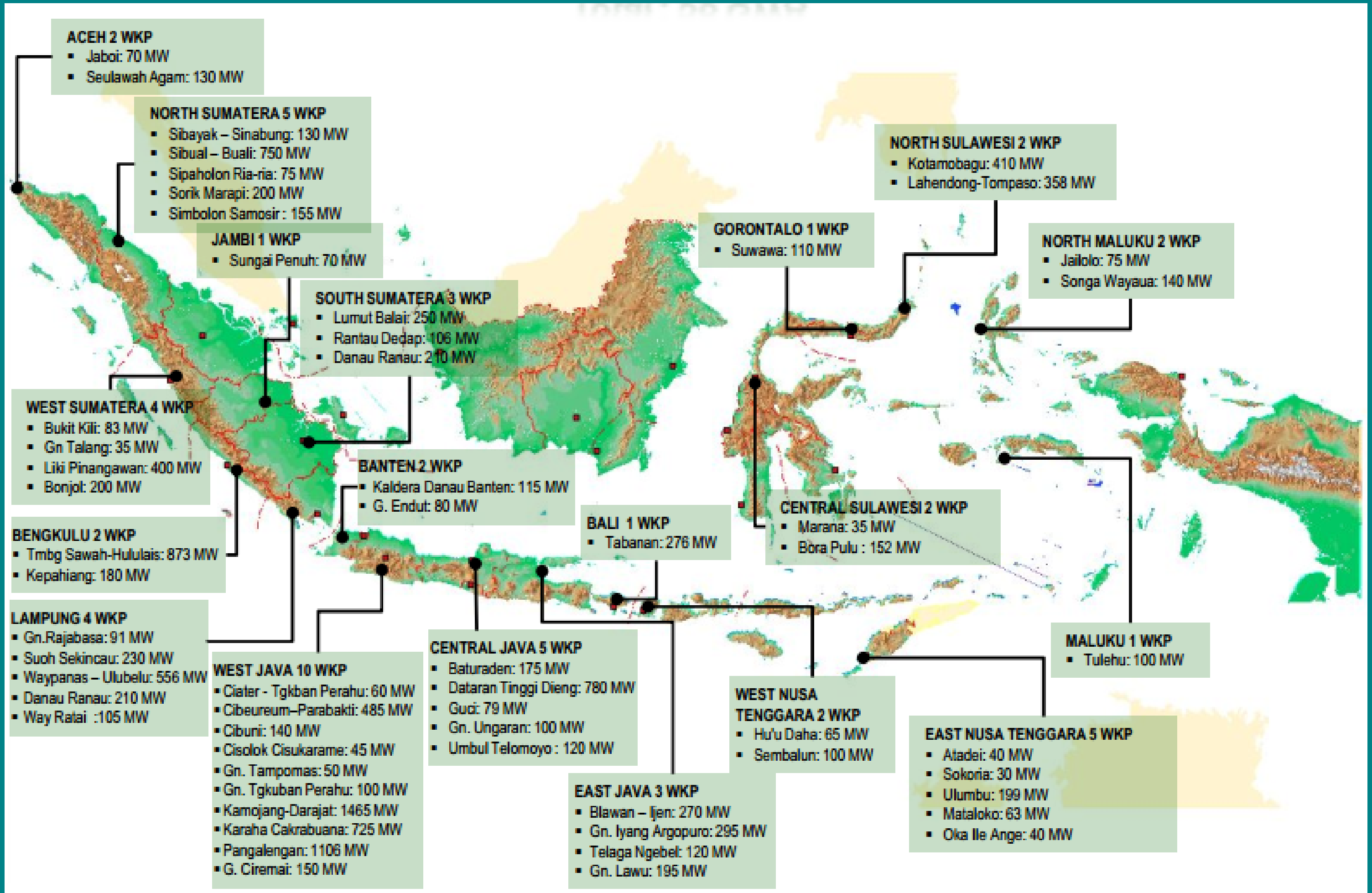
Papua
Speculative : 50 MWe
Probable * : - MWe

Geothermal location

Gambar 1. Potensi Energi Panas Bumi di Indonesia

(Sumber: Sigit Rahardjo, 2013)

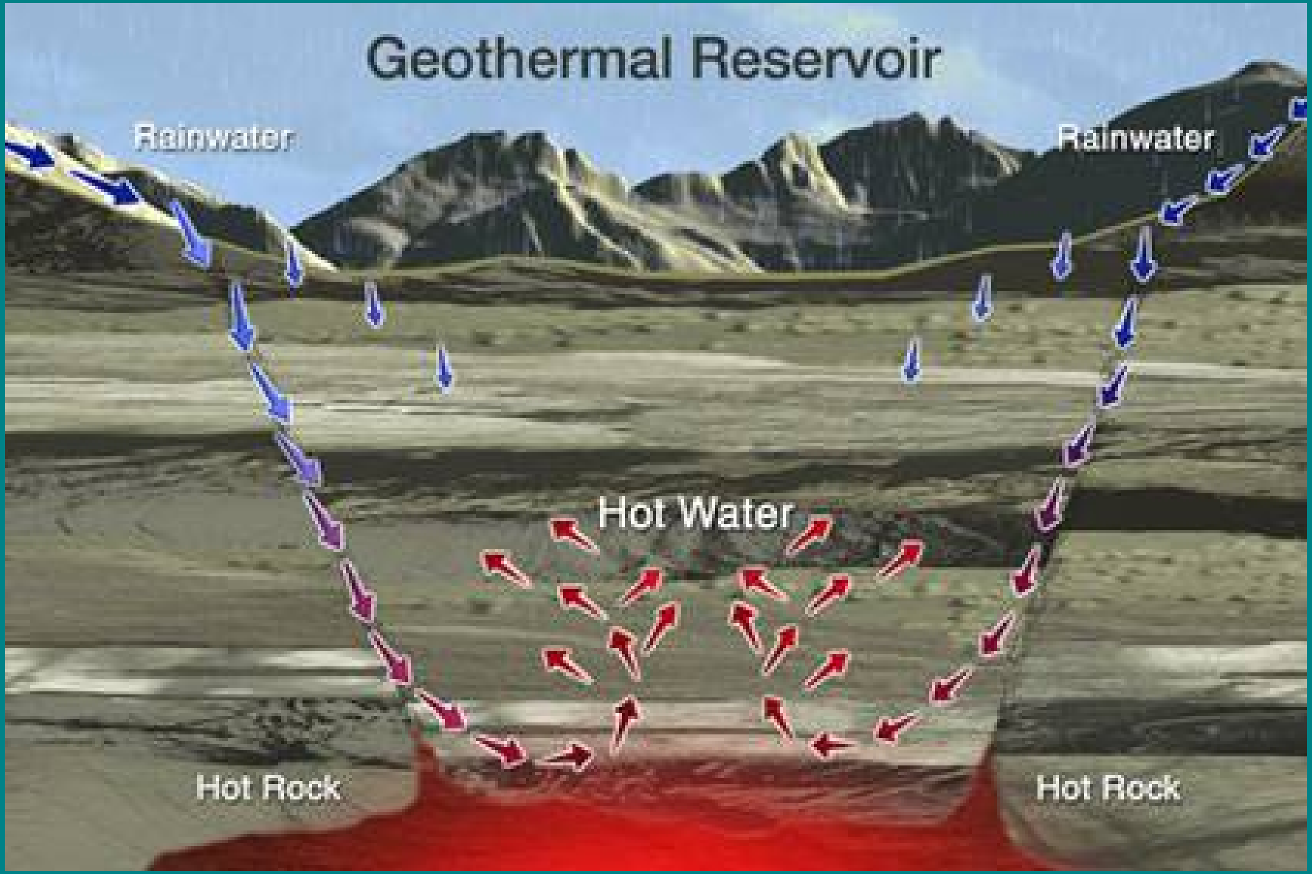
List of Geothermal Power Plant in Indonesia



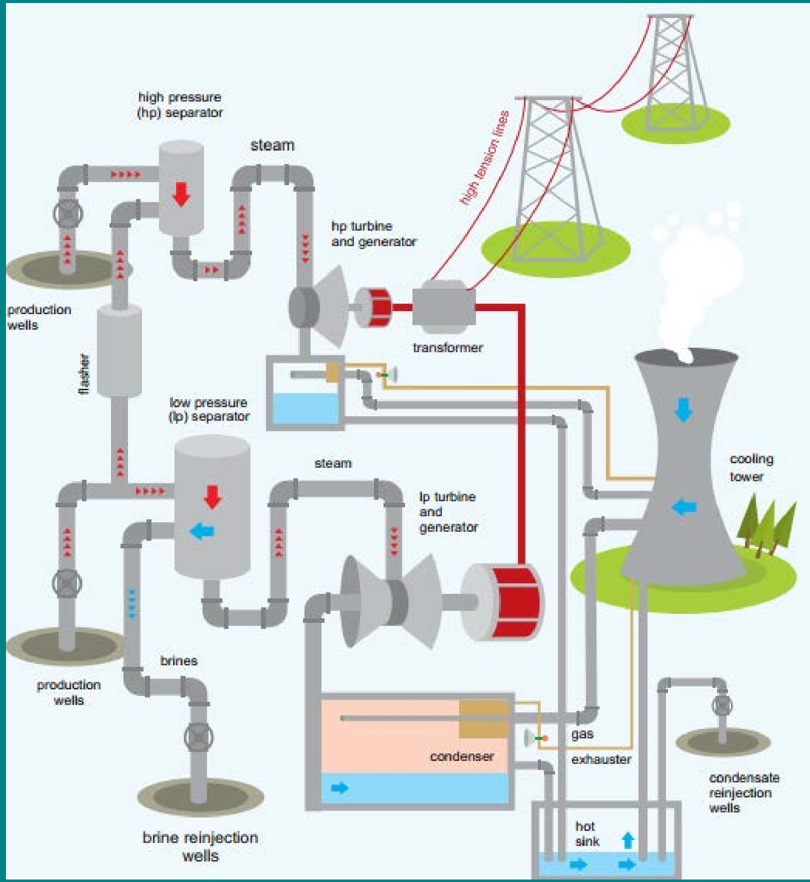
Gambar 2. Potensi Energi Panas Bumi di Indonesia

