Brayton Cycle

- **Closed cycle gas**
- **Heat addition occur at constant pressure**

$$\eta_{\text{th}} = \frac{\left(\text{work out}\right)_{\text{turbine}} - \left(\text{work in}\right)_{\text{compressor}}}{Q_{th}}$$

==

- **Regeneration (Figure)**
- **Intercooling (Figure)**
- **Reheat (Figure)**
- **Example (Figure)**
- **Efficiency (Figure)**

Note: Thermal Efficiency Can Also Be Given By;

$$\eta_{th} = 1 - \left[\frac{p_1}{p_4}\right]^{\frac{1-k}{k}}$$

$$\text{where } k = \frac{C_p}{C_v}$$

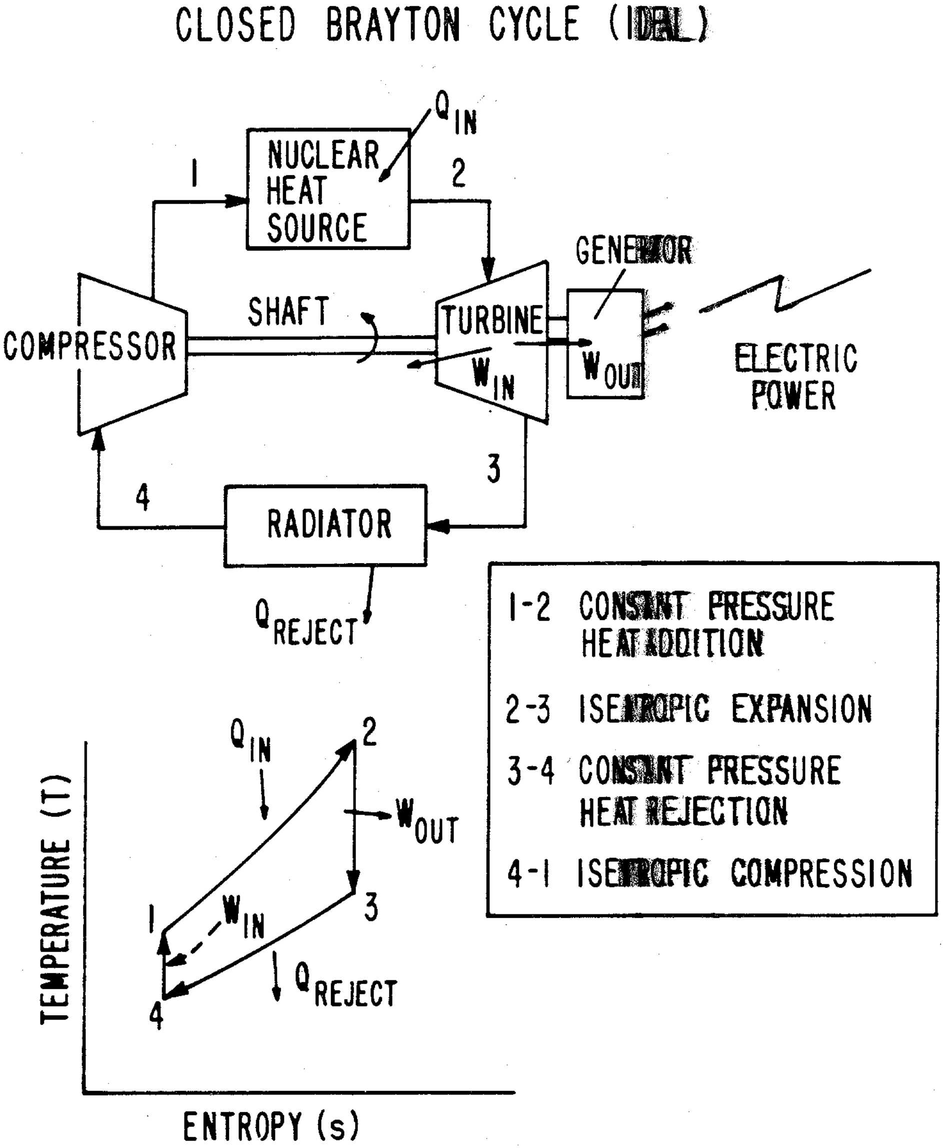


Fig. 5.14 Closed Brayton cycle (ideal).

