Flare Gas-to-Power Using Supercritical CO_2 Power Cycle – Energy and Exergy Analyses

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Abstract

Generating electricity from power cycle using supercritical carbon dioxide (sCO_2) as a working fluid is a step towards efficiency improvement in power production field. The huge amount of studies on this topic shows promising results of utilization low to medium grade heat of power generation. Several layouts, arrangements, and thermodynamical features were presented to improve the performance of the power cycle. A main property of such a power cycle that it utilizes a waste heat to produce electricity. One source of waste heat is flared gas in oil and gas industry, flaring process is considered as an extensive economic loss due to its high heating value. This flare gas is burned in industry due to several purposes, mainly safety and process needs. Utilization of flare gas in producing electricity through sCO_2 cycle is being proposed in this research. Where two cycles were proposed to study the performance of the cycle using flare gas as fuel. Flare To Power sCO2 (FTP1- sCO_2) cycle utilizing the flare gas mixed with natural gas to heat the working fluid of the cycle which sCO2. The second cycle (FTP2- sCO_2) flare gas is utilized in reheating process for the exhaust flow of a primary heated working fluid. The performance of the cycles is evaluated by implementing energetic, and exegetic analysis. The results of the study showed that FTP 1 has higher thermal and overall exergy efficiencies compared with FTP 2. Furthermore, the analysis showed that as maximum pressure increases thermal efficiency increase, the same behavior was found also while increasing T_{max}. The maximum thermal efficiency found to be 44.87% at $T_{max} = 850$ ℃, $P_h = 25\ MPa$, $P_l = 3.3\ MPa$, $T_{min} = 32$℃, and $\dot{m}_{flare} = 0.18\ kg/s$, for a 50 MW power capacity.

Benefit of the study

Compact Turbomachinery

Compact Heat-Exchangers

sCO_2 Major Benefits

+

Utilization of Wasted Energy Resources

Less Greenhouse Gases

Flare Gas Utilization Benefits

=

Less Operational Cost

Efficient System

Proposed Integrated Systems Benefits

Flare Gas Recovery Technologies

Technology	Market/application	Features	Concerns and limiting factors
Process feed or fuel gas	- Refineries - Power generation	- Reduced visible flame - Reduced sound of burning gases	- Composition of flare gases - High compression cost
Gas pipelines	- Domestic gas grid - Power plants - LNG & GTL plants	- Has the lowest cost in case of short distances and large market	- Land ownership - Fluid phase behavior - Transportation distance
Gas reinjection	- Enhanced oil recovery - Clearance of highly contaminated gases	- Reinjection costs are less than of Sulfur removal process	- Reservoir engineering considerations - High compression cost
Natural gas liquids (NGL)	- NGL plants	-	- High Capital and operational costs
Liquified natural gas (LNG)	- Fuel in power stations - LPG	- More safe and cheap for long-distance markets - High storage capability	- Road safety
Compressed natural gas (CNG)	- Fuel for industries and power generation	- Suitable in short and medium distances - Much simpler and less costly than the LNG	- Lower capacity than LNG - High risk of explosion
Natural gas hydrates (NGH)	- Fuel for industries and power generation	- Has potential to be more economical for gas transportation	- Still in laboratory-scale studies - Lower capacity than LNG
Gas to liquid (GTL)/ Gas to chemicals (GTC)	- Hydrogen production - Methanol production - Ammonia production	- Suitable for large distance transportation - Cleaner than traditional fuels	- High flow rate and specific composition are required - lack of maturity
Gas to power/gas to wire	- Generate electricity	- Minimal gas pretreatment - less sensitive for the variable flow rate and composition of the flare gases	- Capital and operational cost need consideration