(Sumber: Jarman, 2012)

List of Geothermal Power Plant in Indonesia



Gambar 3. Model Reservoir Panas Bumi
(Sumber: *Geothermal Education Office* – US)

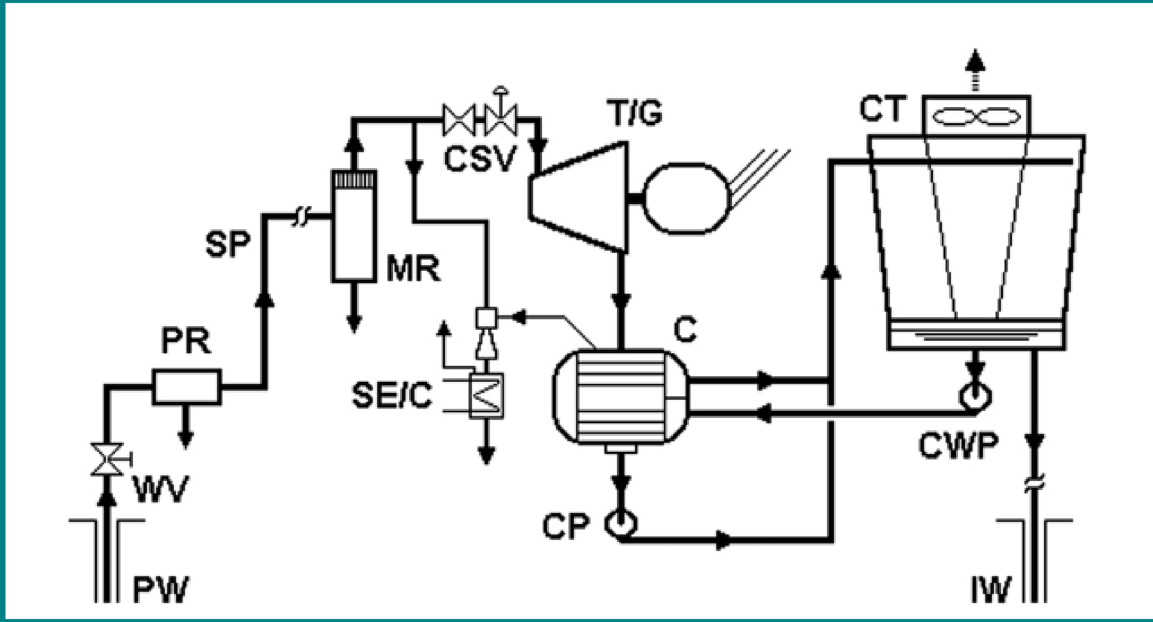


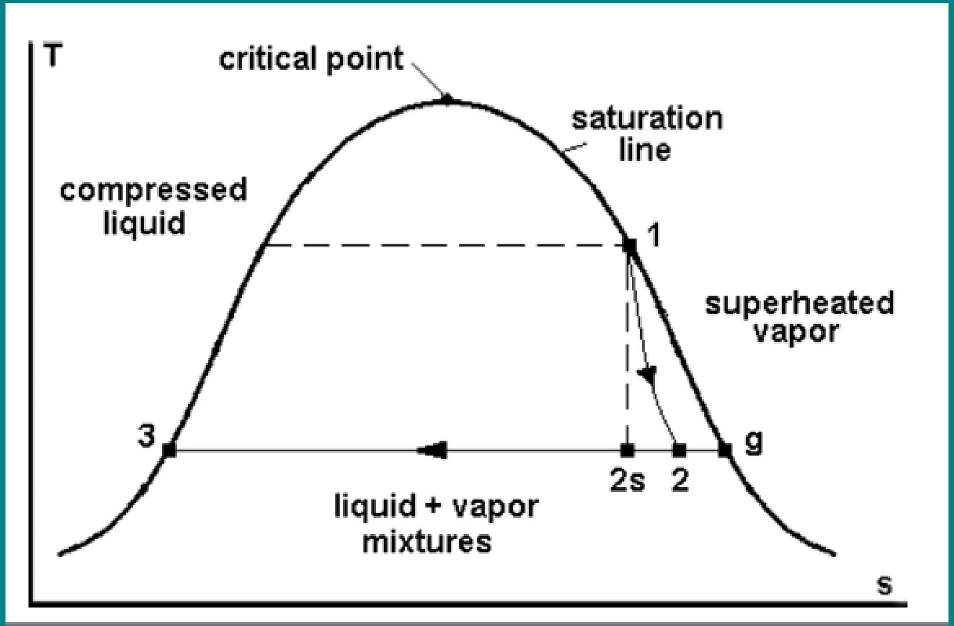
Gambar 4. Diagram Skema Pemanfaatan Tidak Langsung Energi Panas Bumi (Sumber: Modul Pelatihan Panas Bumi oleh WWF-Indonesia)

Steam Cycle System

Dry Steam System

Steam vapor dominated, generated from several production wells & circulated by pipes to the turbine. Example: Kamojang





Steam Cycle System

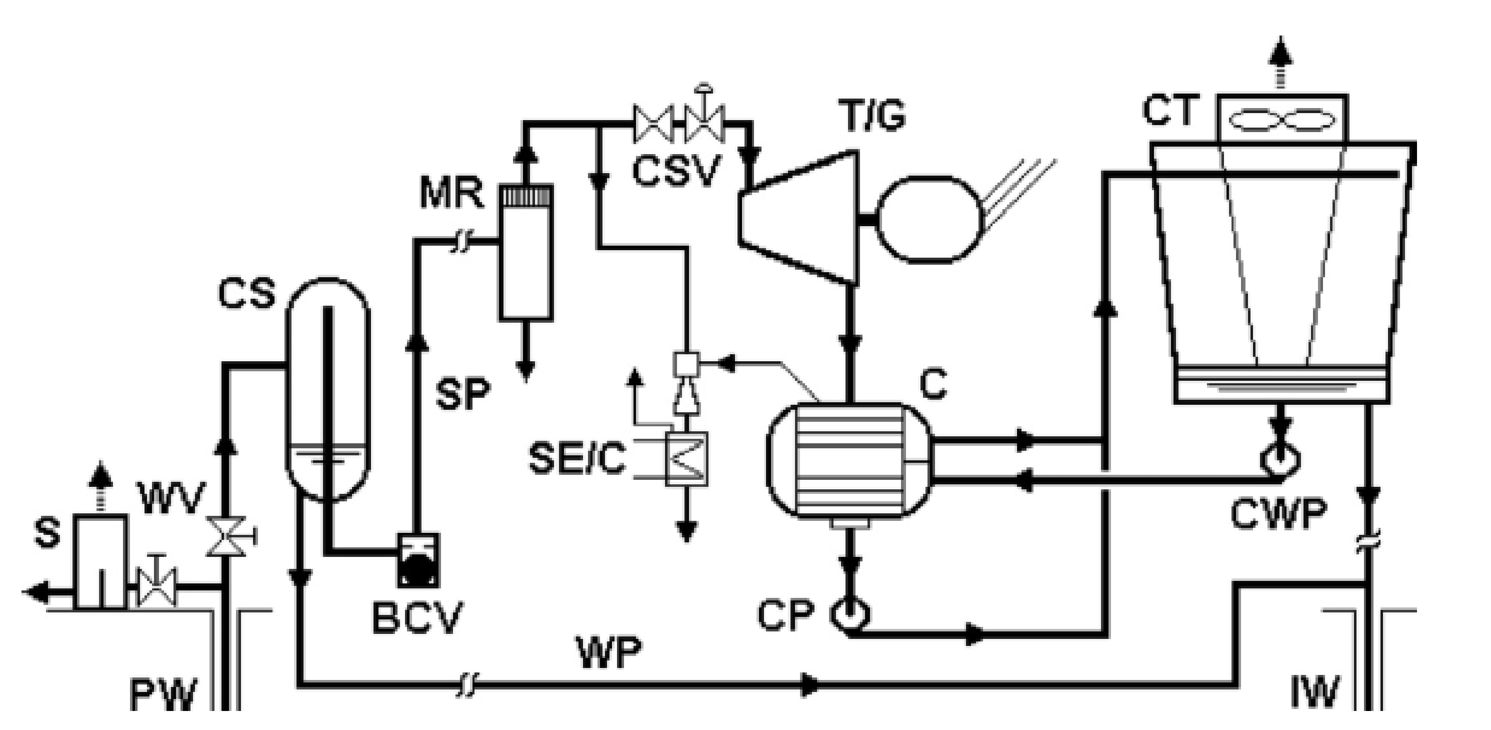
Flash Steam Cycle

- Uses fluid from geothermal reservoir in the form of **vapor-liquid mixture**.
- The liquid must be separated from steam, because it can damaged the turbine.
- There are 2 common types of flash steam cycle :
  - Single flash steam cycle
  - Double flash steam cycle

Steam Cycle System

- **Single Flash Steam Cycle**

Account for 43% of total installed GP capacity in the world. Example : Dieng, Lahendong.