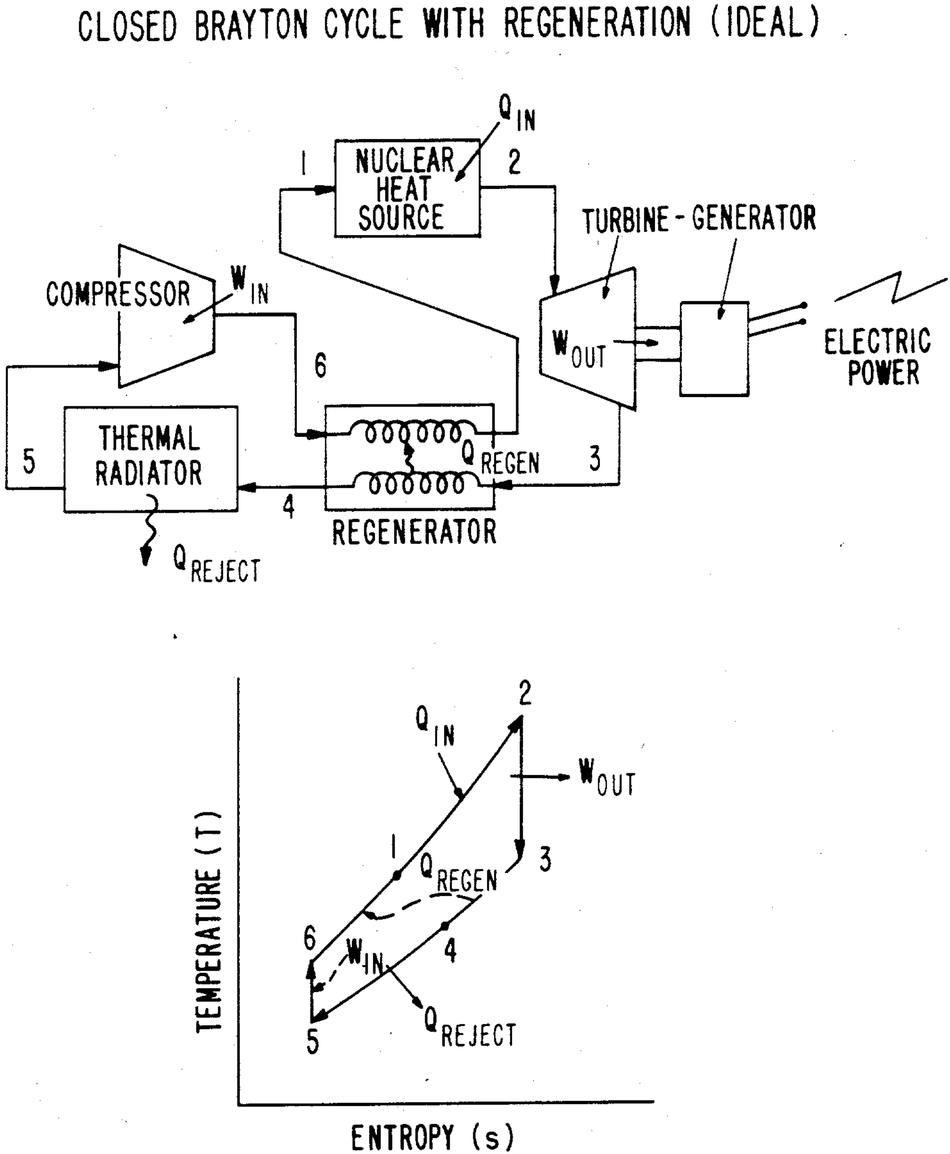


Fig. 5.15 Closed Brayton cycle with regeneration (ideal).