Recuperators Discretized Model

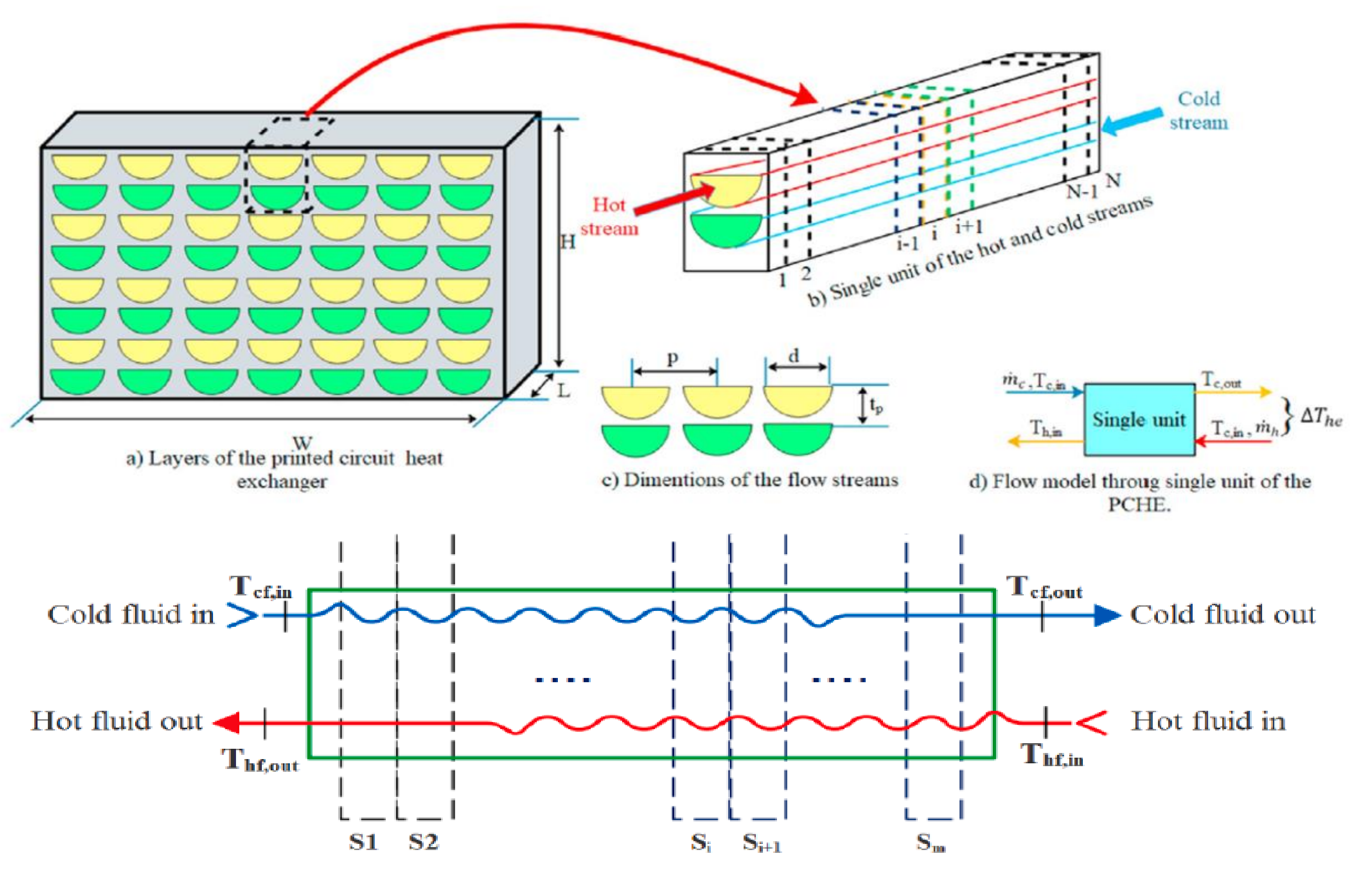

Figure 5: Discretized model of printed type heat exchanger type. [1,2]

Design Parameters

Parameter	Range/ Design Value
Net Electrical Power $\dot{W}_{net}$	50 (MW)
Maximum Pressure P_h	20-30 / 25 (MPa)
Minimum Pressure P_L	3.2 – 4.0 / 3.3 (MPa)
Maximum cycle temperature T_{max}	650 – 850 / 650 (°C)
Minimum cycle temperature T_{min}	32 – 50 / 32 (°C)
Isentropic Efficiency of turbines η_t	90 %
Isentropic Efficiency of compressors $\eta_{Comp.}$	85 %
Efficiency of the generator η_g	95 %
Efficiency of the pumps	90 %
Flare gas flow rate $\dot{m}_{FG}$	0.18 (kg/sec)
Natural gas Lower Heating Value LHV_{NG}	50500 (kJ/kg)
Flare gas Lower Heating Value LHV_{FG}	25452 (kJ/kg)