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Steam Cycle System

Single Flash Steam Cycle

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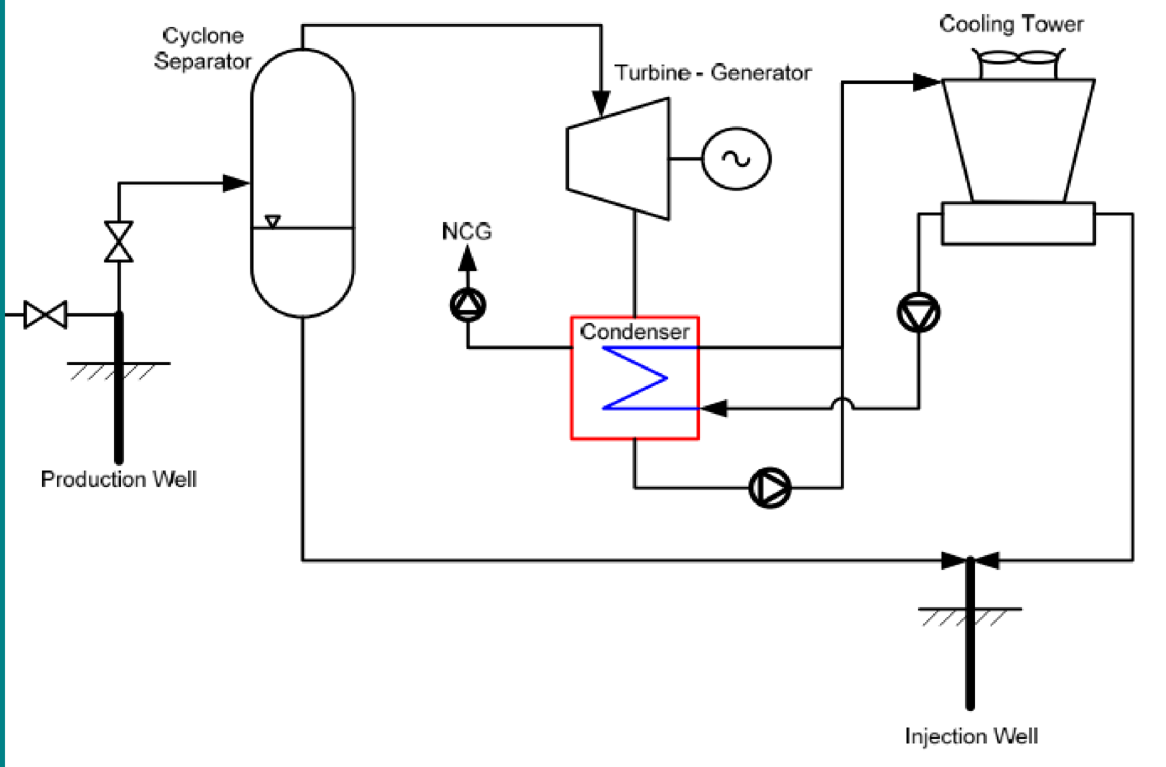

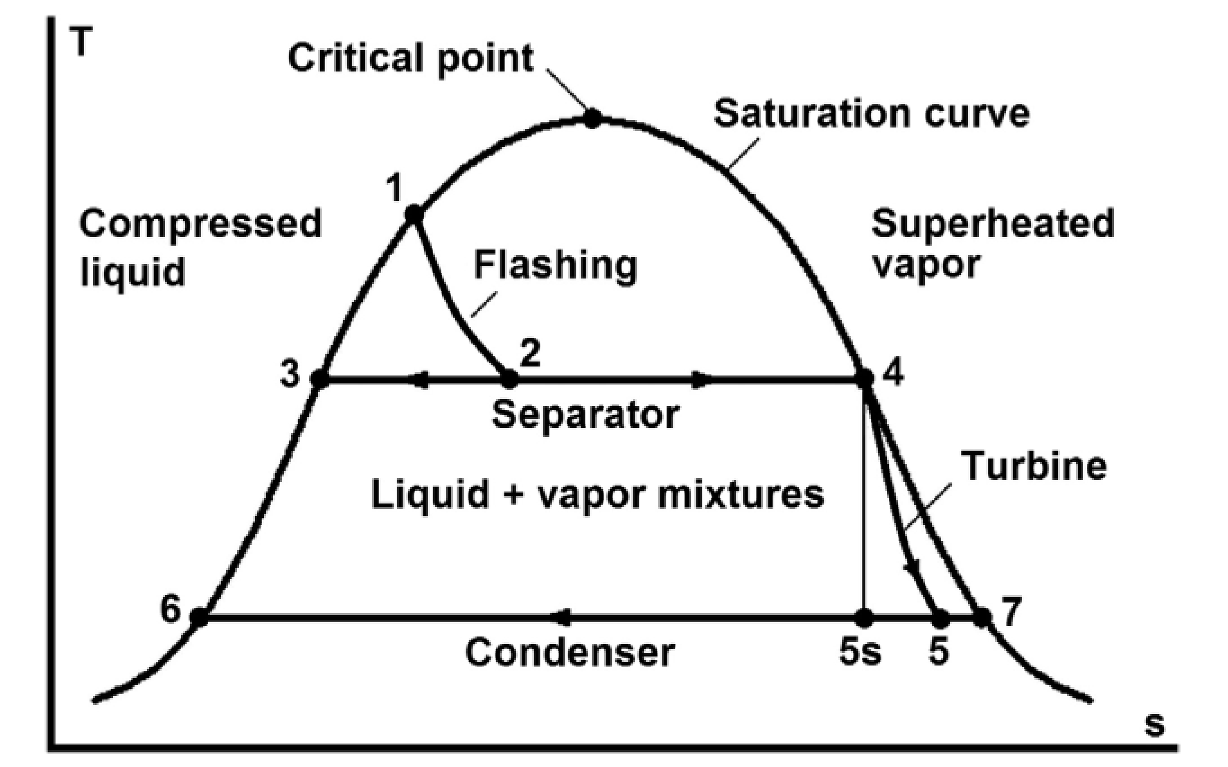

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Steam Cycle System

Double Flash Steam Cycle

Improvement of single-flash can produce 15-20% more power on same geothermal fluid conditions.

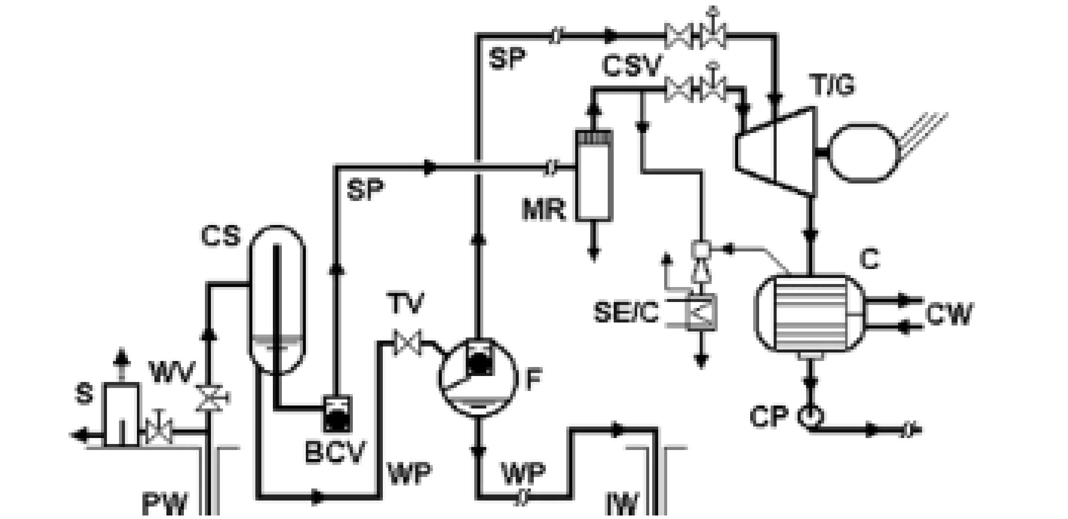

Figure 6.6 Simplified double-flash power plant schematic.

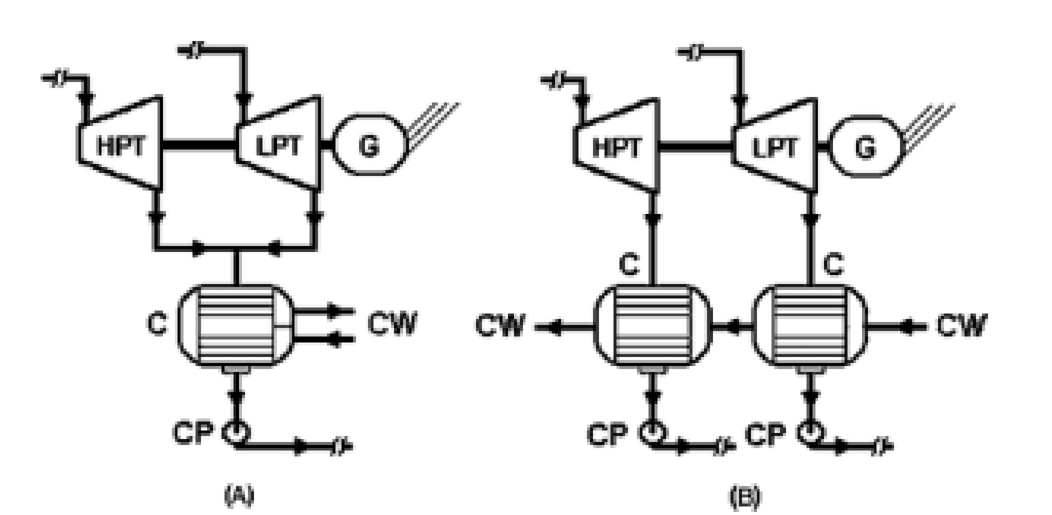

Figure 6.7 Double-flash plant with separate high- and low-pressure turbines.