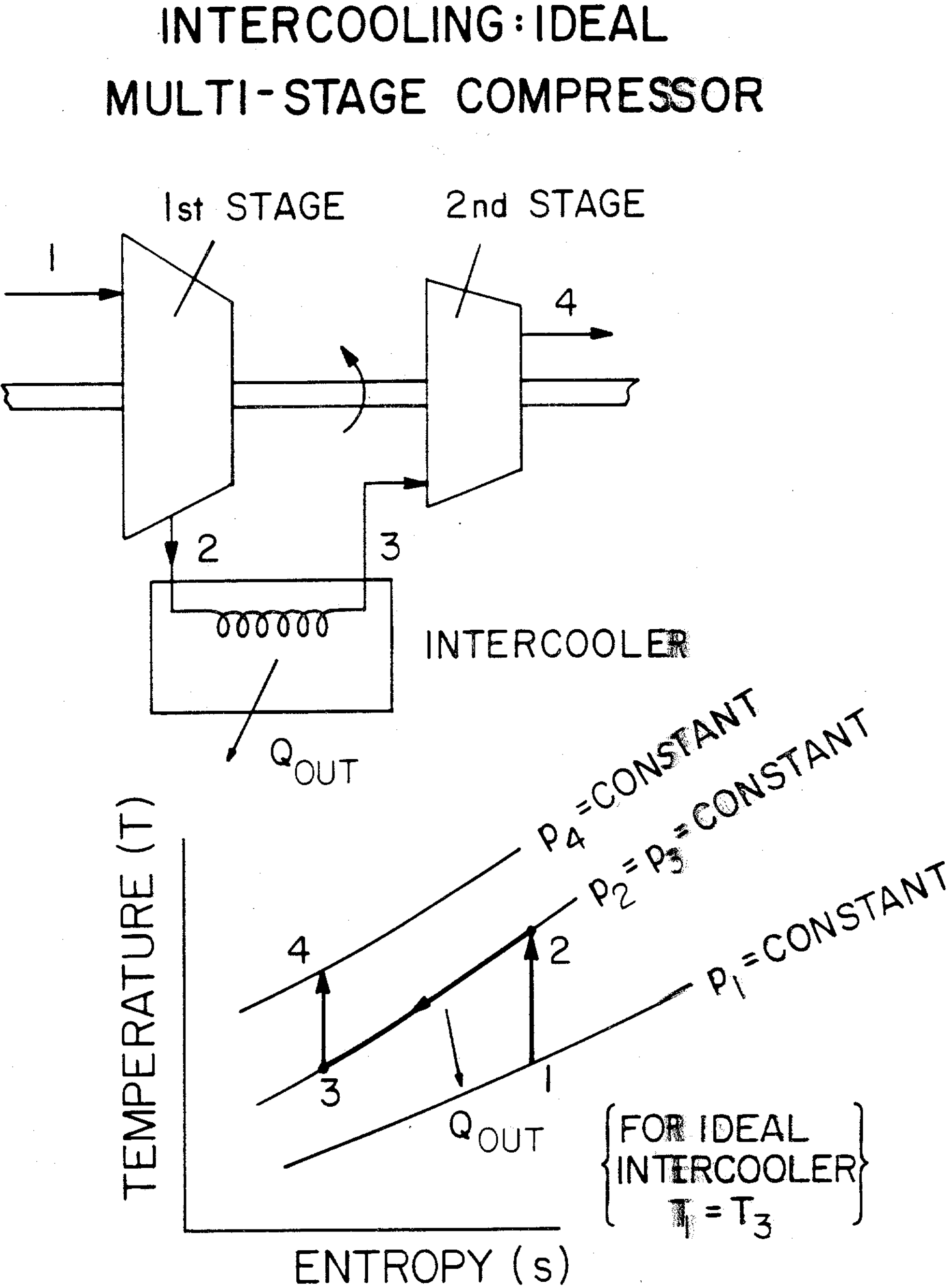


Fig. 5.16 Intercooling: ideal two-stage compressor.

