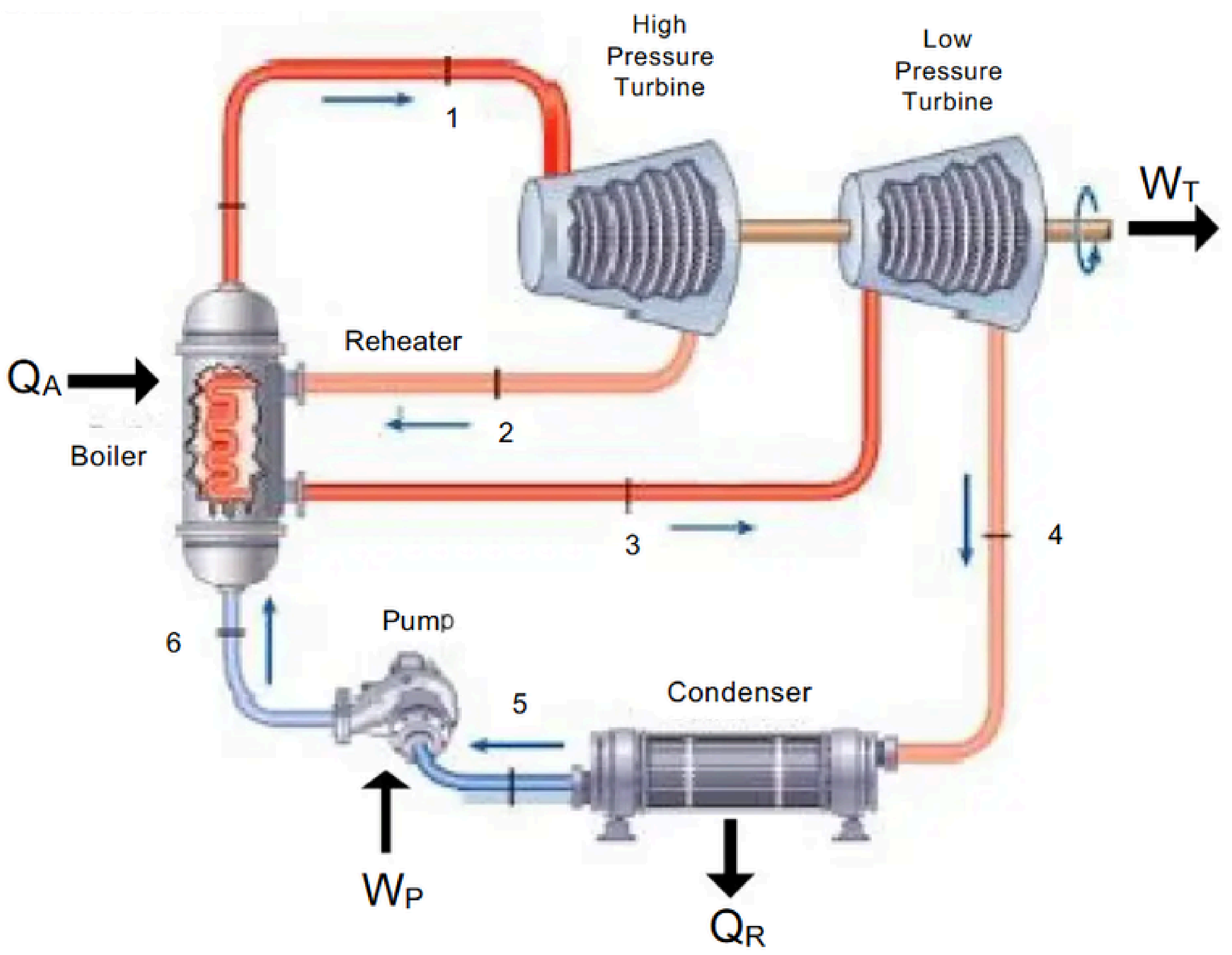
Reheater



SEE 611:ENERGY SYSTEMS

Project Presentation

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fig ref: https://www.scribd.com/document/532044521/Reheat-Cycle

OVERVIEW

Definition: A reheater increases Rankine cycle efficiency by reheating steam before it enters the IP/LP turbine.

