CHAPTER 17: POWER CONVERSION

Contributors

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17. POWER CONVERSION

17.1 Steam Cycle

Different steam cycles have been well developed. A study by EPRI summarized the various advanced steam cycles which maybe available for an advanced coal power plant for the next generation(1). The steam conditions, and the calculated thermal efficiencies of the different steam cycles are summarized on Figure 17.1-1.

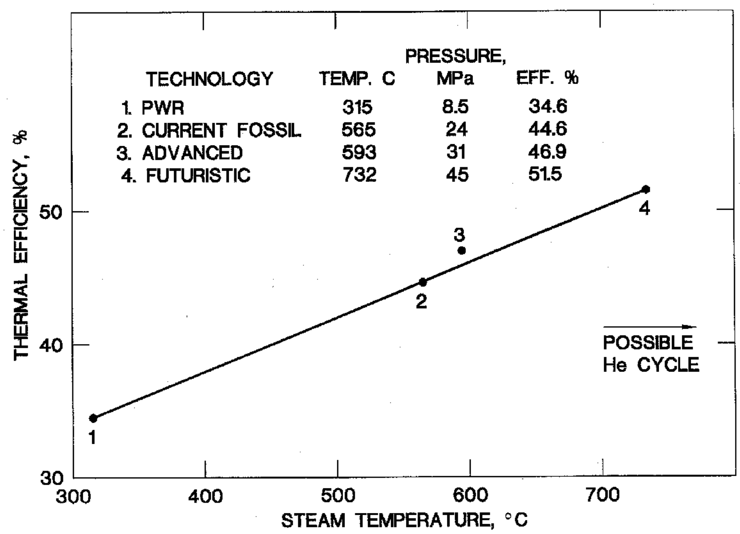


Figure 17.1-1 Steam conditions and power conversion Efficiency for different steam cycles.

17.2 Close cycle gas turbine:

The closed cycle gas turbine has the potential to use high temperature and reaches high thermal efficiency. The efficiency of the gas turbine can be estimated by the following equation:

$$\eta = \frac{\eta_t \frac{T_o}{T_s}\left(1-\beta\left(\frac{1}{r}\right)^{\frac{\gamma-1}{\gamma}}\right) - \frac{3}{\eta_c}\left(r^{\frac{\gamma-1}{3\gamma}}-1\right)}{(1-\eta_x)\left(\frac{T_o}{T_s}-1-\frac{1}{\eta_c}\left(r^{\frac{\gamma-1}{3\gamma}}-1\right)\right)+\eta_x\eta_t\frac{T_o}{T_s}\left(1-\beta\left(\frac{1}{r}\right)^{\frac{\gamma-1}{\gamma}}\right)} \qquad (1)$$

where,

η_t is the turbine efficiency
η_c is the compressor efficiency
η_x is the recuperator efficiency
T_o is the helium temperature
T_s is the sink temperature
r is the compression ratio

β is the pressure drop ratio γ is Cp/Cv

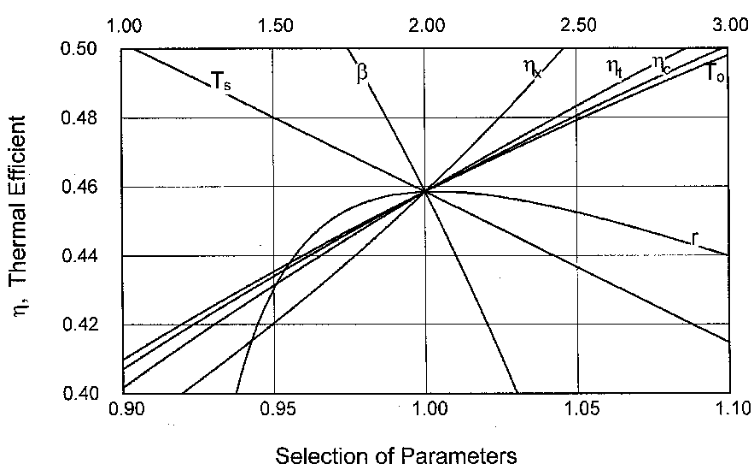
Table 17.2-1 outlines the parameters of the gas turbine design proposed by Wong and Tillack (2,3).

Table 17.2.-1 Key parameters of the power conversion system.

T_o	923 K (650ºC)
T_s	308 K (35ºC)
T_o / T_s	3.00
r	2.0
η_x	0.96
η_c, η_t	0.92
β	1.02 ($\Sigma\Delta p/p$-0.05)
γ	1.66
η	46%

With the assumption of very high efficiencies of different components, a thermal efficiency of 46% can be achieved with a helium temperature of only 650C

Figure 17.2-1 shows the change of the thermal efficiency of the power conversion system as the parameters changes. This figure can be used to estimate the thermal efficiency if the design parameters are different from those on Table 17.2-1.



17.2-1 Power conversion by binary cycle

Binary power conversion cycle has been proposed for efficient thermal conversion (4). Most proposals suggest the use of a either He or K topping cycle, with a steam bottoming cycle. However, more careful consideration suggested that a binary cycle will not be more efficient than the topping cycle along.

Figure 17.2-2 shows the comparison between a binary cycle to that of a single cycle system. Since the binary cycle has to go though both the topping cycle and the bottoming cycle, the temperature of the coolant across the poser conversion system is (T1-T3), which is larger than (T1-T2) for the single cycle. The heat source provides a constant heat. The coolant flow rate is inversely proportional to the required coolant temperature rise in the power plant. Therefore, the coolant flow rate for the binary cycle system is much lower than that of a single cycle.

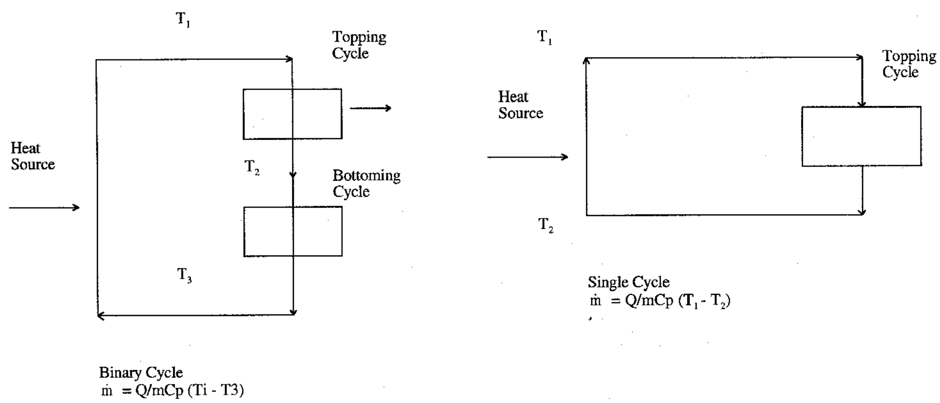


Figure 7.2-2 Comparison between a binary cycle and a single cycle system

For the system outlined, the thermal power to be converted into electricity at the topping cycle of the binary cycle is much less than that to be converted in the single cycle due to the much less coolant flow rate. The other part will be converted by the bottoming cycle, which will certainly have a lower conversion efficiency than the topping cycle. Therefore, the combined efficiency of the topping cycle and bottoming cycle will be less than the single cycle along. Therefore, a binary cycle will not be recommended by a close cycle.

<u>Conclusions:</u>

Various power conversion cycle efficiencies have been investigated. This work will continue during the next phase of APEX evaluation.