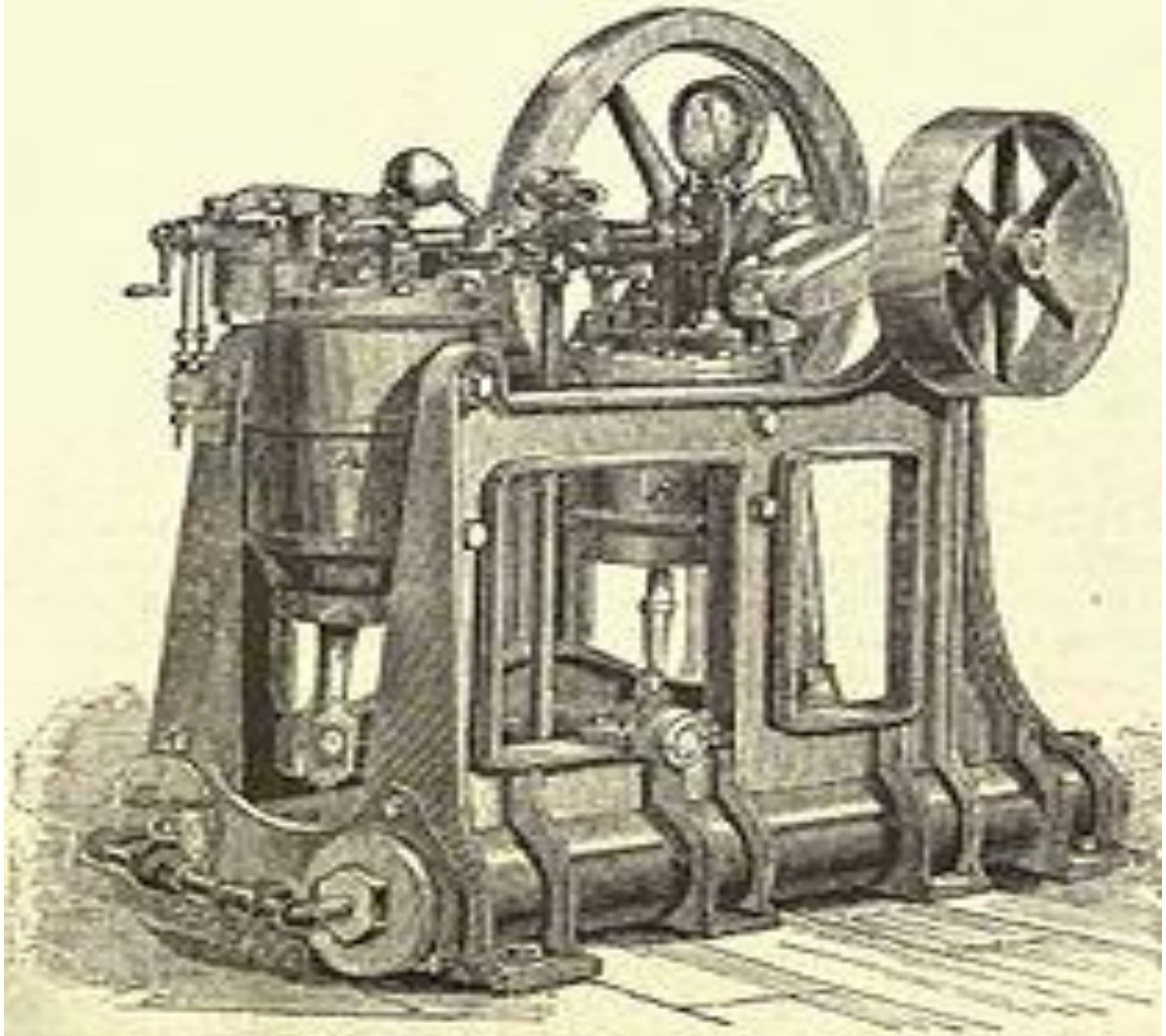