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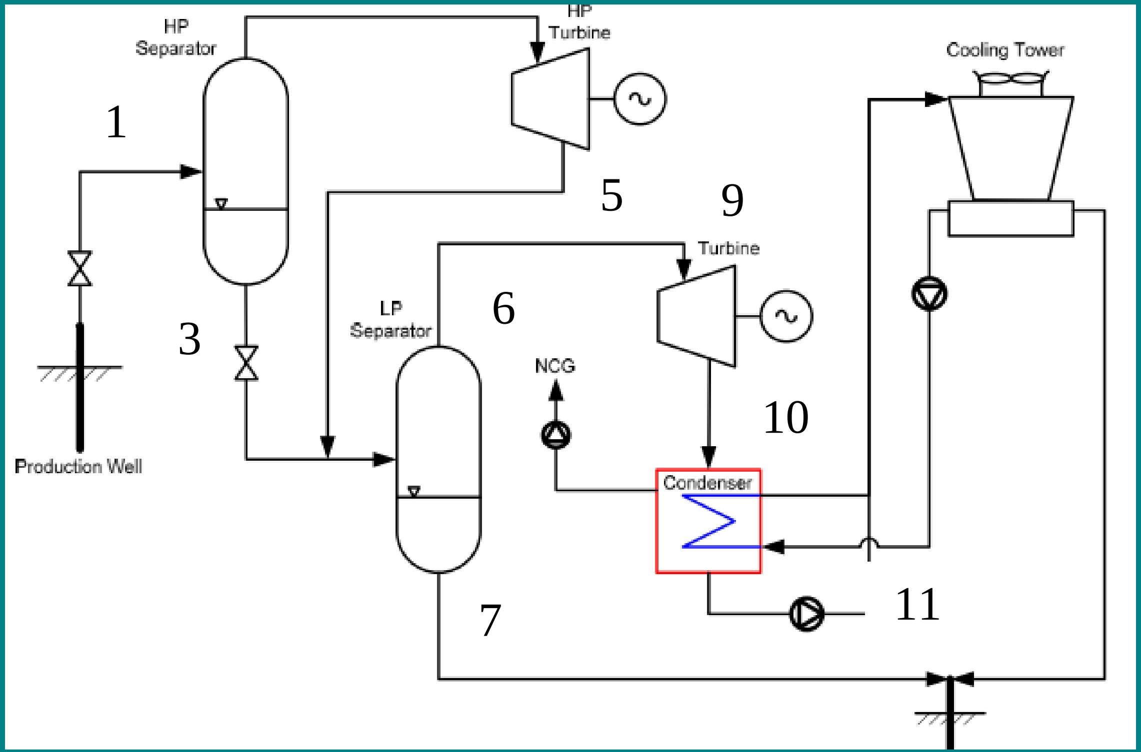
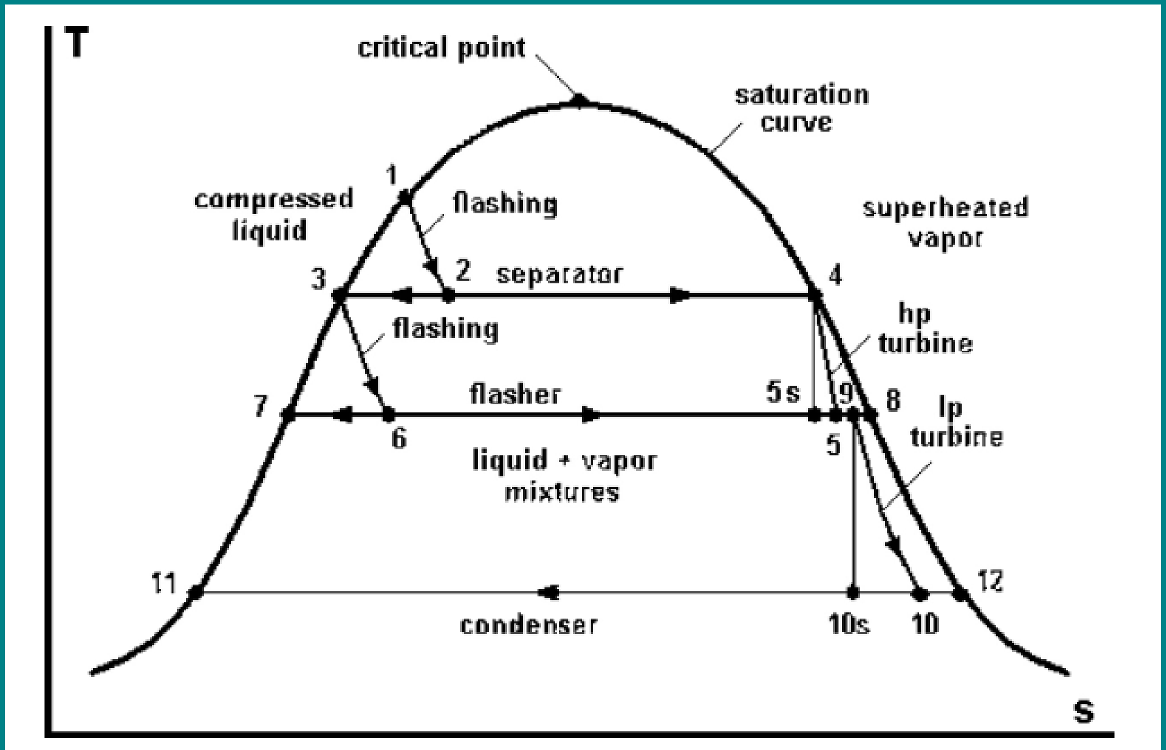
Steam Cycle System

Double Flash Steam Cycle





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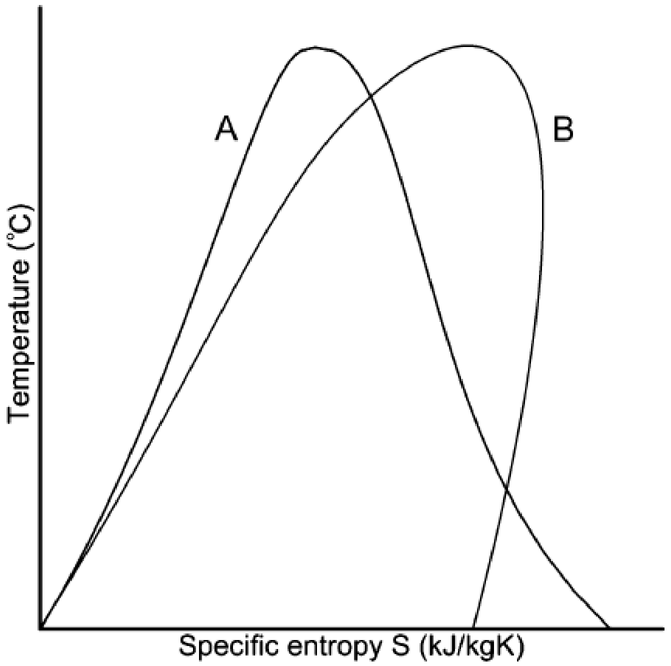
Steam Cycle Sytem

Binary Cycle: Organic Rankine Cycle (ORC)

- A promising technology when low temp. geothermal resource cannot drive steam turbine directly or contaminated with dissolved gasses or corrosive minerals.
- Organic Rankine Cycle (ORC) uses a secondary liquid for delivering energy from geothermal fluid to the application.
- Works in a closed loop working fluid system
- Commonly used as bottoming unit in a flash steam plant to utilize low grade thermal energy from waste brine.

- An isentropic expansion of saturated vapour results in a wet mixture at turbine exit for H2O and a superheated vapour for working fluid B, provided that the expansion starts at a suitable temperature. This removes concern about blade erosion by droplets
- The slope of the liquid side of the envelope is less steep for B than for water so the departure from the Carnot cycle is greater for the organic fluid, which, taken in isolation, would tend to make regenerative heating more attractive than for steam Rankine cycles.
- The saturation envelope for B is fairly wide near its summit, which is beneficial in maximising the proportion of heat added during evaporation and helping to reduce the effect of departure from the Carnot cycle resulting from heating in the liquid state

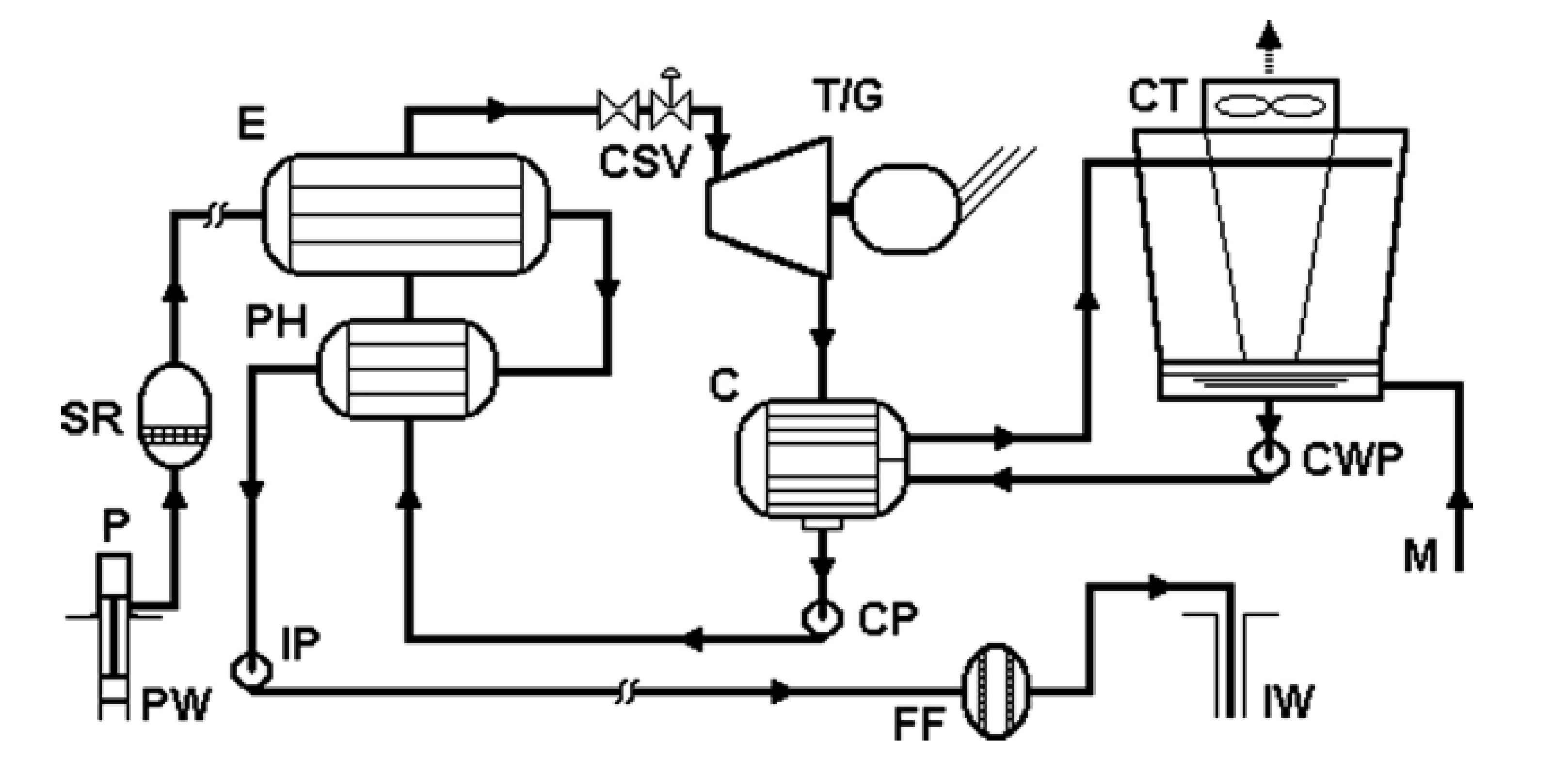
Fig. 11.17 Comparison of the general shapes of T–s envelopes: (A) for water and (B) a sketch representing some organic working fluids, including isopentane. The envelopes are not drawn to scale or placed in their correct relative positions on the axes



- At30 C, a suitable temperature for rejection of heat to the environment and thus the lowest temperature potentially required in the cycle, the saturation pressure of isopentane, in particular, is approximately 1 bar abs. This is mechanically convenient as the condenser leakage potential is minimised.
- The density of gaseous organic fluid is high, which leads to a comparatively smaller turbine for a given output—the rate of transfer of momentum in the blades increases with density.
- Choosing an upper temperature of 220 C for separated geothermal water, and a heat rejection temperature of 30 C, the specific volume ratio for saturated vapour, V220/V30, is 382 for water and approximately an order of magnitude lessfor isopentane and other organic fluids. As for density, this too permits many fewer stages for an ORC turbine than for a steam turbine working between the same temperatures
- The velocity of sound in organic fluids is lower than in steam, and turbine blade tip speeds must be kept subsonic. This might require a gearbox between turbine and alternator, to increase the alternator revs/min to synchronous speed.