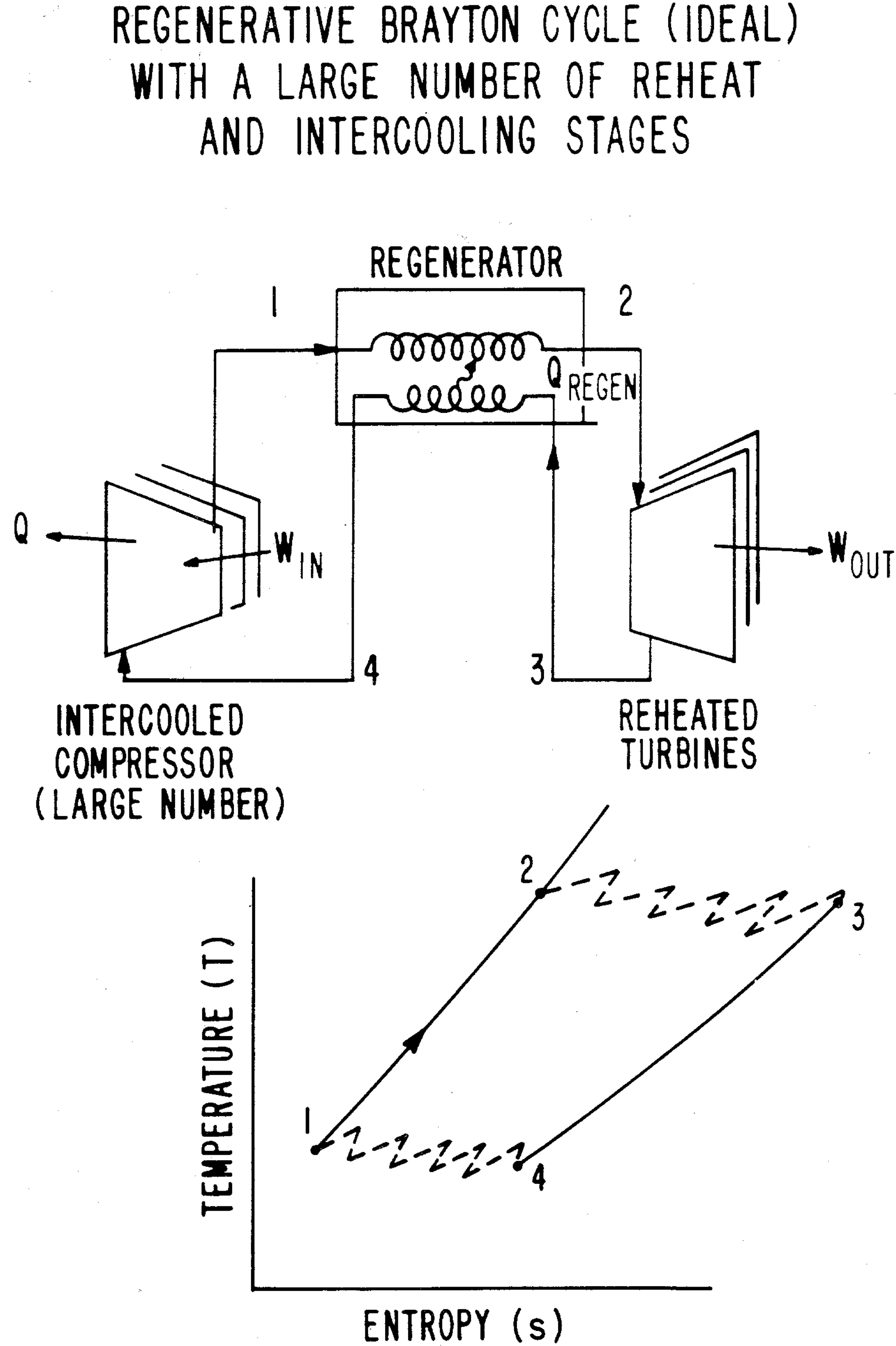


Fig. 5.17 Regenerative Brayton cycle (ideal) with a large number of reheating and intercooling stages.

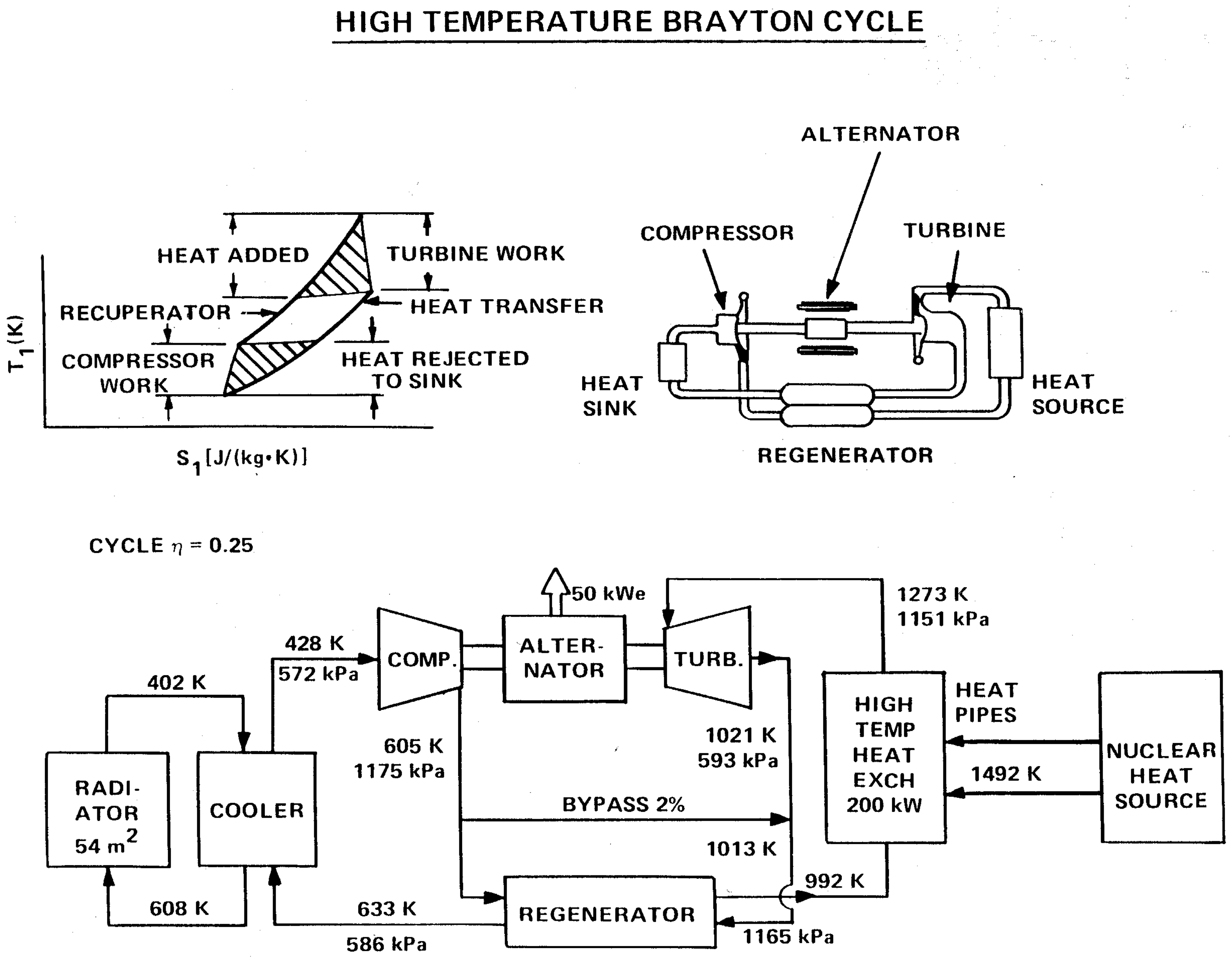


Fig. 5.18 Helium-xenon closed Brayton cycle configuration [1].

