Thermodynamic Analysis of Five Allam sCO_2 Power Cycle Configurations

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Introduction

The Allam cycle is a direct-fired oxy-fuel cycle utilizing supercritical CO_2 with nearly zero emission. A detailed thermodynamic analysis can improve and optimize the Allam cycle.

Objective

- Evaluate efficiencies of four available variants of the Allam cycle using a 2nd Law analysis based on lost work.
- Analyze the performance of a novel externally-fired gas turbine (EFGT) design.

Methodology

Lost work:

$$L\dot{W} = \sum_i \dot{W}_i - \Delta[\dot{m}(B)] + \sum_i \left(1 - \frac{T_0}{T_i}\right)\dot{Q}_i$$

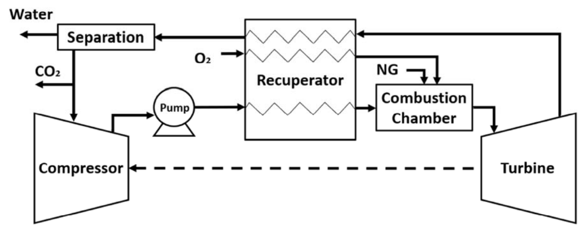
Equivalent to <u>exergy destruction</u>

Electrical efficiency: $\eta_{\text{el}} = \dfrac{\sum \dot{W}}{\dot{m}_{\text{fuel}}(\text{LHV})}$

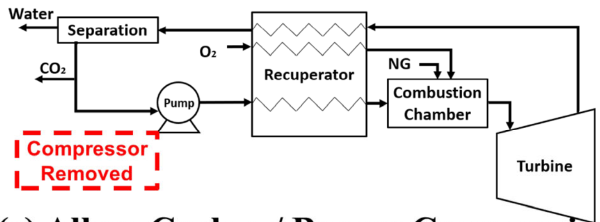
Thermodynamic efficiency: $\eta_{\text{II}} = 1 - \dfrac{L\dot{W}}{L\dot{W} - \sum \dot{W}}$

Simulations of all cycles performed with Aspen Plus having the same net power output (300 MW), turbine inlet temperature, and machinery efficiency.

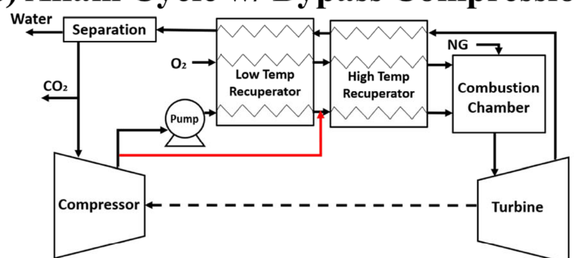
(a) Original Allam Cycle



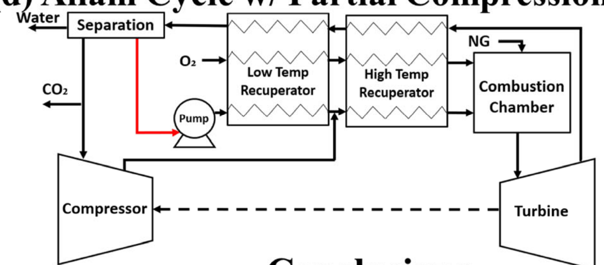
(b) Allam Cycle w/o CO_2 Compression



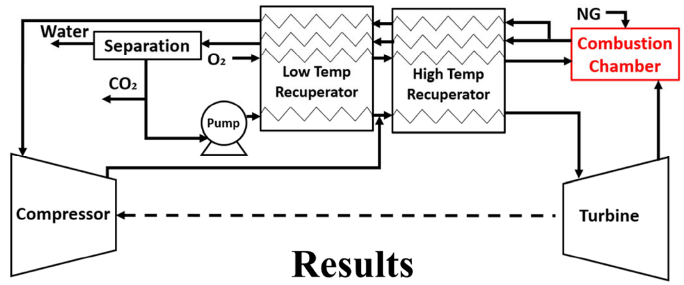
(c) Allam Cycle w/ Bypass Compression



(d) Allam Cycle w/ Partial Compression



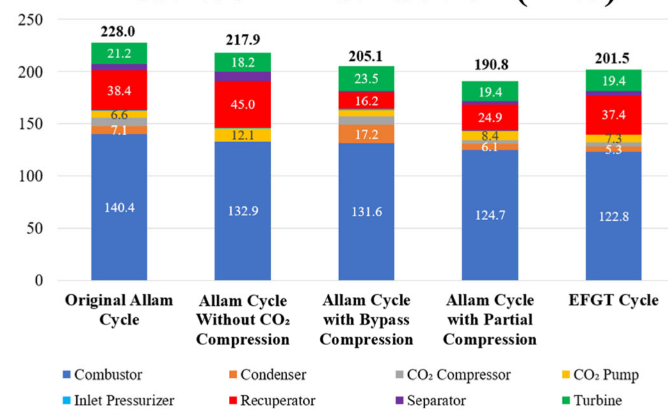
(e) EFGT Cycle



Results

Cycle Name	Electrical Efficiency η_{el} (%)	Thermodynamic Efficiency η_{II} (%)
(a) Original Allam	59.56	56.85
(b) W/O CO_2 Compression	60.47	57.92
(c) Bypass Compression	61.61	59.35
(d) Partial Compression	63.41	61.12
(e) EFGT	64.35	59.82

Lost Work Distribution (MW)



Conclusions

- Lost work calculations explicitly identify the locations of irreversibilities. Combustor always the least efficient unit; next are heat exchangers.
- Among the four variants of Allam cycle, the cycle with partial recompression is most efficient with 37.2 MW lost work and ~4% higher efficiency by balancing lost work effects in the combustor and recuperator.

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