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Proposed Cycles

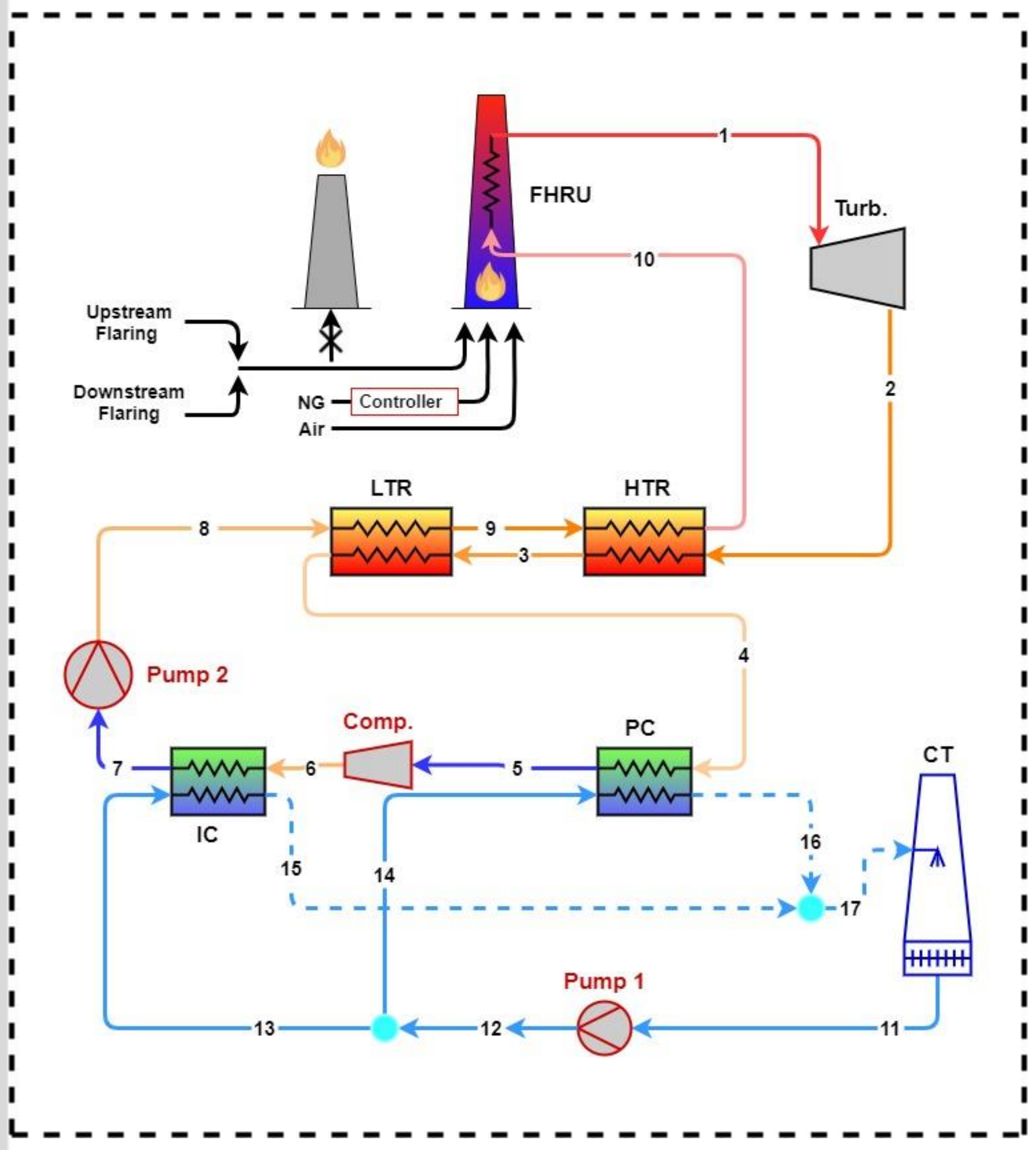

Figure 1: Flare-To-Power 1 sCO_2 cycle (flare mixed with natural gas)