Steam Cycle Sytem

- **Binary Cycle: Organic Rankine Cycle (ORC)**



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Steam Cycle Sytem

- **Binary Cycle: Organic Rankine Cycle (ORC)**

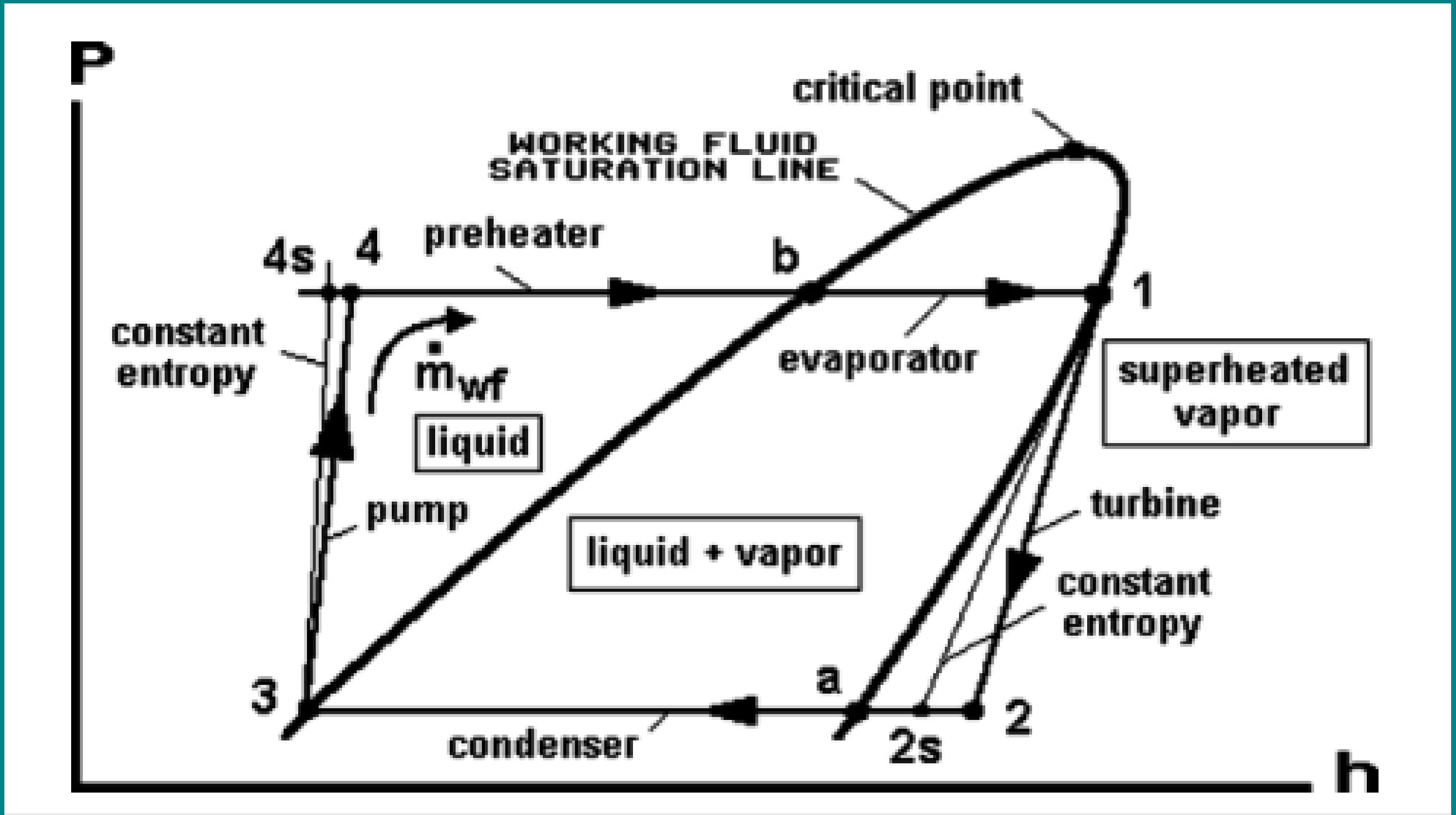

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Table 8.2 Thermodynamic properties of some candidate working fluids for binary plants.

Fluid	Formula	T_c °C	T_c °F	P_c MPa	P_c lbf/in^2	P_s @ 300 K MPa	P_s @ 400 K MPa
Propane	C_3H_8	96.95	206.5	4.236	614.4	0.9935	n.a.
i-Butane	i-C_4H_{10}	135.92	276.7	3.685	534.4	0.3727	3.204
n-Butane	C_4H_{10}	150.8	303.4	3.718	539.2	0.2559	2.488
i-Pentane	i-C_5H_{12}	187.8	370.1	3.409	494.4	0.09759	1.238
n-Pentane	C_5H_{12}	193.9	380.9	3.240	469.9	0.07376	1.036
Ammonia	NH_3	133.65	272.57	11.627	1686.3	1.061	10.3
Water	H_2O	374.14	705.45	22.089	3203.6	0.003536	0.24559

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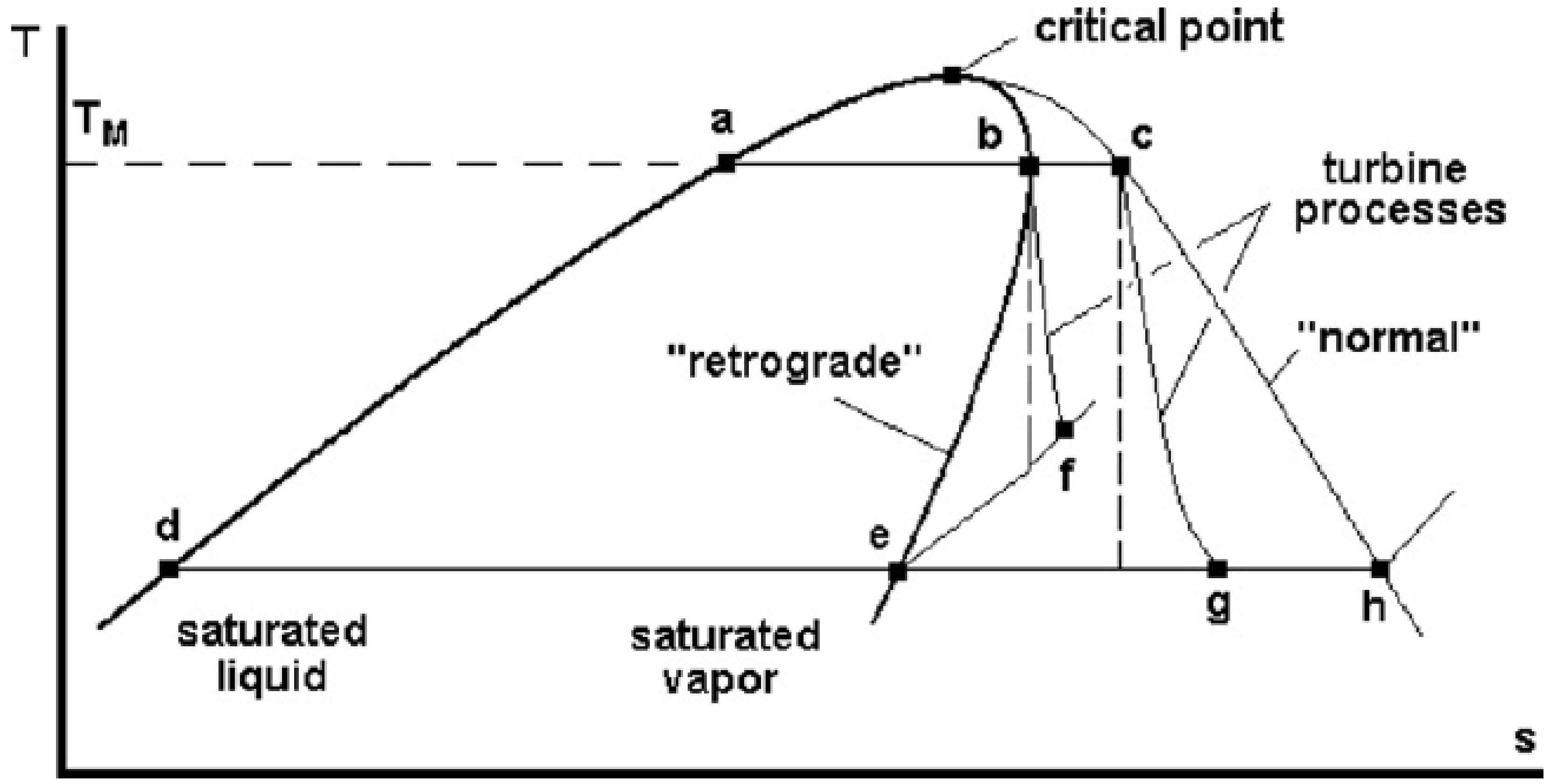

Fig. 8.8 Temperature-entropy diagram contrasting normal and retrograde saturated vapor curves.