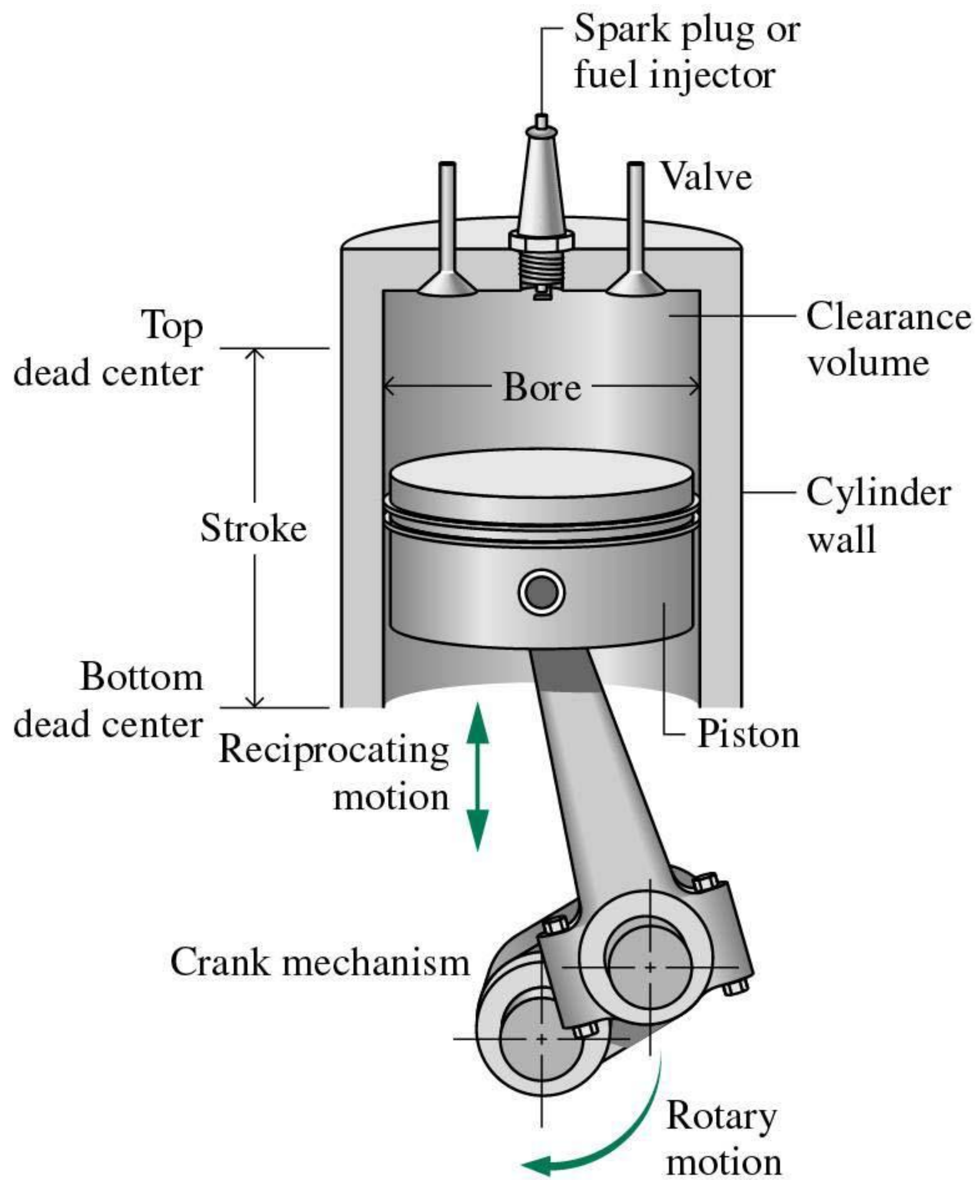


Fig. 40.—Brayton Petroleum Engine.