Purpose: Reduces steam moisture, boosts efficiency, and enhances turbine performance.

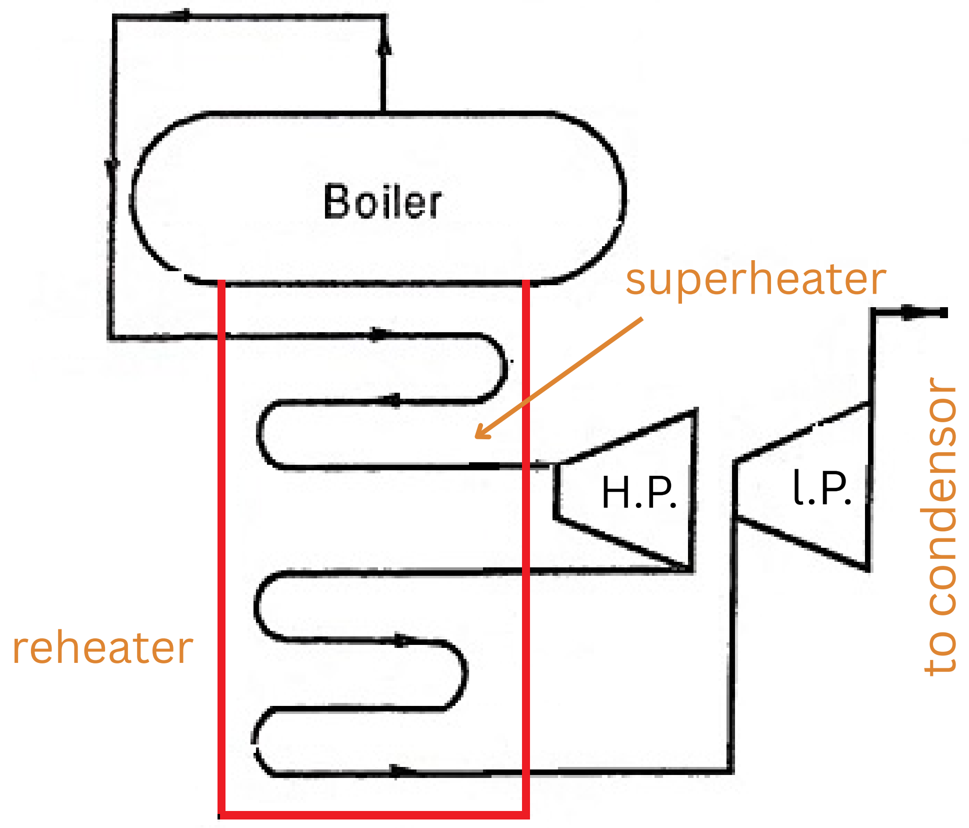
Working Principle: It extracts steam from the HP turbine, reheats it using flue gases, and returns it to the IP/LP turbine.

Types of Reheaters: Single-stage reheater ; Multi-stage reheater

Location: Between HP and IP/LP turbines.

Advantages:
Improves power plant efficiency.
Reduces turbine blade erosion.
Lowers operational costs and emissions.

Applications:
Enhances efficiency by 2-4%; reduces fuel consumption.
Used in cogeneration and desalination systems.