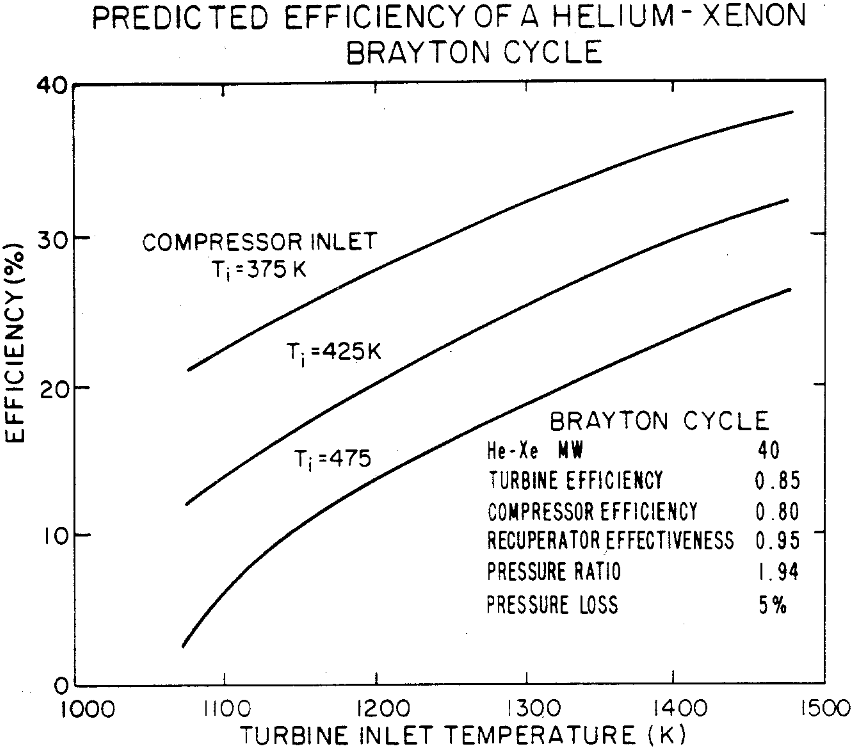


Fig. 5.19 Predicted efficiency of a helium-xenon Brayton cycle [*1*].

Stirling Cycle

This concept was first proposed by a Scottish Minister Robert Stirling (1790-1878) in an attempt to come as close as possible to transferring energy isothermally and reversibly.

See Figure 5.22 of an ideal regenerator

N. V. Phillips in the Netherlands revived the Stirling technology in 1938 for large cryogenic cooling machines

- **In the 1960's General Motors picked up the FPSE for ground transportation**
- **In the 1970's to late 80's concern about air pollution and the oil embargo triggered US R & D for cars.**
- **In the late 70's, a 1-kWe power unit was demonstrated**
- **In the early 80's this had grown to 3 kW_e.**
- **In the early 90's the Space Power Demonstration Engine was tested and produced 25 kW_e at 25%.**

Basic Ideal Stirling Cycle- Figure 5.23

Free Piston Stirling Engine (FPSE)-Figure 5.24

The FPSE displacer motion is produced by gas pressures rather than mechanical linkages. This engine operates at the highest efficiency of all known heat engines.

The FPSE eliminates the need for converting reciprocating motion to rotary motion (and the need for lubrication)

