

Optimization of parameters for heat recovery steam generator (HRSG) in combined cycle power plants

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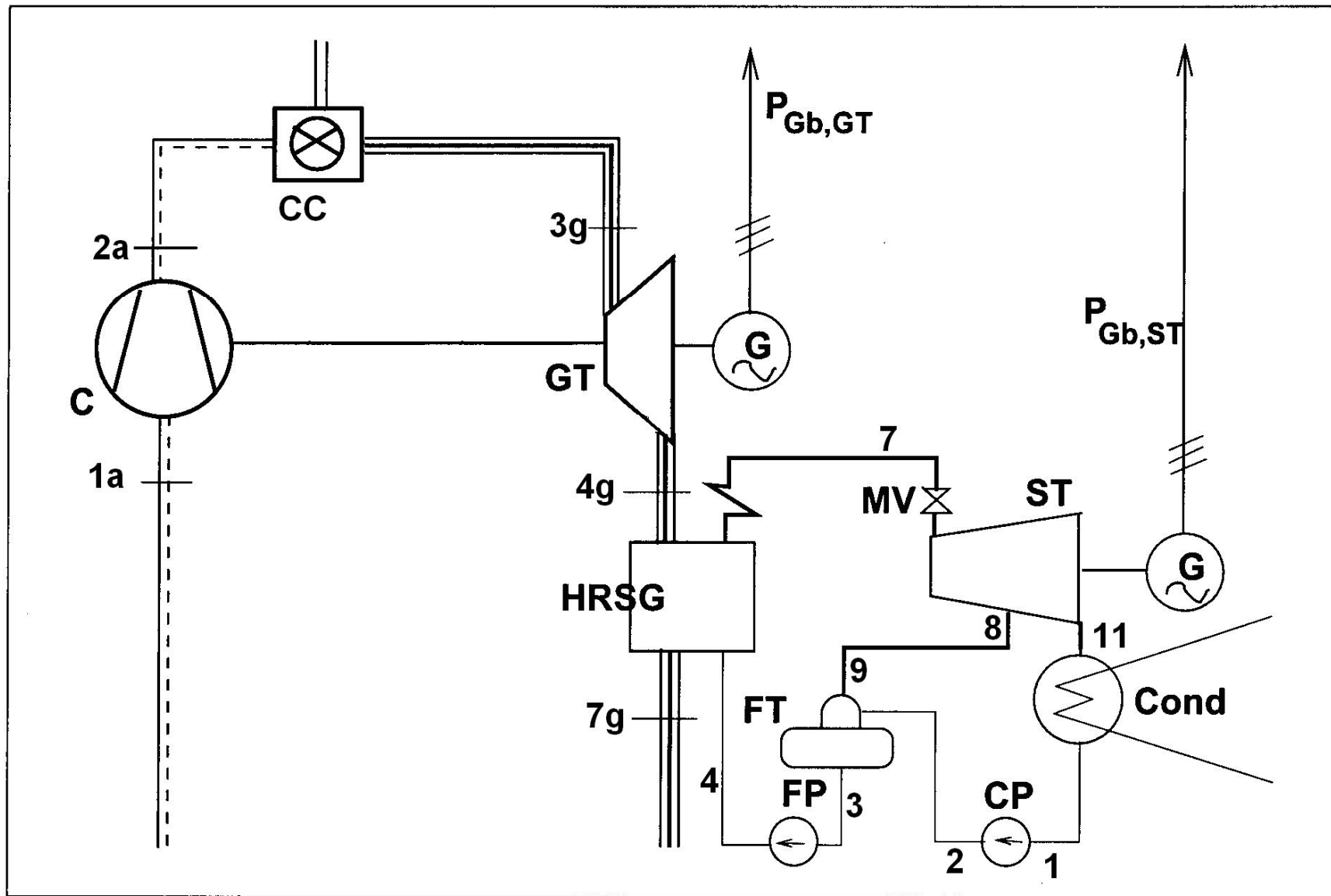
Introduction

This work illustrated thermodynamic and thermoeconomic optimization in HRSG of combined cycle power plants.

