AERO ENGINEERING THERMODYNAMICS

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Unit-4 : AIR STANDARD CYCLES

- **Otto cycle, Diesel cycle, Dual cycle. Indicator diagram, Air standard efficiency, Mean effective pressure. Brayton cycle - Effect of Reheat, Regeneration and Intercooling. Isentropic efficiency of Turbine and Compressor. Equivalent Carnot cycles- Stirling and Ericsson cycle, Humphrey cycle.**

THE BRAYTON CYCLE WITH INTERCOOLING, REHEATING, AND REGENERATION

- The net work of a gas-turbine cycle is the difference between the turbine work output and the compressor work input, and it can be increased by either decreasing the compressor work or increasing the turbine work, or both.

- The work required to compress a gas between two specified pressures can be decreased by carrying out the compression process in stages and cooling the gas in between that is, using *multistage compression with intercooling.*

THE BRAYTON CYCLE WITH INTERCOOLING, REHEATING, AND REGENERATION

- As the number of stages is increased, the compression process becomes nearly isothermal at the compressor inlet temperature, and the compression work decreases.

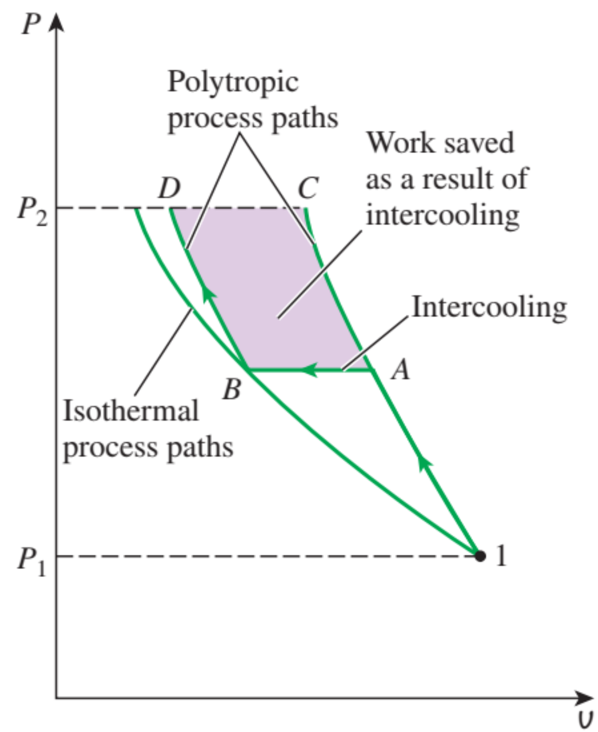
- Likewise, the work output of a turbine operating between two pressure levels can be increased by expanding the gas in stages and reheating it in between—that is, utilizing *multistage expansion with reheating.*

THE BRAYTON CYCLE WITH INTERCOOLING, REHEATING, AND REGENERATION

- This is accomplished without raising the maximum temperature in the cycle.

- As the number of stages is increased, the expansion process becomes nearly isothermal.

- **Comparison of work inputs to a single-stage compressor (1*AC) and a* two-stage compressor with intercooling (1*ABD).***

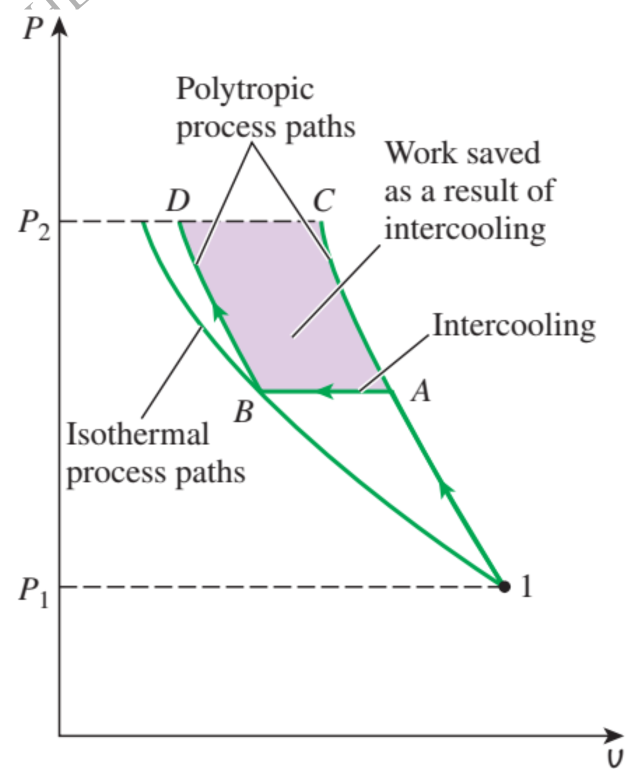


THE BRAYTON CYCLE WITH INTERCOOLING, REHEATING, AND REGENERATION

- *The steady-flow compression or expansion work is proportional to the specific volume of the fluid.*

- *Therefore, the* ***specific volume*** *of the working fluid* should be as *low as possible during a compression* process *and as high as possible during an expansion* process*. This is precisely what intercooling* and reheating accomplish.