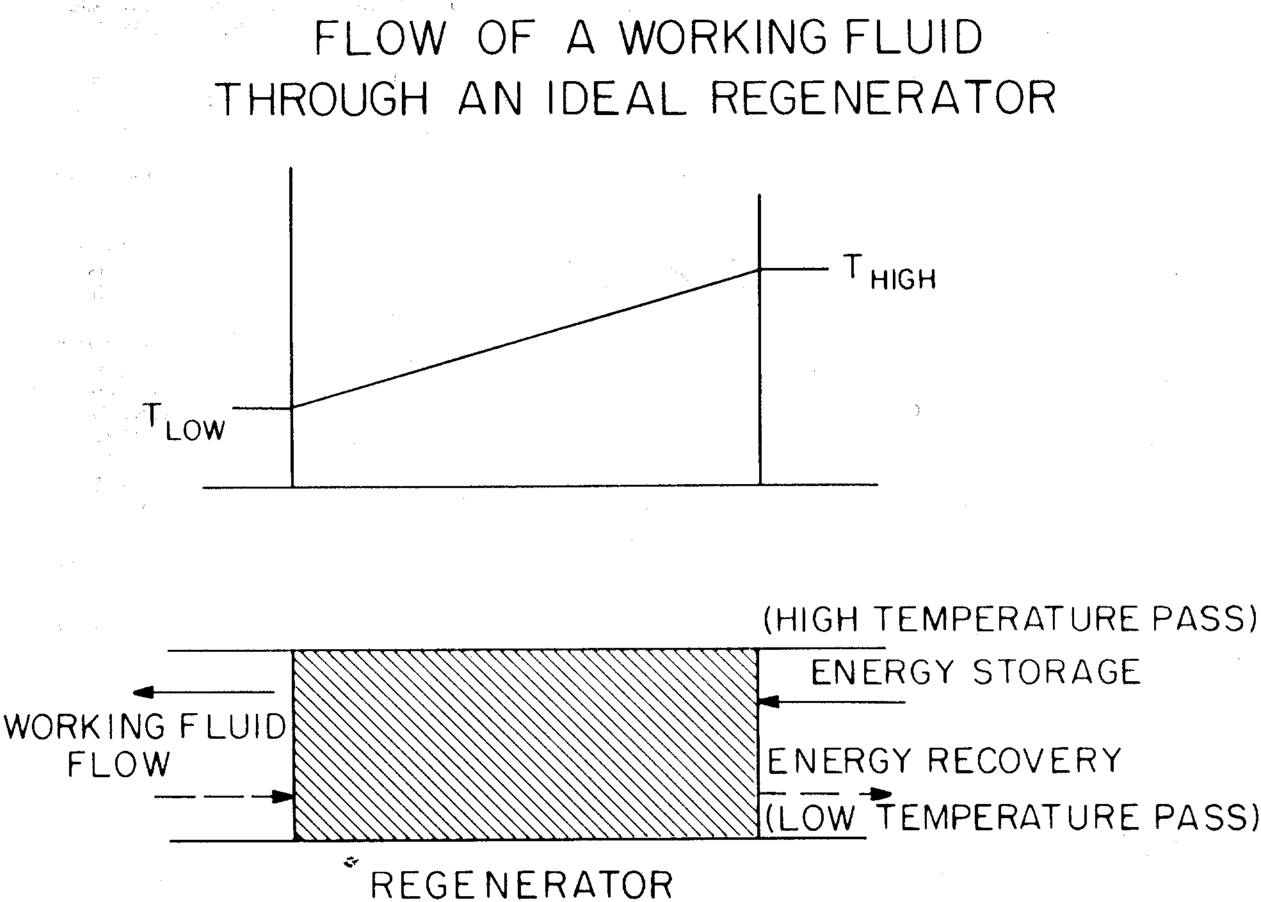


Fig. 5.22 Flow of a working fluid through an ideal regenerator.