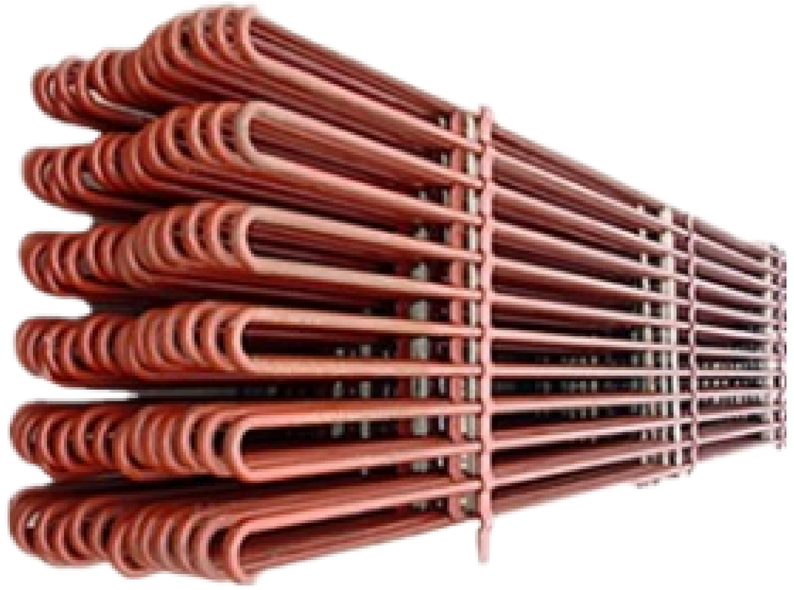


Schematic diagram considering the reheating part for Mundra Thermal Power Plant, unit 5 (Adani Power, India)

Mundra Thermal Power Plant, unit 5 (660 MW)

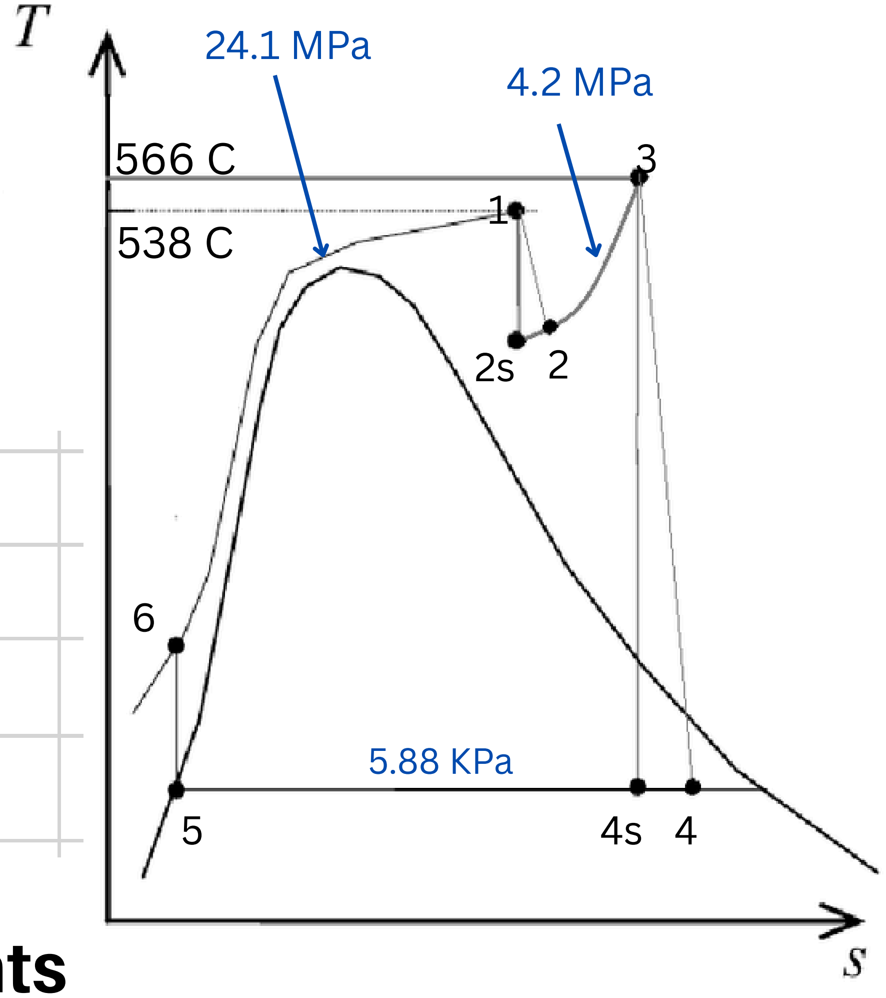
Parameters	values
Type	supercritical, with reheating
Net efficiency	**38.5%** (with reheater)
Coal Consumption	0.58 kg/kWh
Main Steam	24.1 MPa, 538°C
Reheat Steam	4.2 Mpa, 320°C in, 566°C out
Steam Flow Rate	450 kg/s
Flue Gas Inlet/outlet Temp	800, 400 C
final moisture content	9.5% (achieved via reheat)