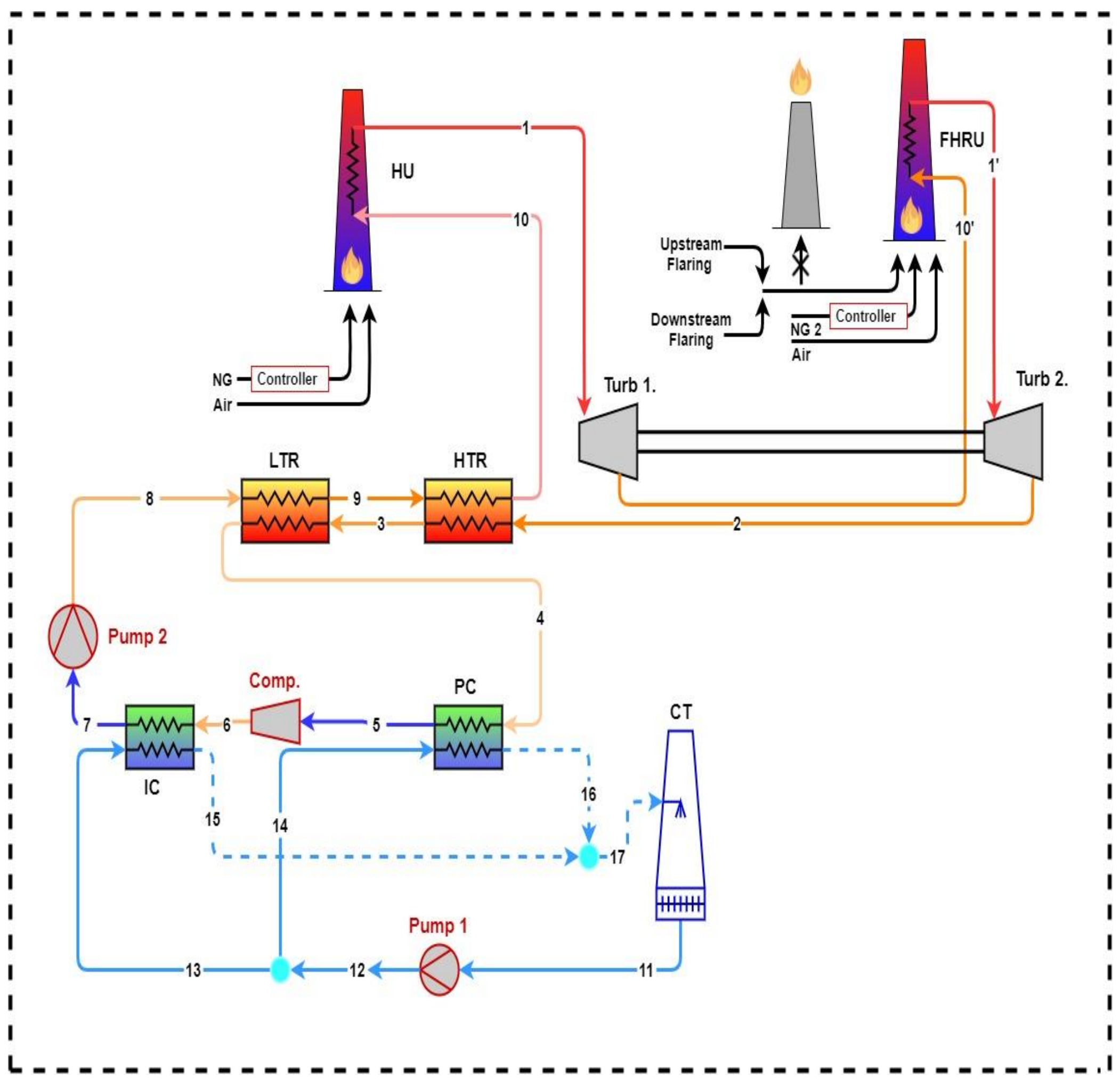

Figure 2: Flare-To-Power 2 sCO_2 cycle (flare burned for reheating)