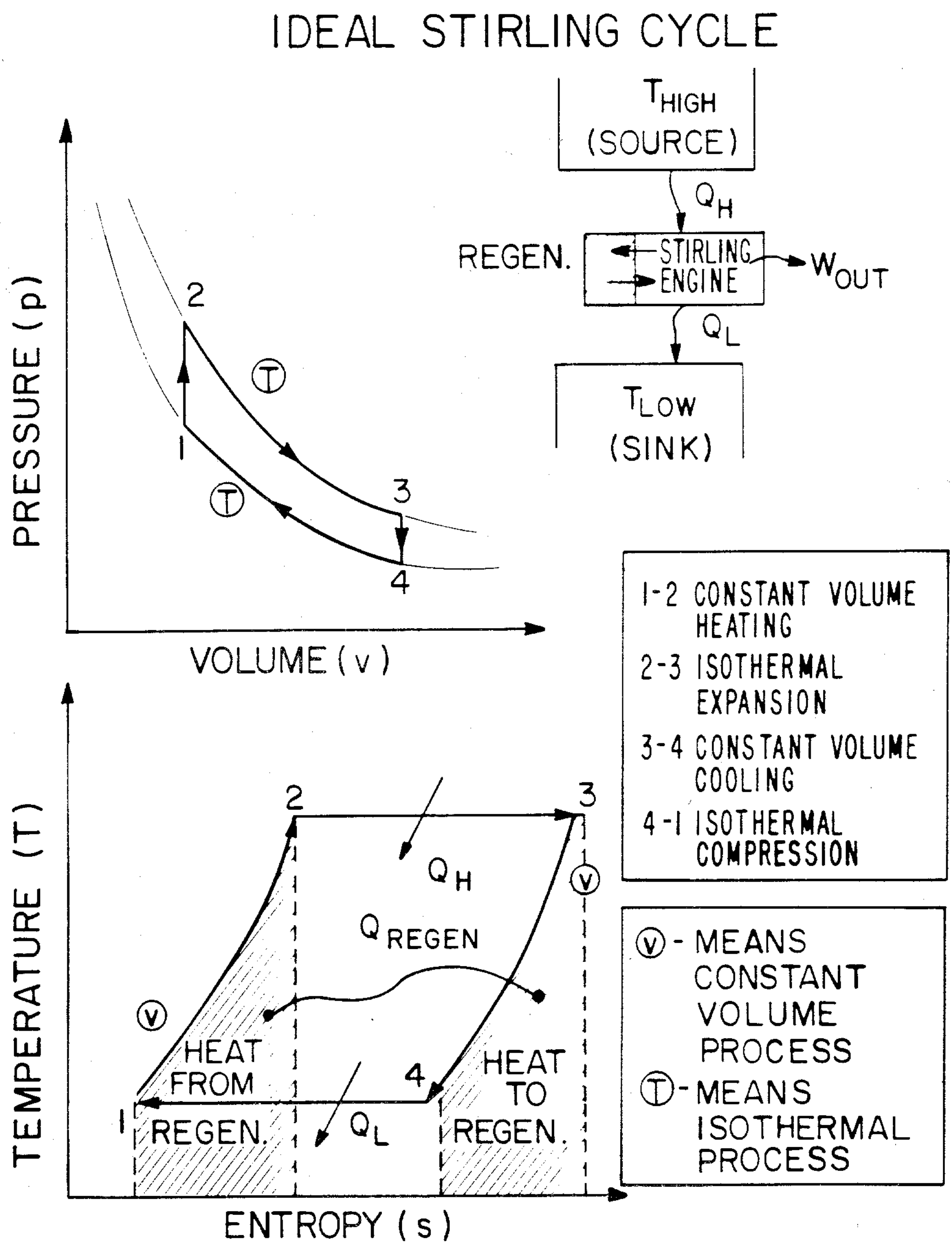
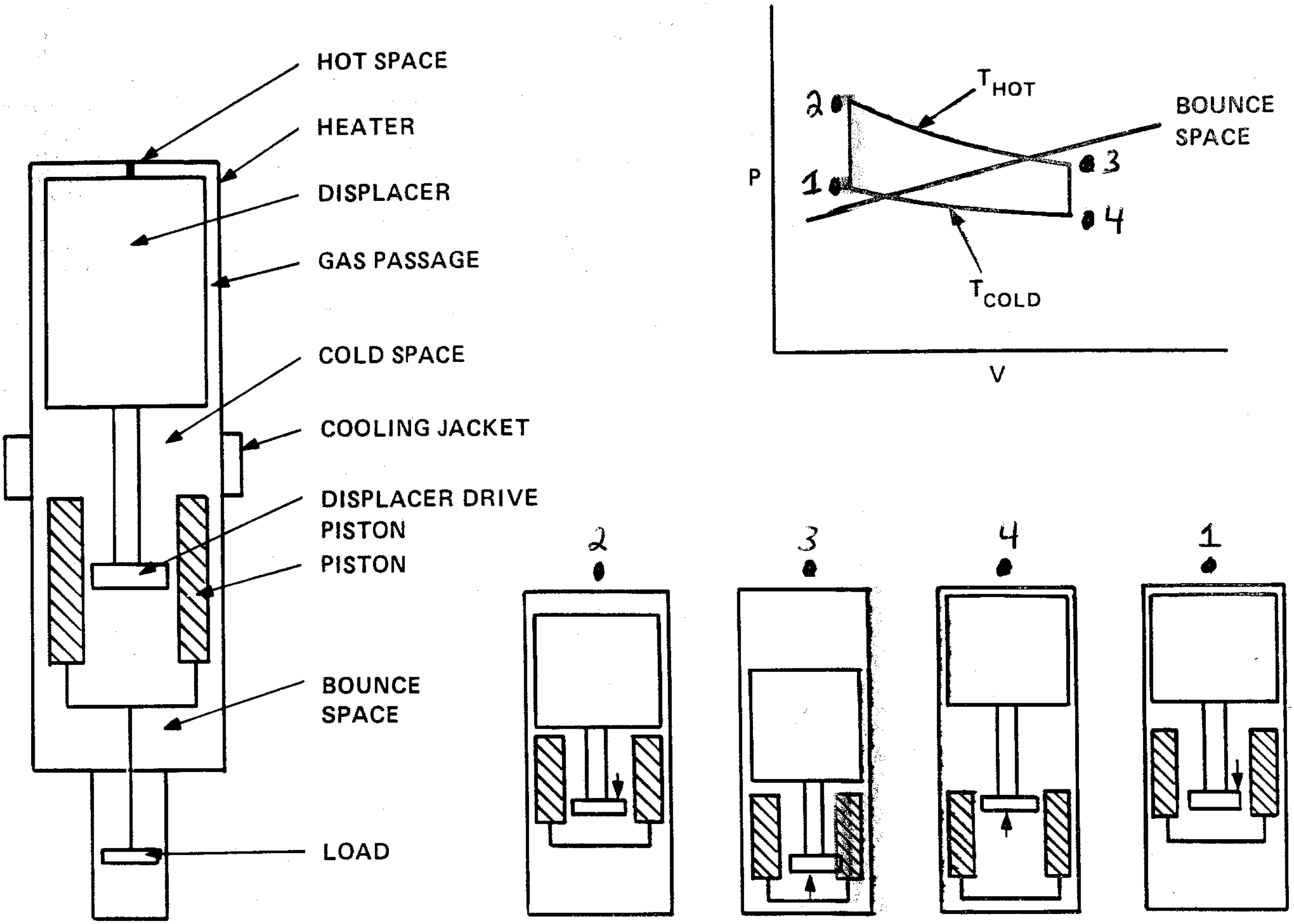


Fig. 5.23 Ideal Stirling cycle.