- **Comparison of work inputs to a single-stage compressor (1*AC) and a* two-stage compressor with intercooling (1*ABD).***



THE BRAYTON CYCLE WITH INTERCOOLING, REHEATING, AND REGENERATION

- The exhaust gases are rich in oxygen, and reheating can be accomplished by simply spraying additional fuel into the exhaust gases between two expansion states.

- The working fluid leaves the compressor at a lower temperature, and the turbine at a higher temperature, when intercooling and reheating are utilized.

- This makes regeneration more attractive since a greater potential for regeneration exists.

- Also, the gases leaving the compressor can be heated to a higher temperature before they enter the combustion chamber because of the higher temperature of the turbine exhaust.

A gas-turbine engine with two-stage compression with intercooling, two-stage expansion with reheating, and regeneration.

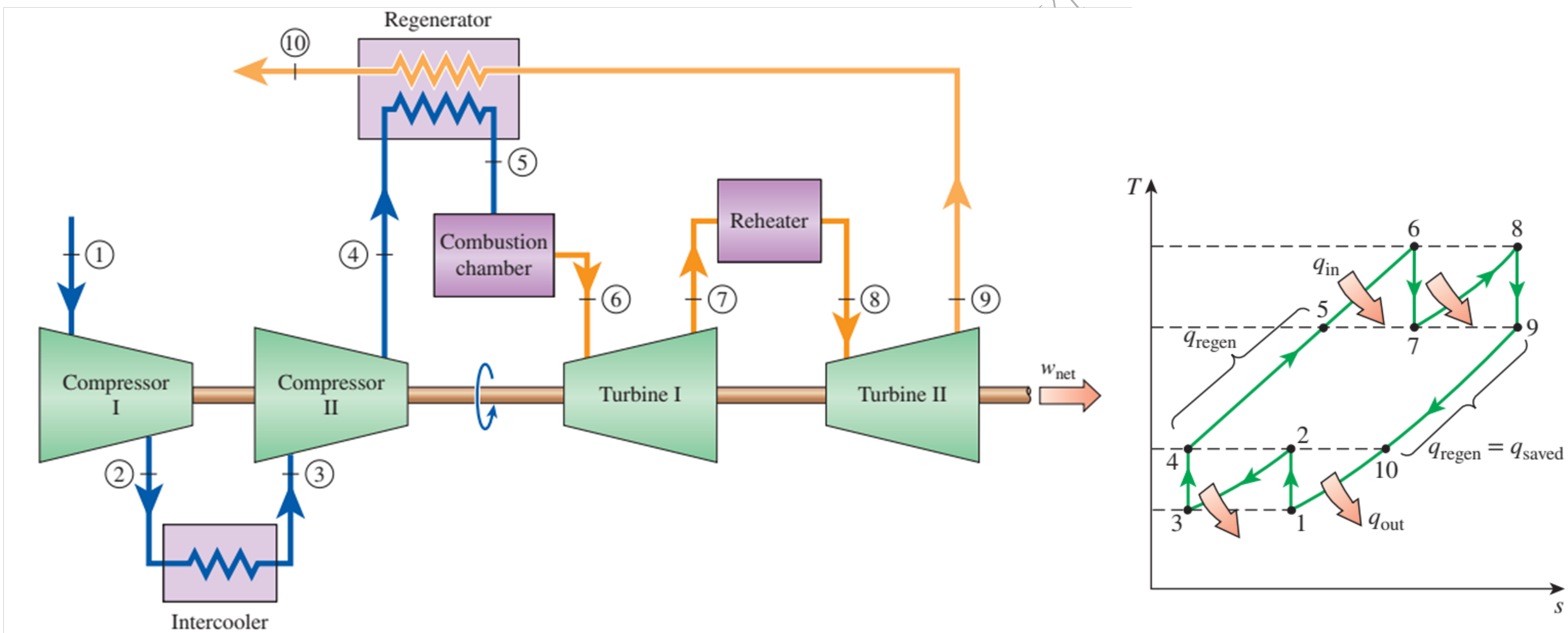


FIGURE 10–44
A gas-turbine engine with two-stage compression with intercooling, two-stage expansion with reheating, and regeneration.

Intercooler

A gas-turbine engine with two-stage compression with intercooling, two-stage expansion with reheating, and regeneration.