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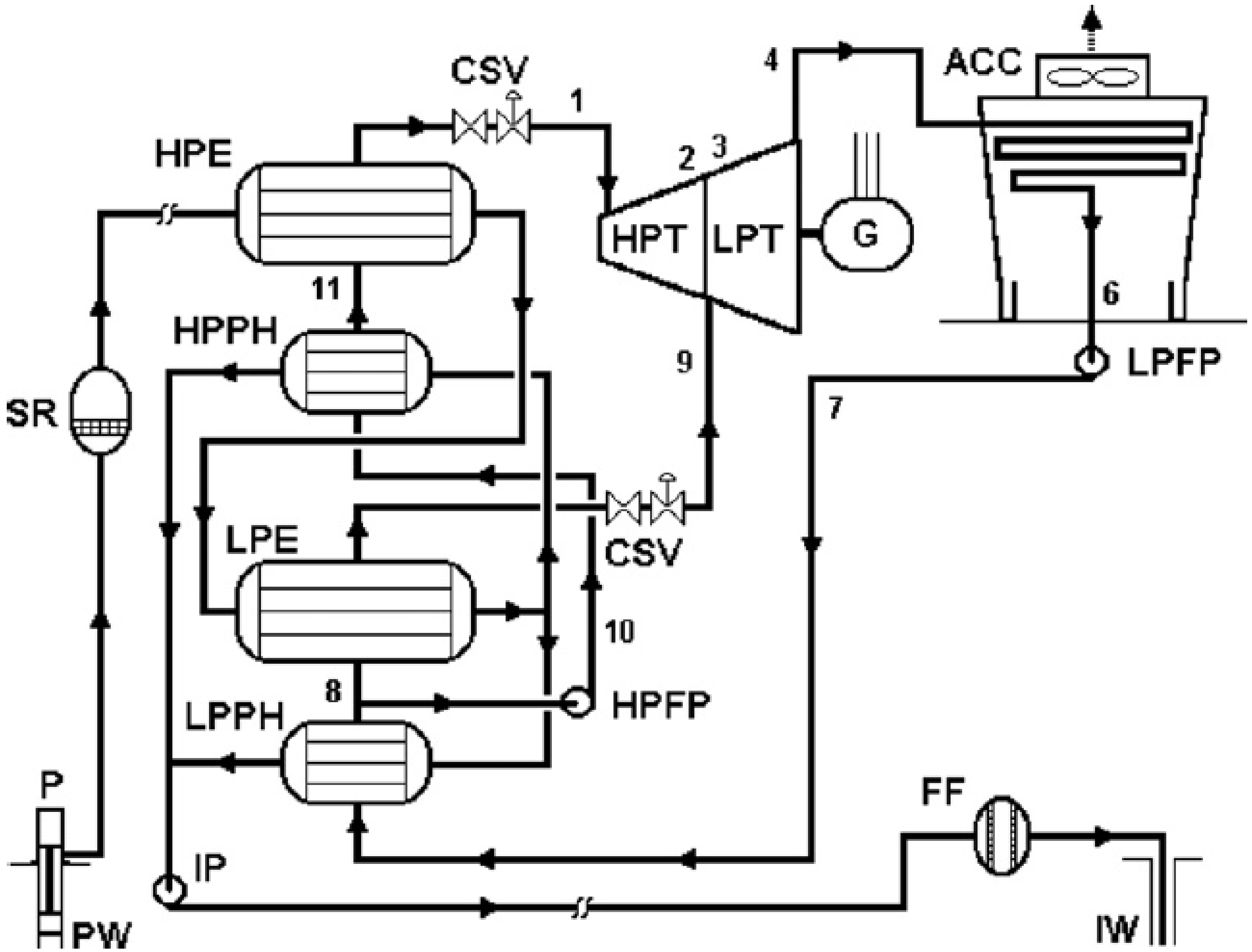

Fig. 8.10 Dual-pressure binary plant: simplified schematic flow diagram.

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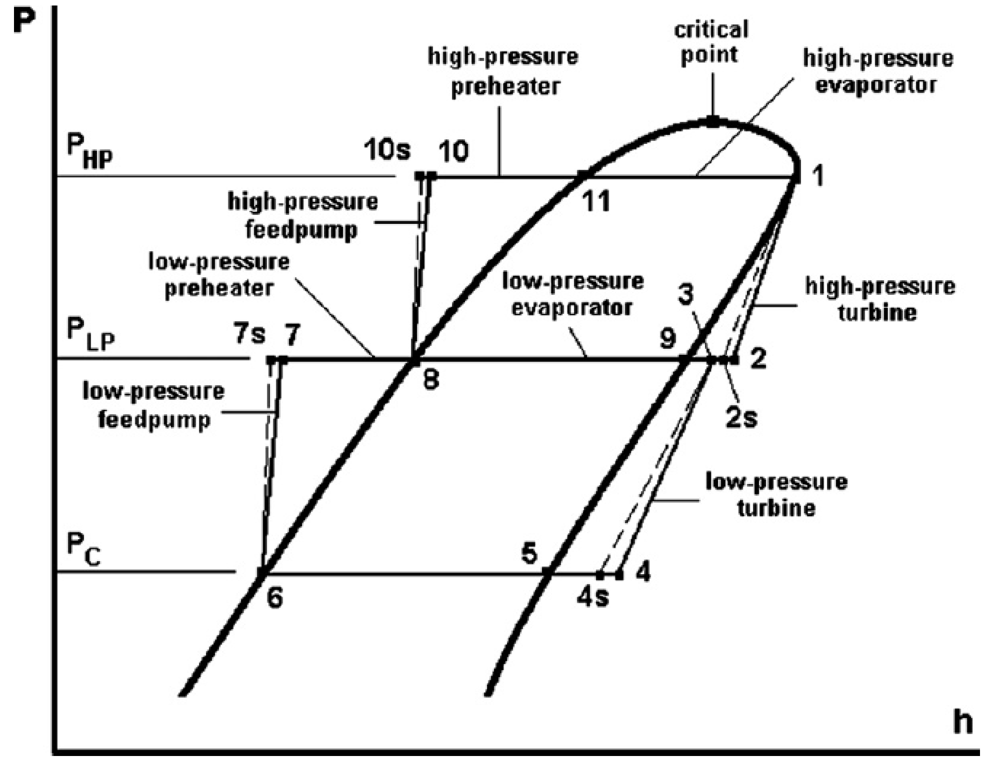

Fig. 8.11 Dual-pressure binary plant: pressure-enthalpy process diagram.

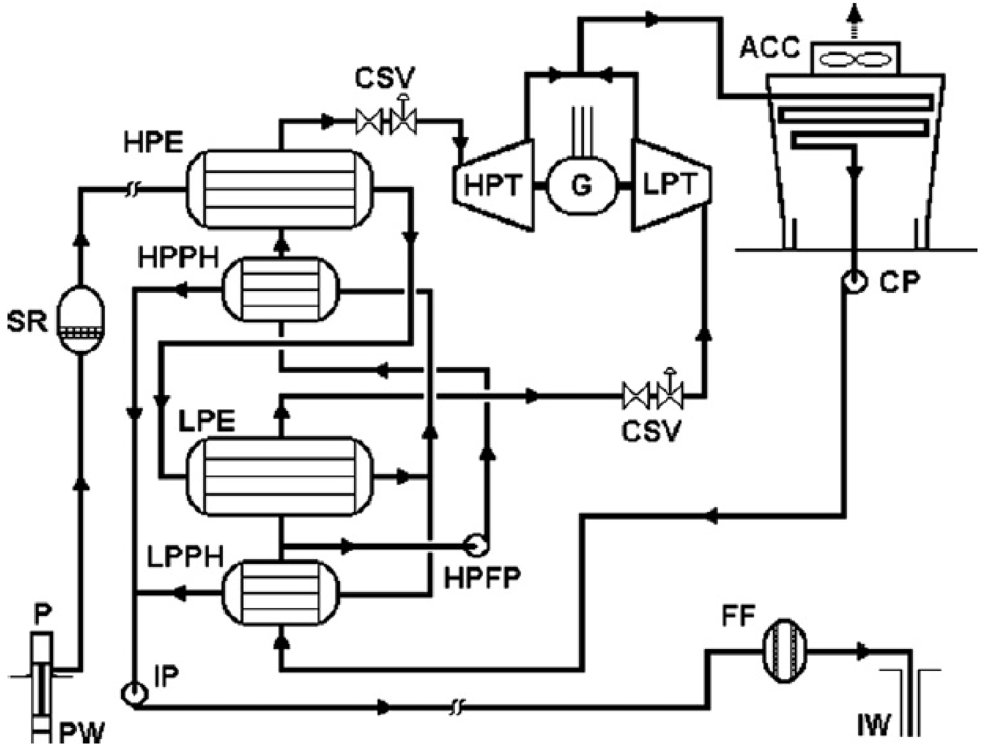

Fig. 8.12 Dual-pressure binary plant: separate high- and low-pressure turbines.

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Table 8.5 Comparison of efficiencies of single- and dual-pressure binary cycles [17].

Working fluid	Brine temperature	Thermal efficiency, %		Utilization efficiency, %	
		Basic	Dual-press	Basic	Dual-press
i-C_4H_{10}	93°C (200°F)	5.5	4.6	31.9	39.7
i-C_5H_{12}	93°C (200°F)	5.2	4.2	30.5	37.0
i-C_4H_{10}	149°C (300°F)	10.3	9.8	48.8	56.9
i-C_5H_{12}	149°C (300°F)	9.8	8.8	44.6	51.5
i-C_5H_{12}	204°C (400°F)	13.7	13.1	57.7	61.2

Note: The condensing and dead-state temperatures were both taken as 38°C (100°F).