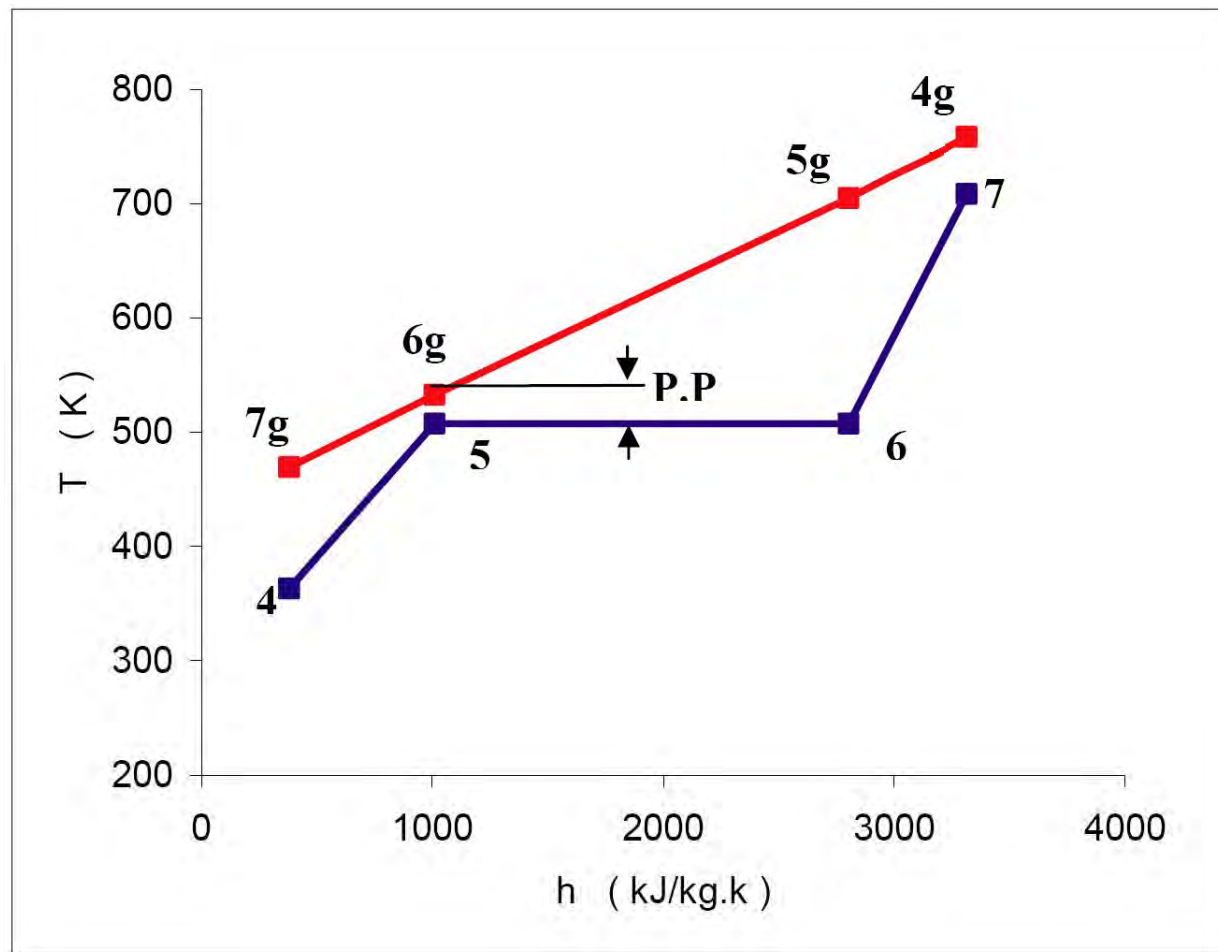
- **Thermodynamic** optimization is minimization of the thermal **exergy losses** due to decreasing the pinch point (**P.P**).
- **Thermoeconomic** optimization is minimization of the total HRSG cost: **cost of exergy losses + installation cost**.