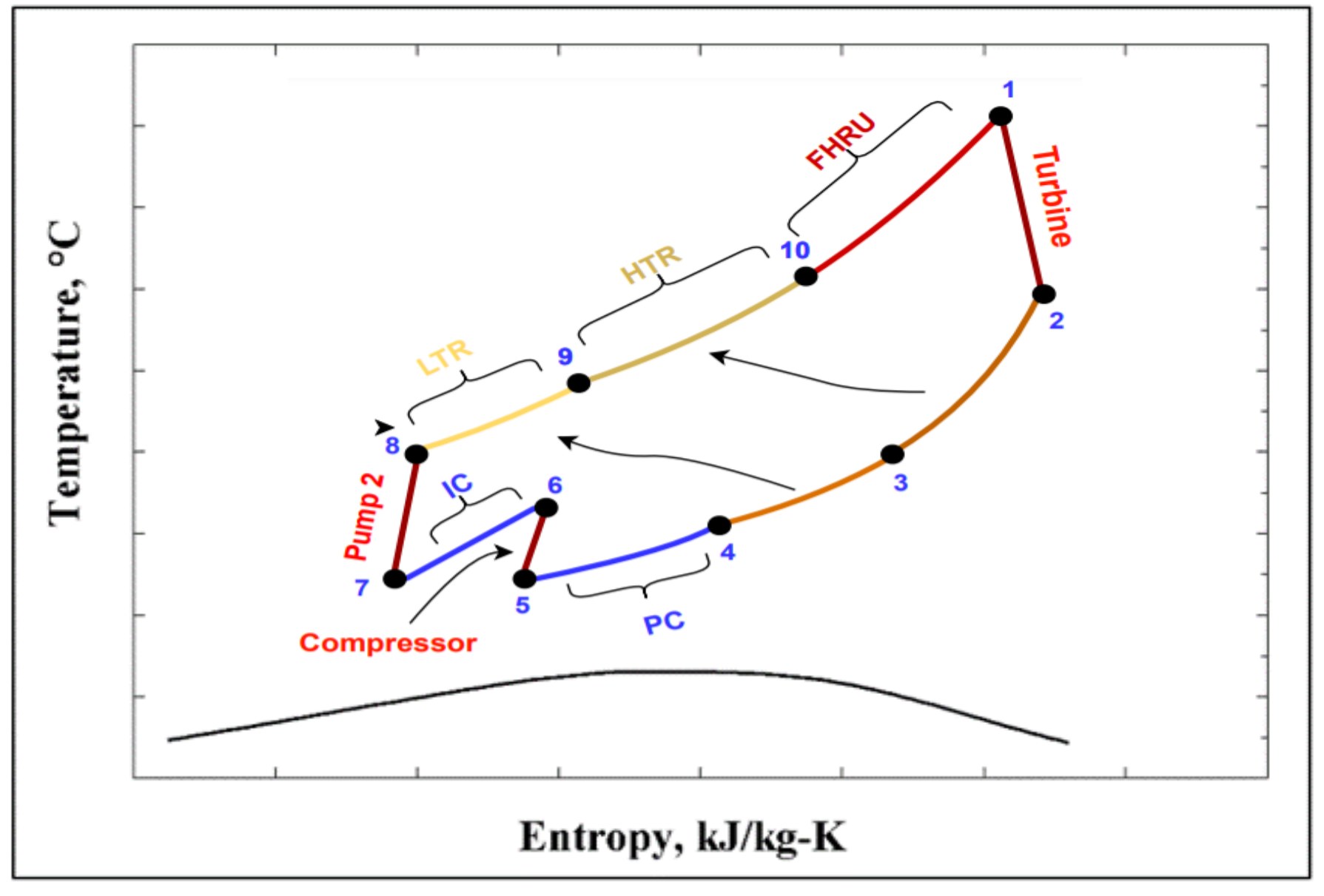

Figure 3: Flare-To-Power 1 sCO_2 T-S diagram

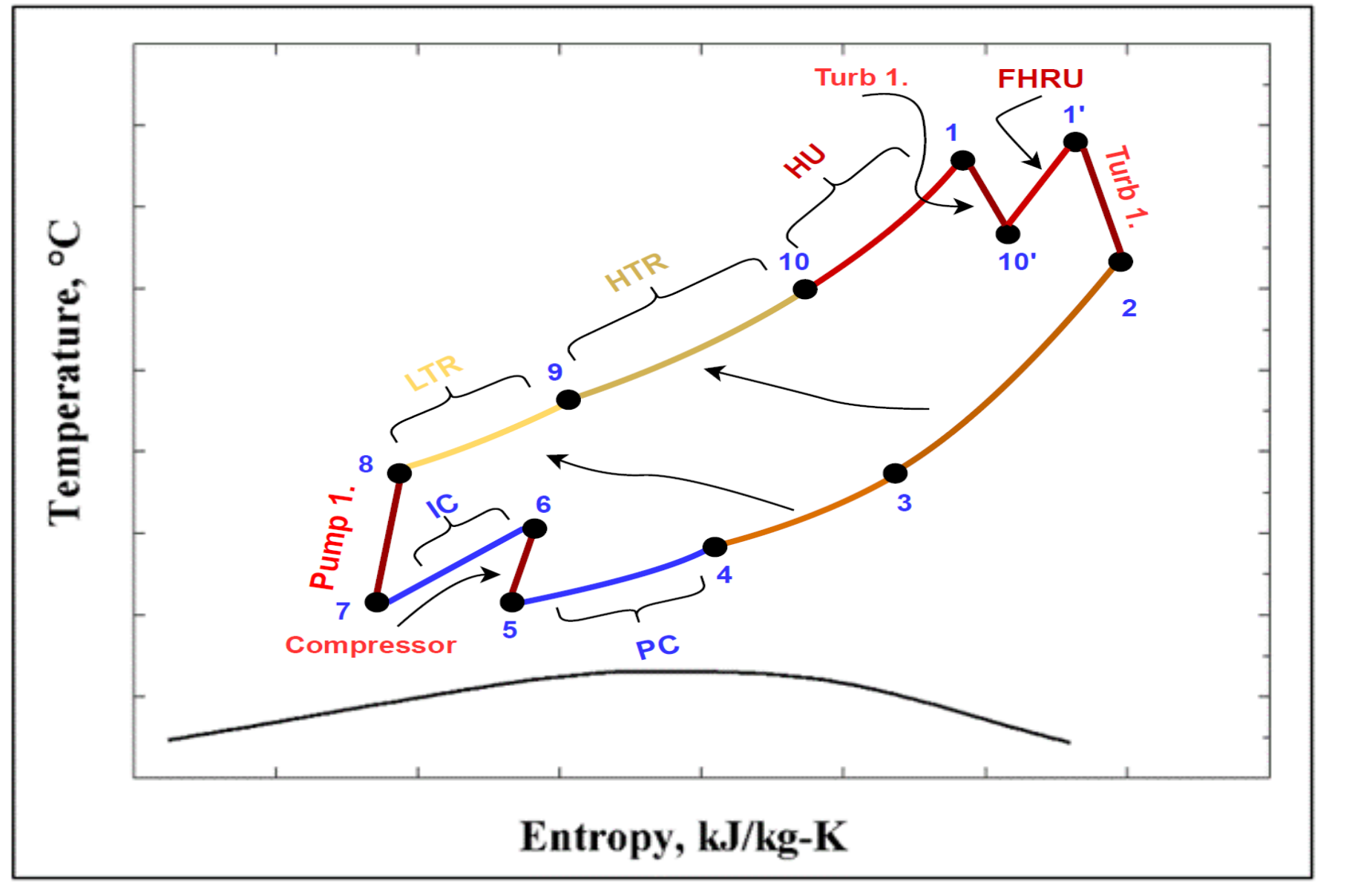