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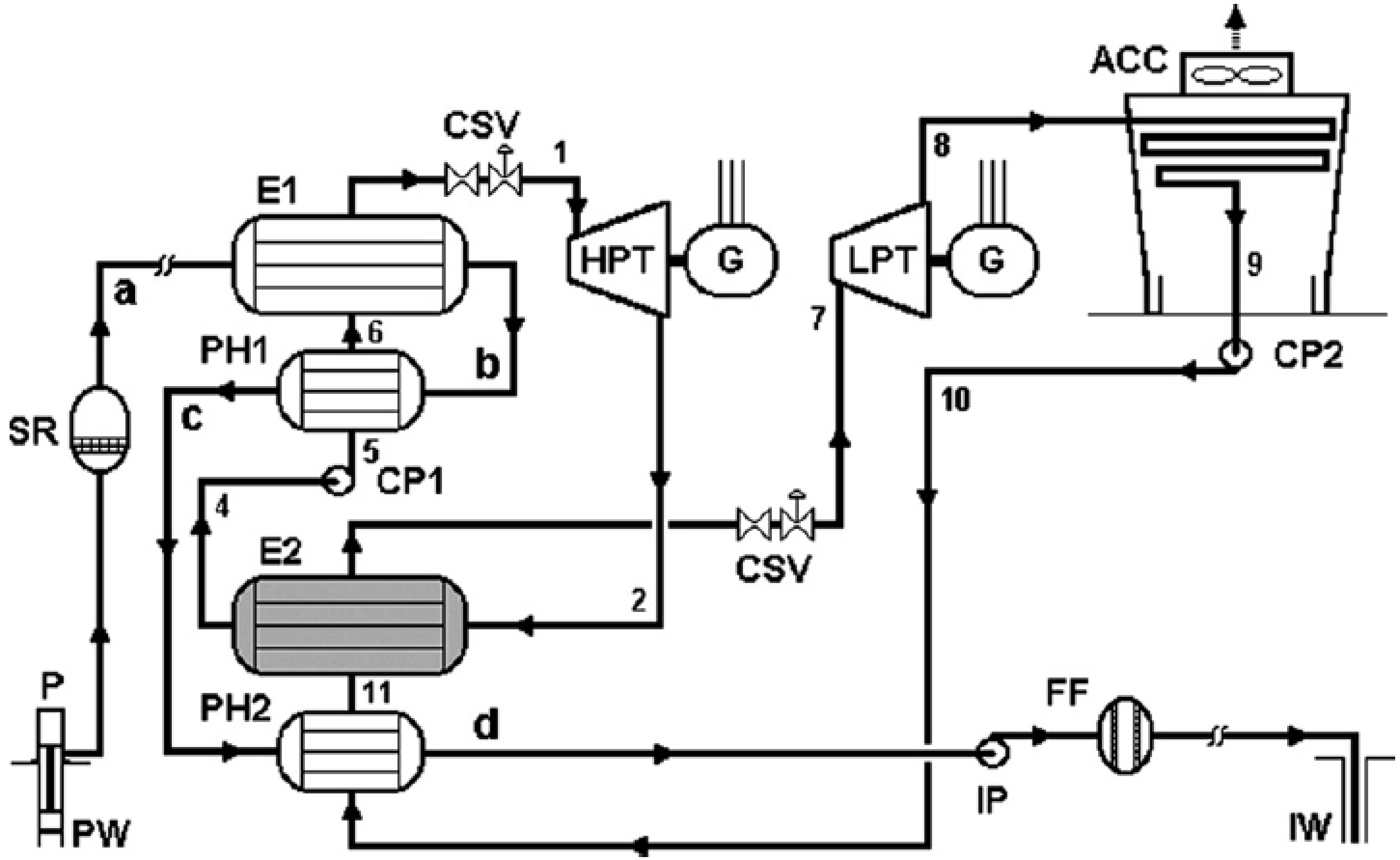

Fig. 8.13 Dual-fluid cascaded binary cycle featuring a heat recuperator.

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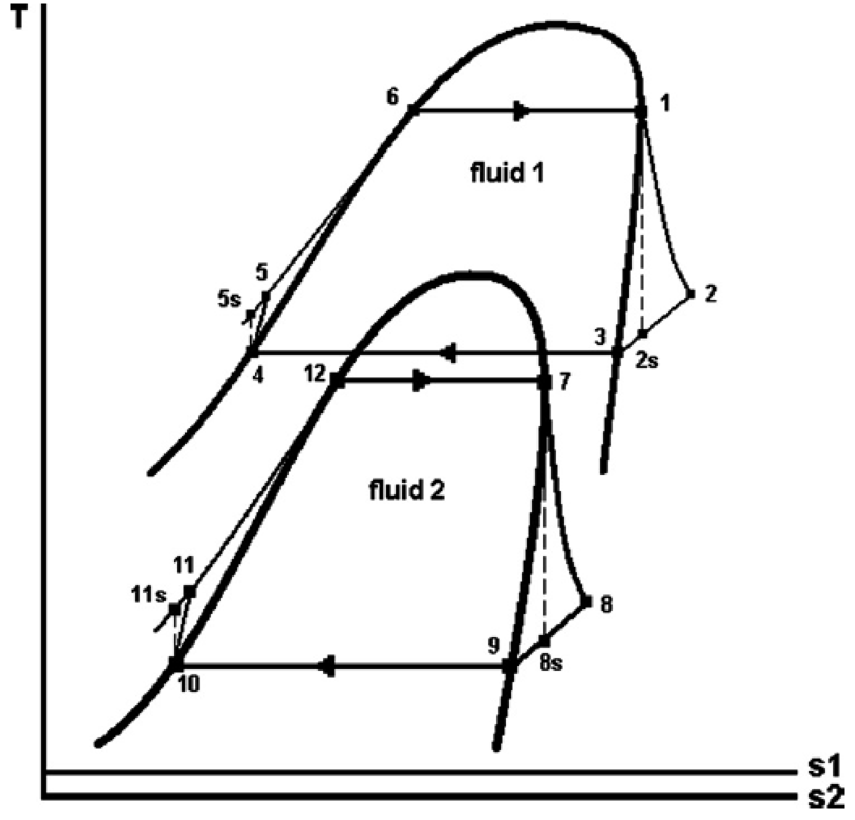

Fig. 8.14 Dual-fluid process diagram in temperature-entropy coordinates.

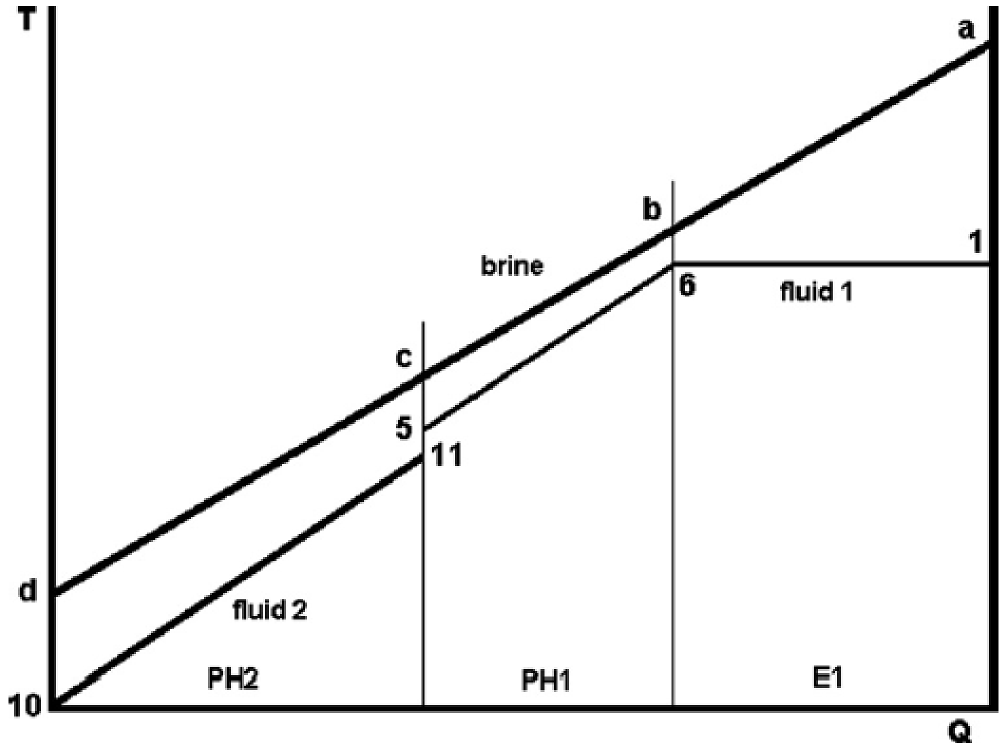

Fig. 8.15 Dual-fluid binary plant: temperature-heat transfer diagram for brine heat exchangers with subcritical working fluid pressures.

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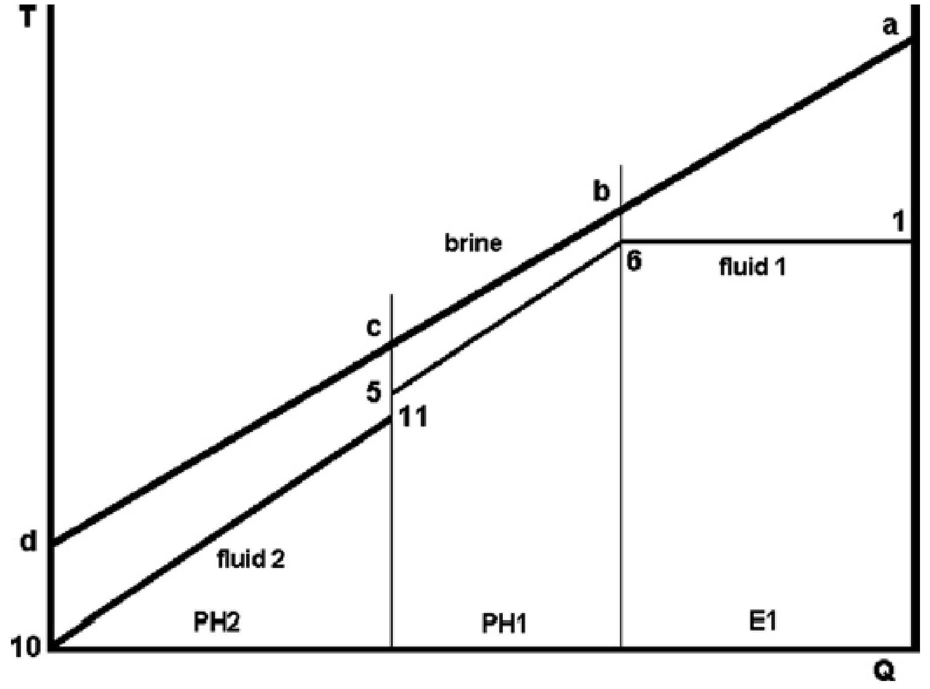

Fig. 8.15 Dual-fluid binary plant: temperature-heat transfer diagram for brine heat exchangers with subcritical working fluid pressures.