Heat Balance Diagram of CCGT



Pinch Point (P.P) Definition



P.P: Δ between t of gas leaving the evaporator and the water saturation t .



Example of Optimization

Main characteristics of the CCGT plant:

Gas Turbine:

Gross Power	200	MW
Gas turbine inlet temperature	1423	K
Efficiency	0.393	
Gas exit temperature	758	K
Air mass flow	571.60	kg/s



Example of Optimization

Steam Turbine:

Gross power	103.68	MW
Maximum steam pressure	28	bar
Steam condenser pressure	0.08	bar
Feed water temperature	363	K
Steam mass flow	70.12	kg/s
Min. designed Δt for P.P	10	K



Example of Optimization

Assumptions of economic parameters:

Life of plant	20	year
Operating hours	7446	h.year ⁻¹
Selling price of power	0.0625	\$/kWh

Installed costs of the sections of the HRSG

• Economizer	45.70	\$/m ²
• evaporator	34.80	\$/m ²
• Superheater	96.20	\$/m ²

The overall heat transfer coefficients for the sections of the HRSG

• Economizer	42.60	W/m ² K
• evaporator	43.60	W/m ² K
• Superheater	50	W/m ² K



Thermodynamic Optimization

- The **thermodynamic optimization** of the HRSG due to min. of exergy losses.
- For a heat exchanger at steady state, the availability balance equation is given by:

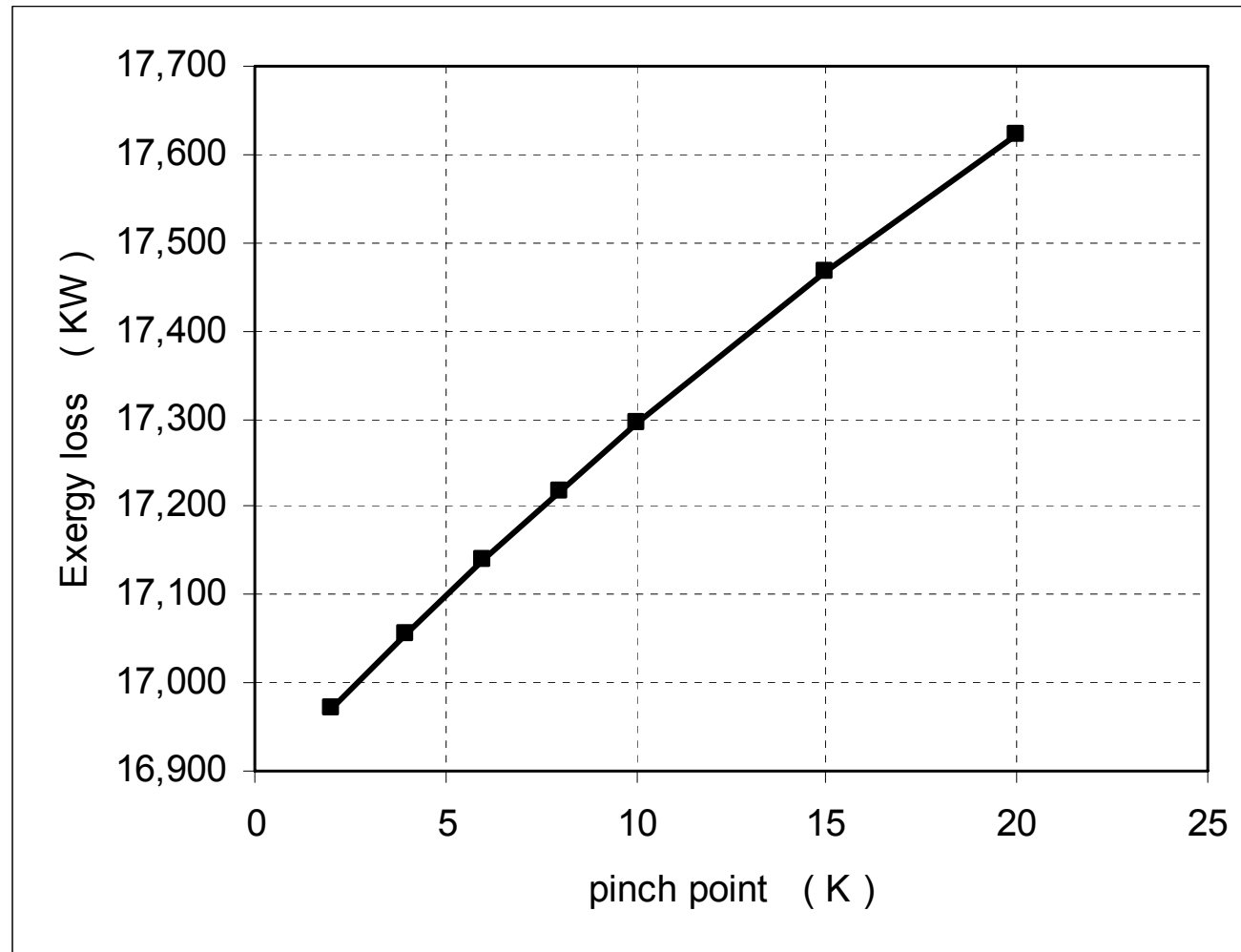
$$I_{HRSG} = \dot{E}_{in} - \dot{E}_{out} = \sum (\dot{m}e)_{in} - \sum (\dot{m}e)_{out}$$