Figure 4: Flare-To-Power 2 sCO_2 T-S diagram

Sensitivity Analysis

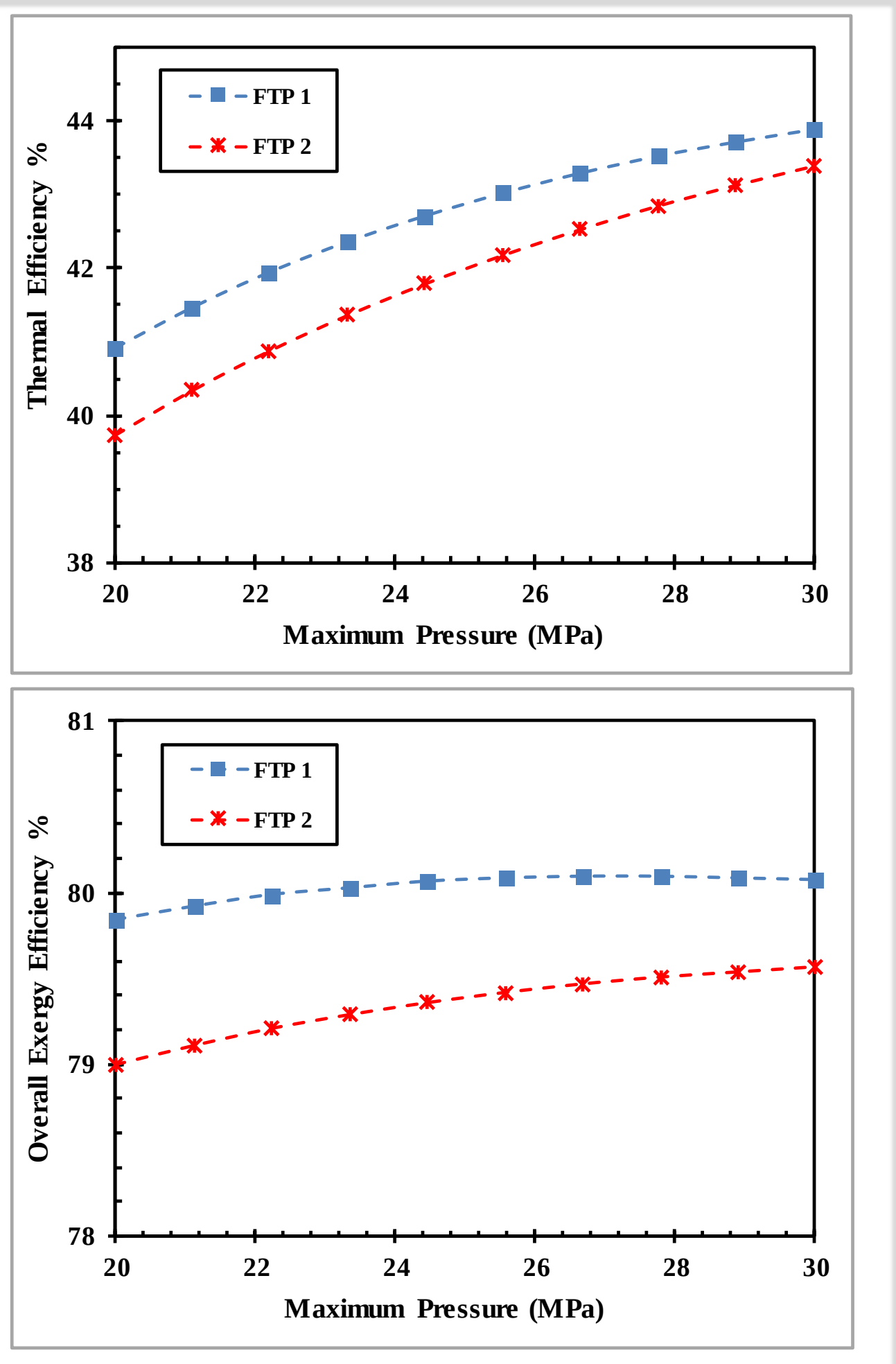