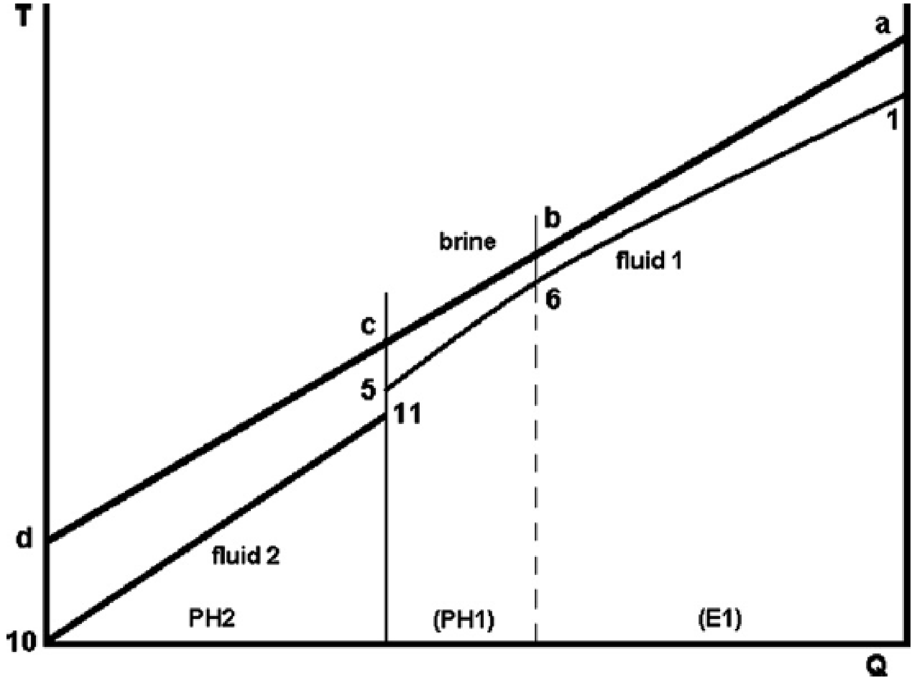

Fig. 8.16 Dual-fluid binary plant: temperature-heat transfer diagram for brine heat exchangers with supercritical pressure for working fluid 1.

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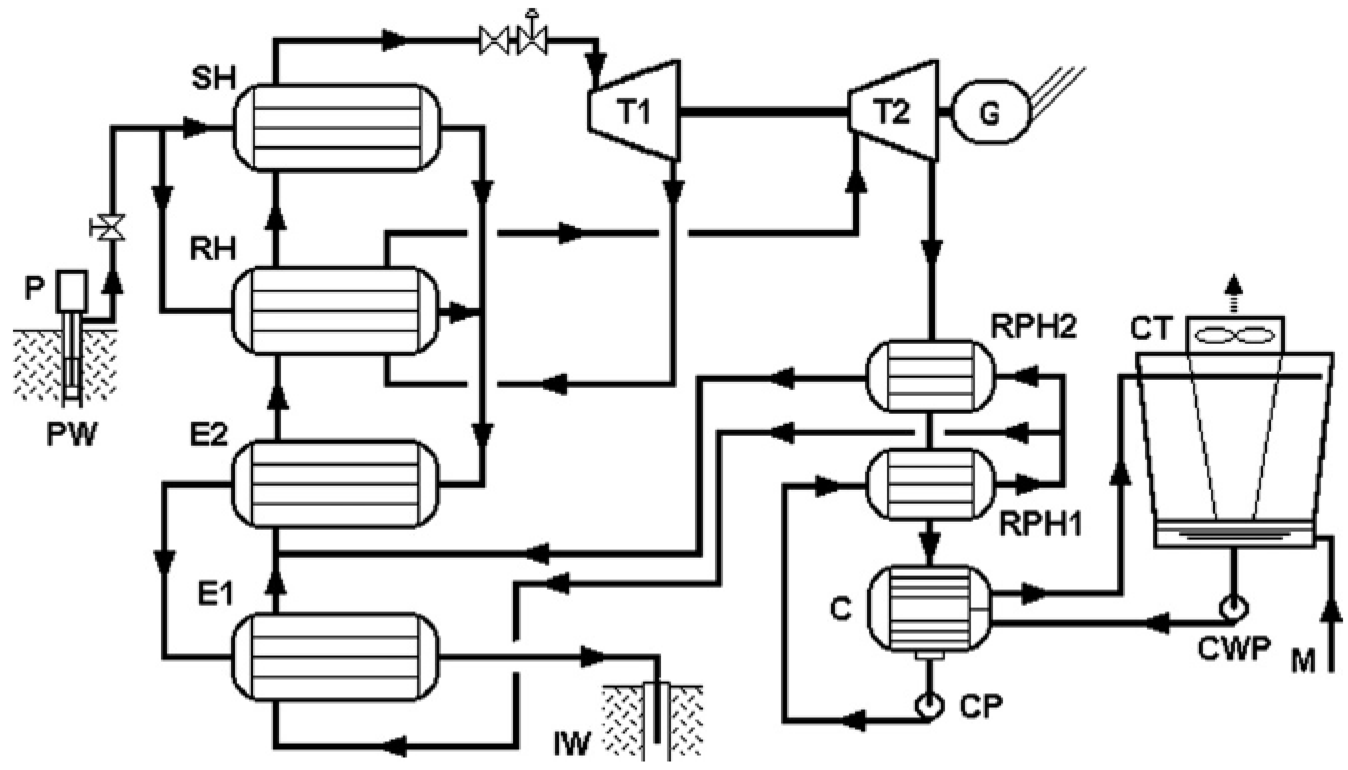

Fig. 8.17 Typical Kalina cycle employing a reheater and two recuperative preheaters.

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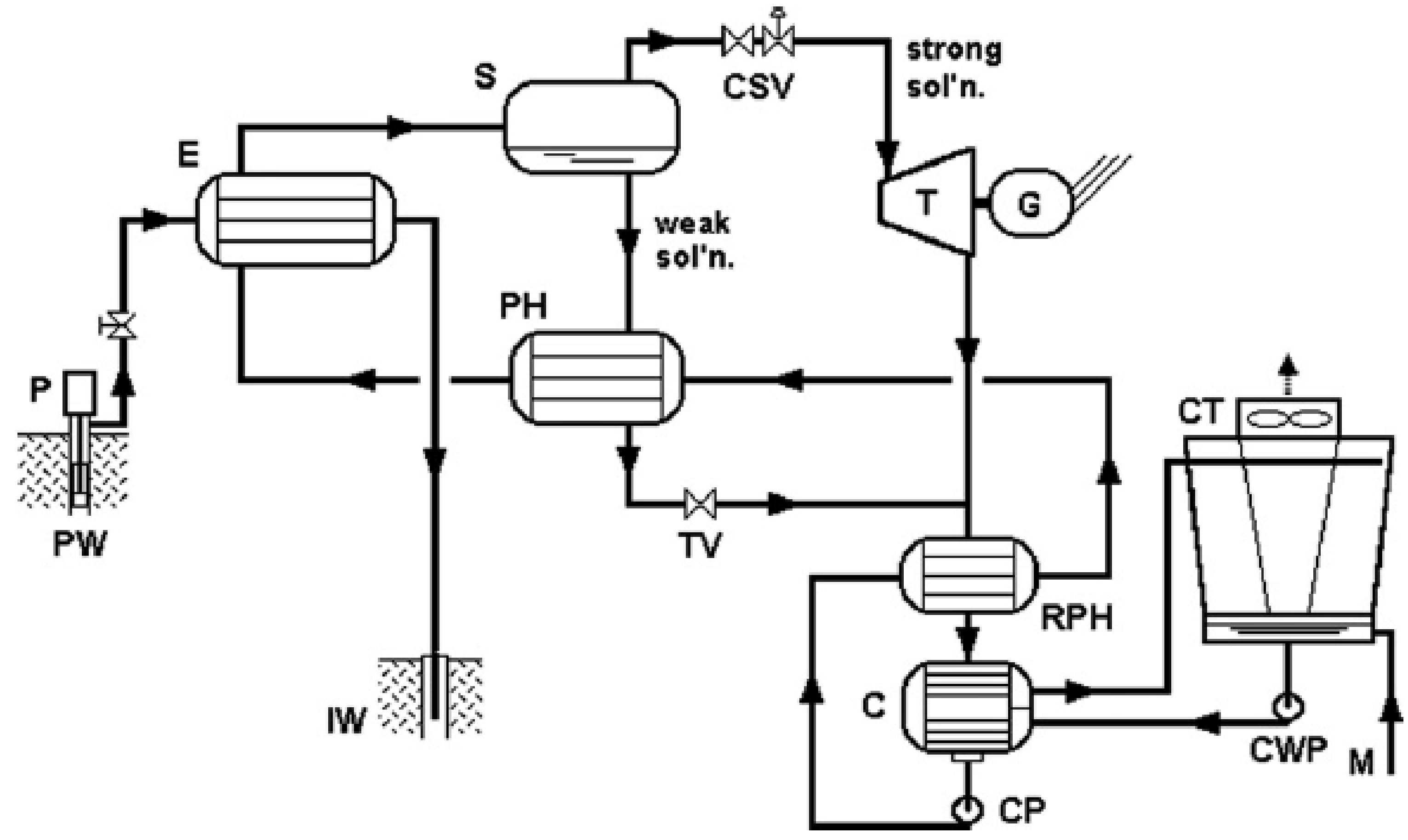

Fig. 8.18 Kalina cycle with variable composition of the water-ammonia working fluid.

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Thank You