- The HRSG **exergy losses** can be calculated as :

$$I_{HRSG} = m_g \cdot [(h_{4g} - T_0 s_{4g}) - (h_{7g} - T_0 s_{7g})] - m_s \cdot [(h_4 - T_0 s_4) - (h_7 - T_0 s_7)]$$



Thermodynamic Optimization



The relation between **exergy loss** and **P.P** is linear.



Thermoeconomic Optimization

1. Cost of exergy loss of the HRSG:

$$K_I = k_I \cdot H \cdot I_{HRSG}$$

2. Cost of the HRSG:

$$K_{HRSG} = \sum_e k_e A_e + \sum_V k_V A_V + \sum_{sh} k_{sh} A_{sh}$$



Thermoeconomic Optimization

3. The total cost of HRSG:

The **total annualized cost** of the HRSG is:

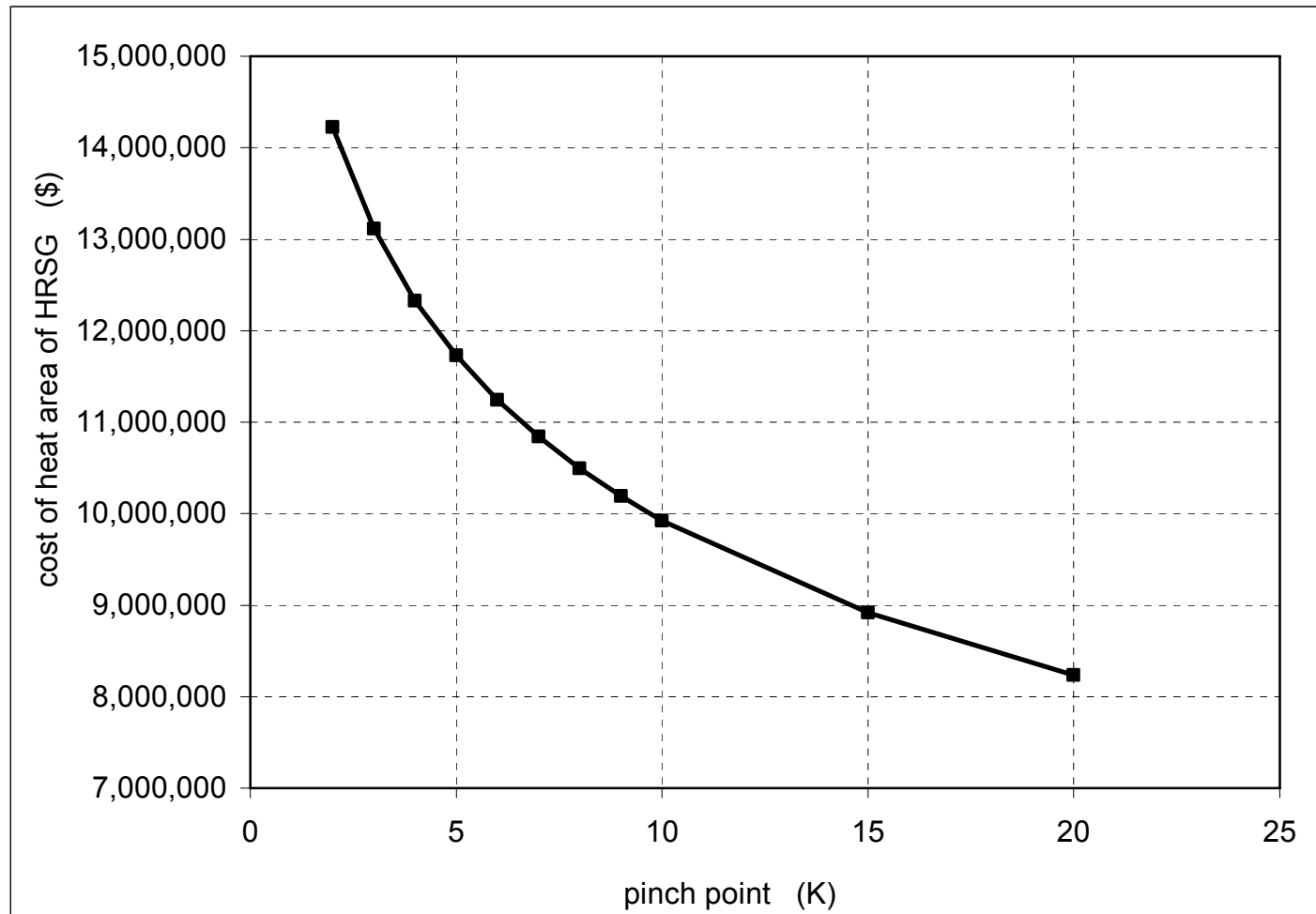
$$\begin{aligned} K &= K_I + K_{HRSG} \\ &= k_I \cdot H \cdot I + \frac{1}{D} \sum_e k_e A_e + \sum_v k_v A_v + \sum_{sh} k_{sh} A_{sh} \end{aligned}$$

The **heat exchange surface** is:

$$A_i = \frac{Q_i}{U_{m,i} \cdot \Delta T_{m,i}}$$



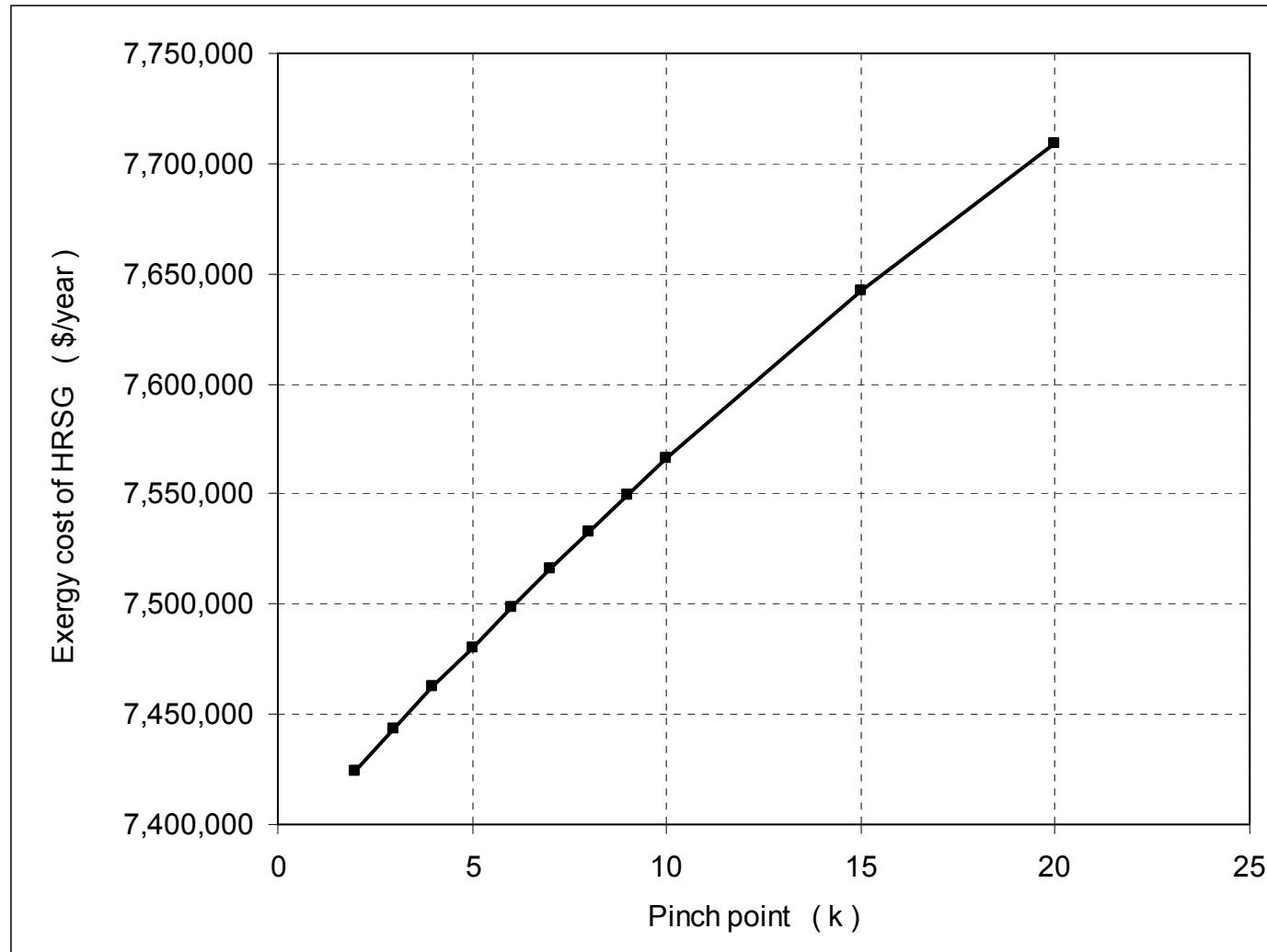
Results and Discussion - Cost of heat area