COMPONENT ANALYSIS



Materials Used

Component	Material	Key Property
Tubes	SA-213 T91	Creep resistance at 566°C
Headers	SA-335 P91	High-pressure weldability
Casing	SA-516 Gr. 70	Structural support



The components of the reheater are:

- Reheater Tubes
- Steam Inlet & Outlet Valves
- Superheater & Boiler Integration

Assumptions

- Steady-State Process
- Negligible Kinetic & Potential Energy Changes
- Adiabatic System
- No Pressure Losses
- Thermodynamic Equilibrium
- Single-Phase Flow
- Constant Specific Heats
- Turbine Efficiency (ηturb): 88%
- Generator Efficiency (ηgen): 99%

T-S Diagram Points

Point	Process	Pressure	Temp	Enthalpy	Entropy
1	Boiler Outlet	24.1 MPa	538°C	3395	6.42
2	HP Turbine Exit	4.2 MPa	320°C	3004	6.6
3	Reheater Outlet	4.2 MPa	566°C	3580	7.01
4	LP Turbine Exit	5.88 kPa	35°C	2308	7.57

at point 2s From steam tables at 4.2 MPa and s2s=s1=6.42:

If s2s falls in superheated region: **h2s**≈2950 kJ/kgh

so, **h2**=h1−ηturb(h1−h2s)=3395−0.88(3395−2950)=3004kJ/kg

similarly, s4s=s3=7.01 =sf+*x4s* · sfg = 7.01=0.476+x4s×7.92 ⇒x4s=0.825

h4s = *hf*+*x4s* · *hfg* = 137+0.825×2423 = 2136kJ/kg

h4=*h3*−*ηturb*(*h3*−*h4s*)=3580−0.88(3580−2136)=2308kJ/kg let's perform some calculations for our design

Steam Flow Rate (ṁ)

Enthalpy drop (Δh) = $h_{in} - h_{out} = 3395 - 2127 = 1268\,\mathrm{kJ/kg}$

$$\dot{m} = \frac{P_{net}}{\Delta h \times \eta_{turb} \times \eta_{gen}} = \frac{660,000}{1268 \times 0.88 \times 0.99} = 450\,\mathrm{kg/s}$$

Reheater Heat Duty (Q)

$$Q = \dot{m} \times (h_{hot} - h_{cold}) = 450 \times (3580 - 3004) = 259\,\mathrm{MW}$$

Flue Gas Flow Rate (ṁ_gas)

Specific heat (C_p) = 1.1 kJ/kg·K

$$\dot{m}_{gas} = \frac{Q}{C_p \times \Delta T} = \frac{259,000}{1.1 \times (800 - 400)} = 588\,\mathrm{kg/s}$$

LMTD (Log Mean Temperature Difference)

$$\Delta T_1 = 800 - 320 = 480^\circ C$$
$$\Delta T_2 = 400 - 566 = 166^\circ C \text{ (absolute)}$$

$$\mathrm{LMTD} = \frac{480 - 166}{\ln(480/166)} = 296^\circ C$$

Heat Transfer Area (A)

Overall heat transfer coefficient (U) = 100 W/m²K

$$A = \frac{Q}{U \times \mathrm{LMTD}} = \frac{259 \times 10^6}{100 \times 296} = 8,750\,\mathrm{m}^2$$

Tube Sizing

Minimum Wall Thickness (ASME BPVC Sec. I):

$$t = \frac{P \cdot D_o}{2S + P} + \text{corrosion allowance} = \frac{4.2 \times 50.8}{2 \times 80 + 4.2} + 1.5 = 6.5\,\mathrm{mm}$$

let the Number of tubes (N) = 600 ; Tube length (L) = 25 m

and as calculated, Tube OD = 50.8 mm, thickness = 6.5 mm (SA-213 T91)

Therefore, let's check this using the calculation of the required area.

$$\text{Total area} = N \times \pi \times D_o \times L = 600 \times \pi \times 0.0508 \times 25 = 8,750\,\mathrm{m}^2 \checkmark$$

which is fine

now,

Flue Gas Ducting size : Duct Cross-Section (for 15 m/s gas velocity):

$$A = \frac{\dot{m}_{gas}}{\rho \cdot v} = \frac{588}{0.45 \times 15} = 87\,\mathrm{m}^2$$

ρ = Flue gas density (~0.45 kg/m³ at 600°C).