- The gas enters the first stage of the compressor
- at state 1, is compressed isentropically to an intermediate pressure *P2, is* cooled at constant pressure to state 3 (*T3 T1), and is compressed in the second* stage isentropically to the final pressure *P4. At state 4 the gas enters the* regenerator, where it is heated to *T5 at constant pressure. In an ideal regenerator,* the gas leaves the regenerator at the temperature of the turbine exhaust, that is, *T5 T9. The primary heat addition (or combustion) process takes*

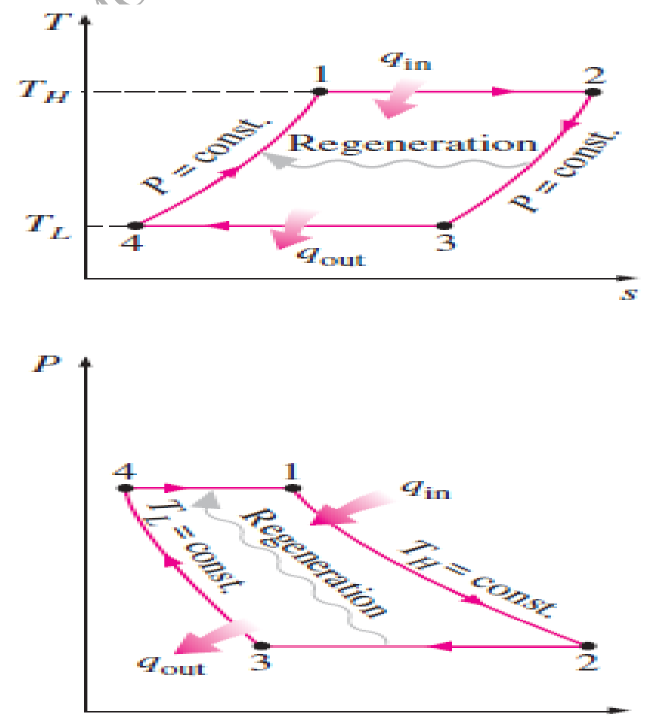
A gas-turbine engine with two-stage compression with intercooling, two-stage expansion with reheating, and regeneration.

- place between states 5 and 6. The gas enters the first stage of the turbine at state 6 and expands isentropically to state 7, where it enters the reheater. It is reheated at constant pressure to state 8 (*T8 T6), where it enters the second* stage of the turbine. The gas exits the turbine at state 9 and enters the regenerator, where it is cooled to state 10 at constant pressure. The cycle is completed by cooling the gas to the initial state (or purging the exhaust gases).

- The work input to a two-stage compressor is minimized when equal pressure ratios are maintained across each stage. It can be shown that this procedure also maximizes the turbine work output. Thus, for best performance we have

$$\frac{P_2}{P_1} = \frac{P_4}{P_3} \quad \text{and} \quad \frac{P_6}{P_7} = \frac{P_8}{P_9}$$

- If the number of compression and expansion stages is increased, the ideal gas-turbine cycle with intercooling, reheating, and regeneration approaches the Ericsson cycle, and the thermal efficiency approaches the theoretical limit (the Carnot efficiency).
- However, the contribution of each additional stage to the thermal efficiency is less and less, and the use of more than two or three stages cannot be justified economically.



(c) Ericsson cycle

- As the number of compression and expansion stages increases, the gasturbine cycle with intercooling, reheating, and regeneration approaches the Ericsson cycle.

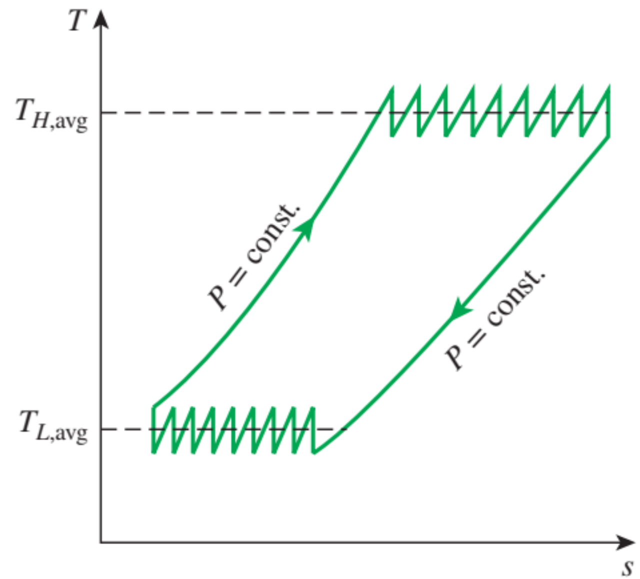


FIGURE 10–46
As the number of compression and expansion stages increases, the gas-turbine cycle with intercooling, reheating, and regeneration approaches the Ericsson cycle.