The **cost of heat area** of HRSG decreases with increasing **P.P**



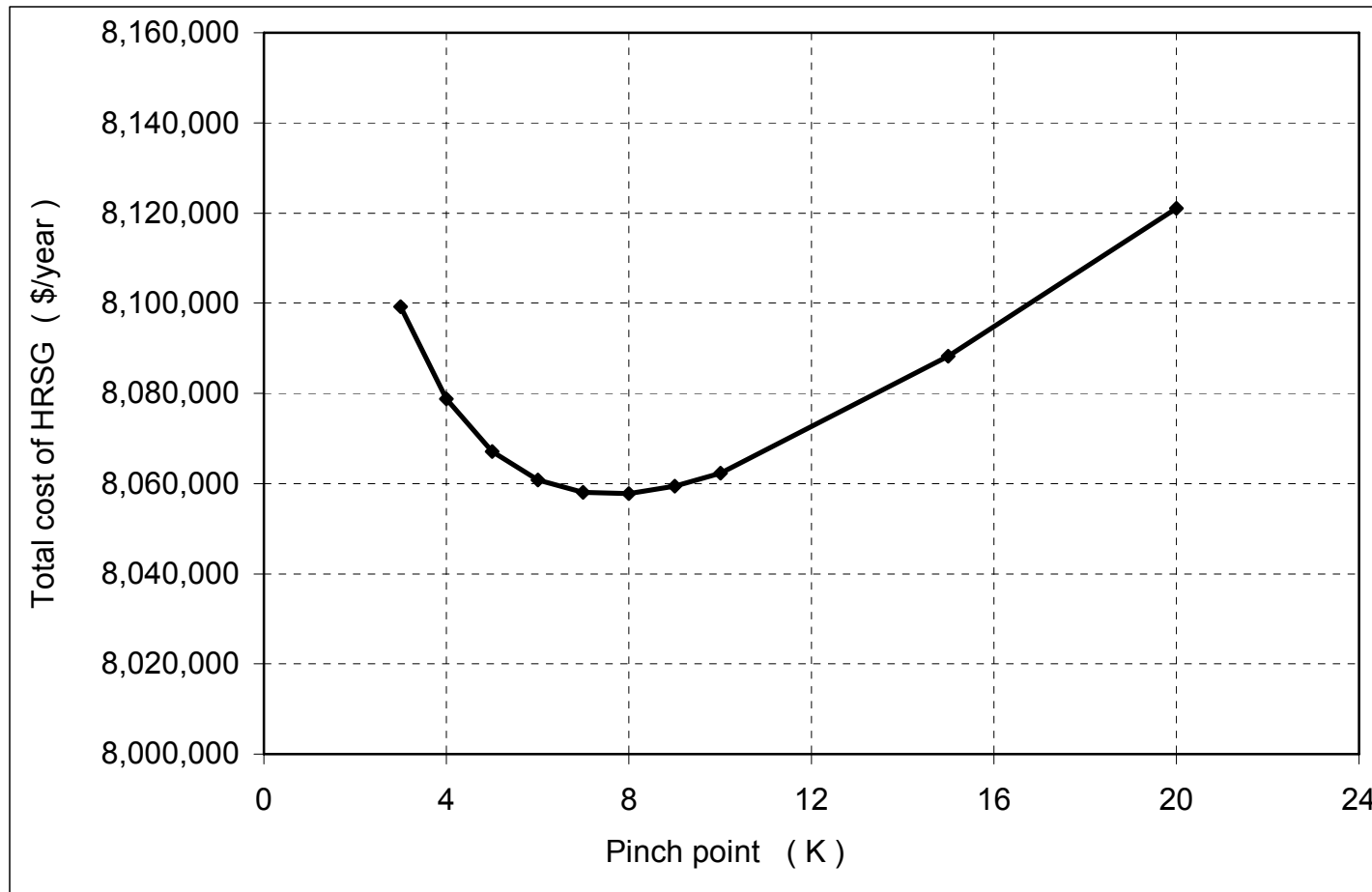
Results and Discussion - Exergy loss cost



The relation between **exergy loss cost** of HRSG and **P.P** is very close to linear.



Results and Discussion - Total cost of HRSG



The **total cost of HRSG** decreases with increasing the **P.P** until pinch point **8 K** and than increases with increasing the **P.P**.



Conclusions

- The thermodynamic optimization was carried out by means of the minimization of exergy losses due to the temperature difference between the hot (gas) and the cold stream (steam).
- The exergy loss decreases almost linearly by reduction of the P.P.
- The thermoeconomic optimization was performed by analyzing the total cost of HRSG (the sum of the costs related to the exergy losses plus the costs of HRSG components).
- The variation of values for the pinch-points in the range between 3 and 20 K has shown that the optimal value is at **8 K**.



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