Figure 6: Effect of Maximum Pressure

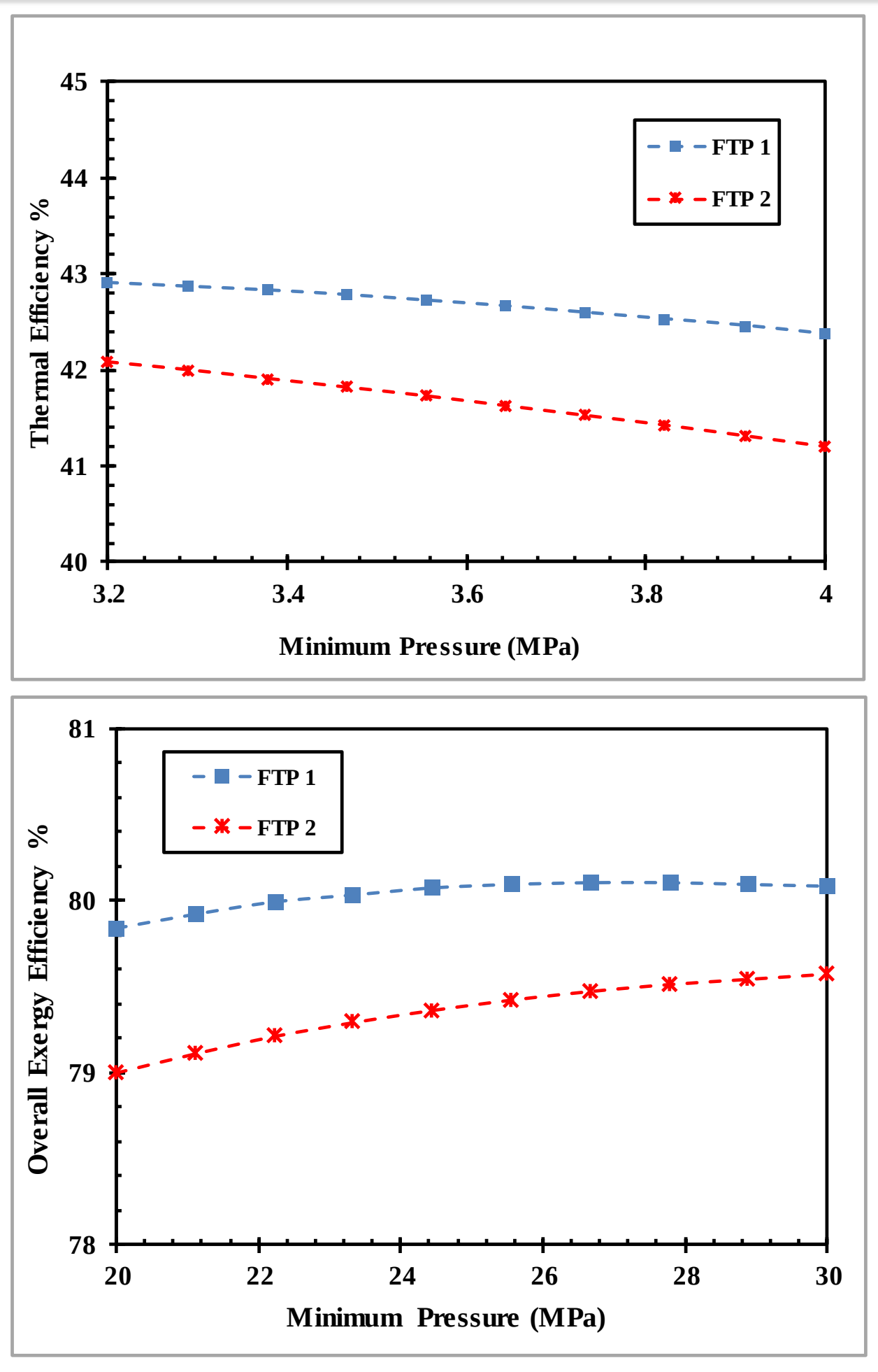

Figure 7: Effect of Minimum Pressure