Rectangular Duct: 8 m × 11 m | Insulation: 150 mm mineral wool

steam quality calculations

hf=137kJ/kg; hfg=2423 kJ/kg

$$x = \frac{h - h_f}{h_{fg}} \qquad x_4 = \frac{2308 - 137}{2423} = \frac{2171}{2423} = 0.896$$

Further extraction is done, which reduces moisture to 9.5% (empirical plant data).

Calculation for HP Turbine Exit (Without Reheat)

Pressure (P1): 24.1 MPa; *Temperature (T1)*: 538°C; *Enthalpy (h1)*: 3395 kJ/kg;

Entropy (s1): 6.42 kJ/kg·K ; *Pressure (P2)*: 5.88 kPa (0.00588 MPa)

sf = 0.476 kJ/kg·K ; sfg = 7.92 kJ/kg·K ; hf = 137 kJ/kg ; hfg = 2423 kJ/kg

s2s=s1=sf+x2s · sfg => x=0.75

h2s=hf+x2s · hfg=137+0.75×2423=1954kJ/kg

h2=h1−ηturb(h1−h2s)=3395−0.88(3395−1954)=2127 kJ/kg(at 5.88 kPa)

=> x2 = 0.82 ie 18 % moisture not desirable

Efficiency Calculation

Qin=Q1+Q2 = (h1−hpump out)+(h3−h2)=(3395−161)+(3580−3004) = 3810kJ/kg

Wnet=Whp+Wlp−Wpump=(h1−h2)+(h3−h4)=(3395−3004)+(3580−2308)=1639kJ/kg

$$\eta_{th} = \frac{W_{net}}{Q_{in}} = \frac{1639}{3810} = 0.43$$

Adjusted to 38% with auxiliary losses (per plant data).

similarly calculating for without reheater we get the efficiency as 32.4%

CONCLUSION

Parameter	Without Reheat	With Reheat	Justification
Reheater Tube dimension	NA	600 × Ø50.8 mm × 25 m	Heat duty + erosion control
Reheater Tube layout	NA	Staggered pitch (127 mm)	Ash cleaning access
Reheater Tube material	NA	Material: SA-213 T91 (9Cr-1Mo)	Creep resistance at 566°C
HP Turbine Exit Enthalpy	2127 kJ/kg	3004 kJ/kg	Reheat interrupts expansion, preserving energy for LP turbine.
LP Turbine Exit Moisture	18%	9.50%	Reheat reduces moisture by reheating steam before LP expansion.
Thermal Efficiency (η_th)	38.50%	43.00%	Higher mean temperature of heat addition (+576 kJ/kg in reheater).
Net Plant Efficiency	32.40%	38%	Boiler/generator losses applied to η_th; matches supercritical benchmarks.
Coal Consumption	0.62 kg/kWh	0.58 kg/kWh	Efficiency gain reduces coal use by ~6.5%.
Turbine Blade Life	Erosion risk (18% moisture)	Safe (9.5% moisture)	Moisture >12% damages blades; reheat keeps it below limit.
Heat Rate	~9,810 kJ/kWh	~9,200 kJ/kWh	Lower heat rate = Higher efficiency (↓ fuel input per kWh).
Capital Cost	Lower	Higher (+15-20%)	Reheater adds tubes, headers, and controls.
Operational Complexity	Simple	Moderate	Additional valves/flue gas controls needed for reheat.

key outcomes from the results

Moisture Reduction: Steam moisture reduction prevents turbine damage.

Efficiency Improvement: Reheater increases overall plant efficiency by 6-10%.

Fuel & Cost Reduction: Fuel savings of 7-12% lead to cost savings of ₹100 - ₹150 million annually (for a 500 MW plant).

Emission Reduction: Lower fuel usage reduces CO_2 emissions by 5-10%.

Thermal Stress Reduction: Lowers temperature gradients, extending lifespan

Operational Reliability: Maintains stable power generation with optimal steam parameters.

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Material Standards (ASME & ASTM)

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THANK YOU!