OPERATING PRINCIPLES OF FREE PISTON STIRLING ENGINE (FPSE)



2-3 [redacted] PISTON EXPANDS WORKING GAS; DISPLACER ON PISTON.

3-4 [redacted] PRESSURE IN BOUNCE SPACE GREATER THAN PRESSURE IN WORKING SPACE, FORCING DISPLACER TOWARD HOT SPACE, WORKING GAS MOVE INTO COOLED SPACE, PRESSURE DROPS.

4-1 [redacted] PISTON DRIVEN INTO WORKING SPACE BY HIGHER BOUNCE SPACE PRESSURE.

1-2 [redacted] DISPLACER DRIVEN TOWARD COLD SPACE BY WORKING SPACE PRESSURE HIGHER THAN BOUNCE SPACE PRESSURE.

Fig. 5.24 Operational principles of free piston Stirling engine (FPSE) [2].

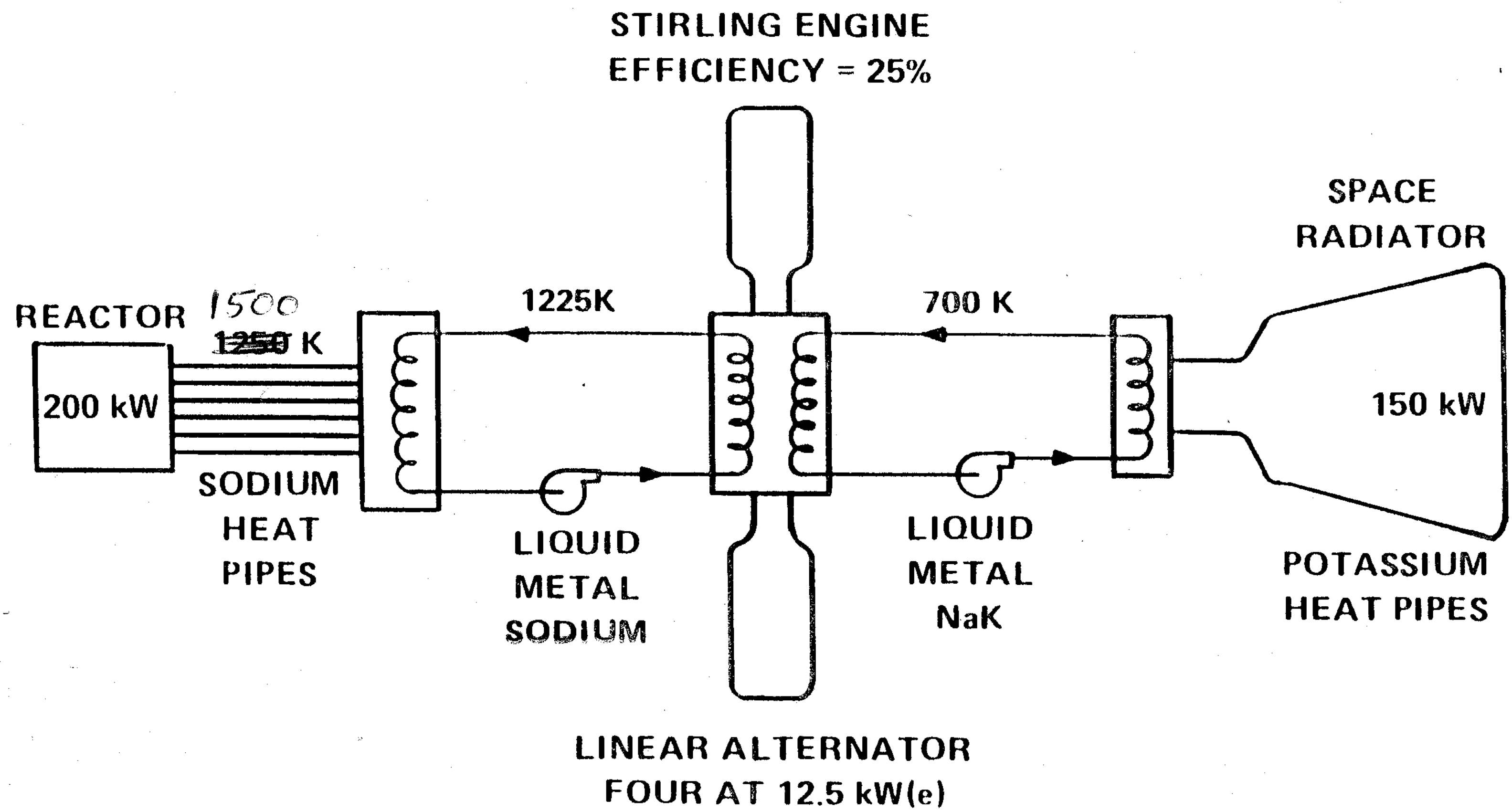


Fig. 5.26 Reference design 50 kW_e free piston Stirling engine with linear alternator [/].