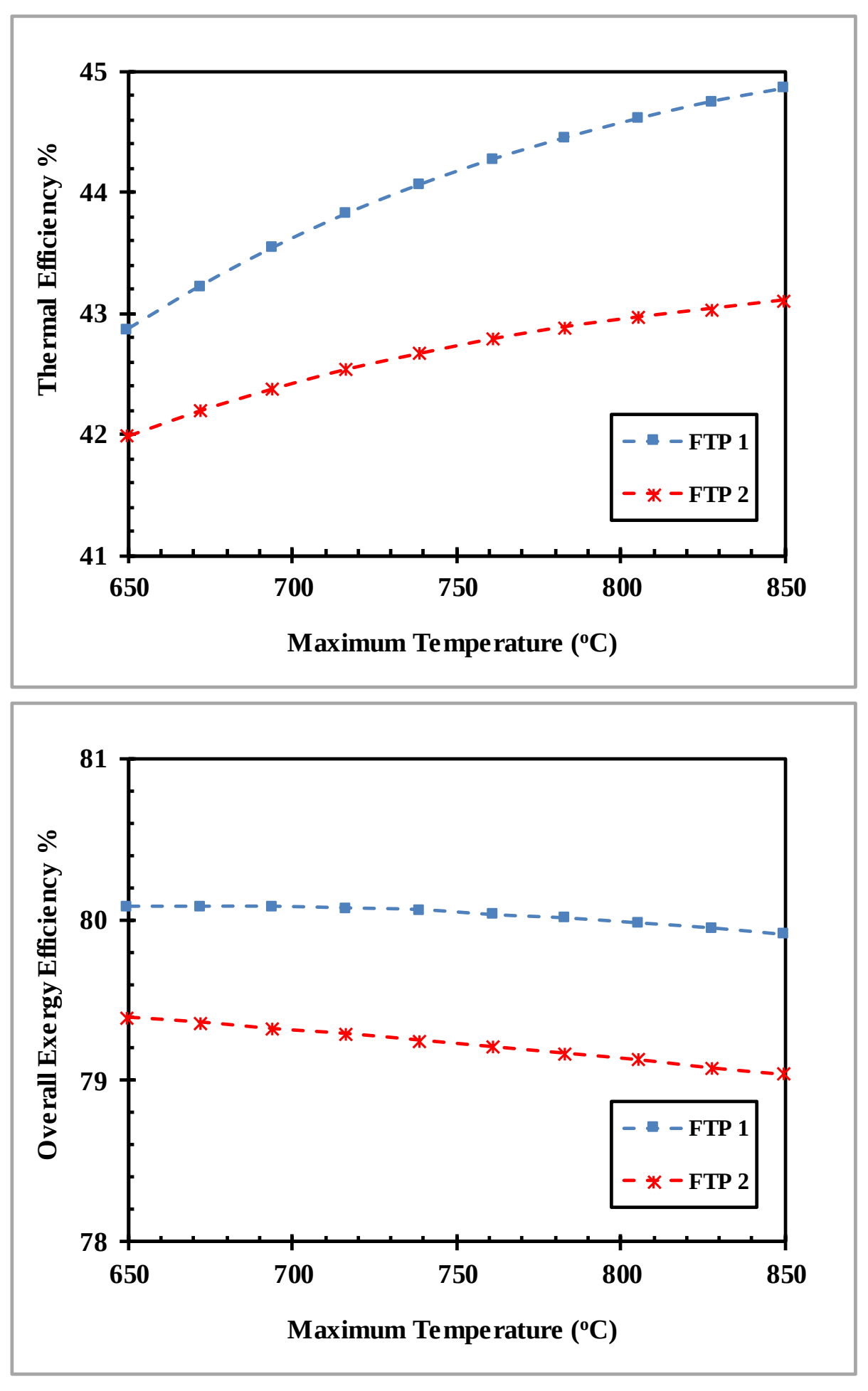

Figure 8: Effect of Maximum Temperature

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