Spark plug or
fuel injector
Valve
Top
dead center
Clearance
volume
Bore
Stroke
Cylinder
wall
Bottom
dead center
Reciprocating
motion
Piston
Crank mechanism
Rotary
motion

Brayton cycle

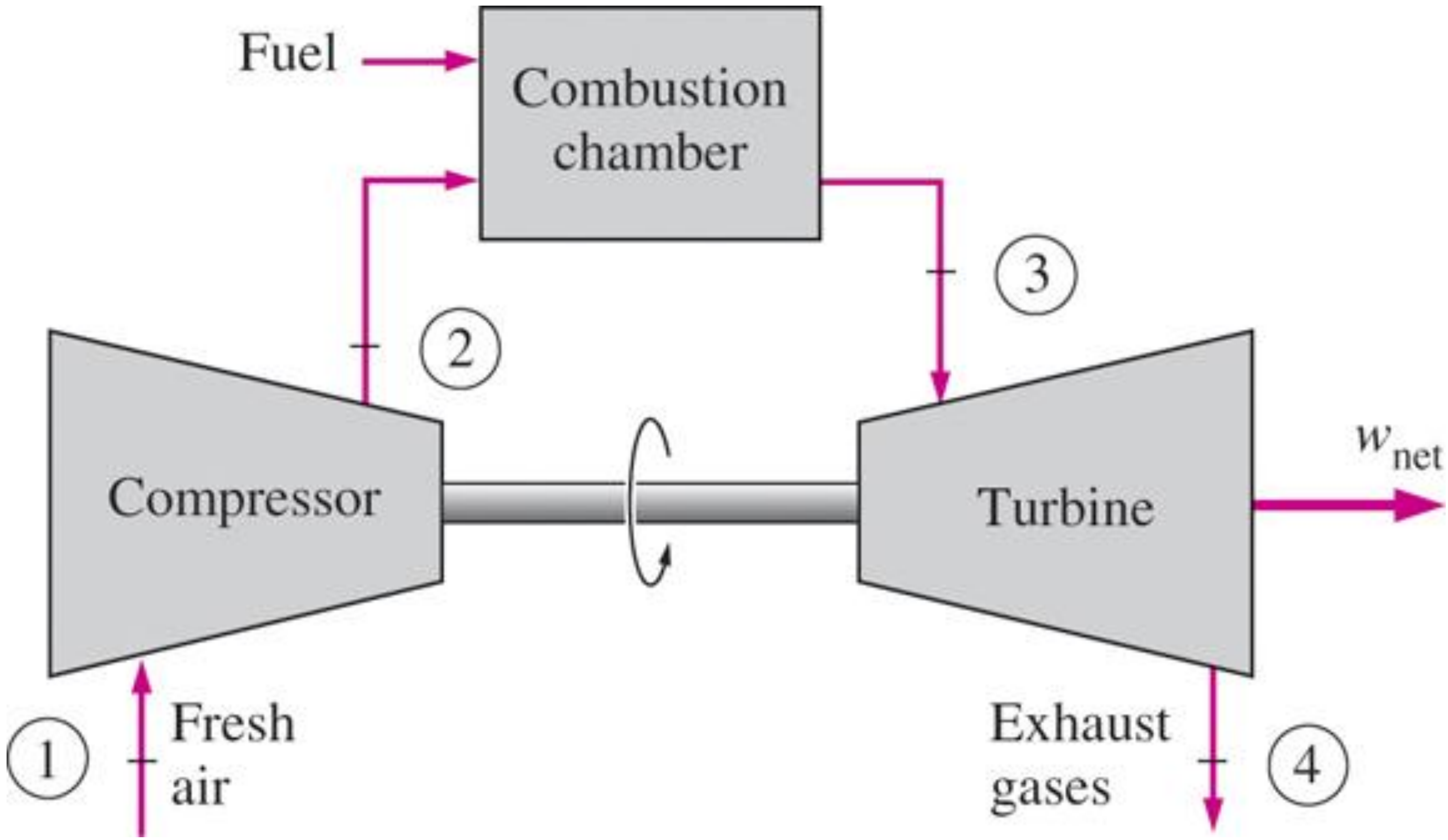
- Uses
- Auxiliary power generation
- Stand-alone power generation
- Naval propulsion
- Jet engine

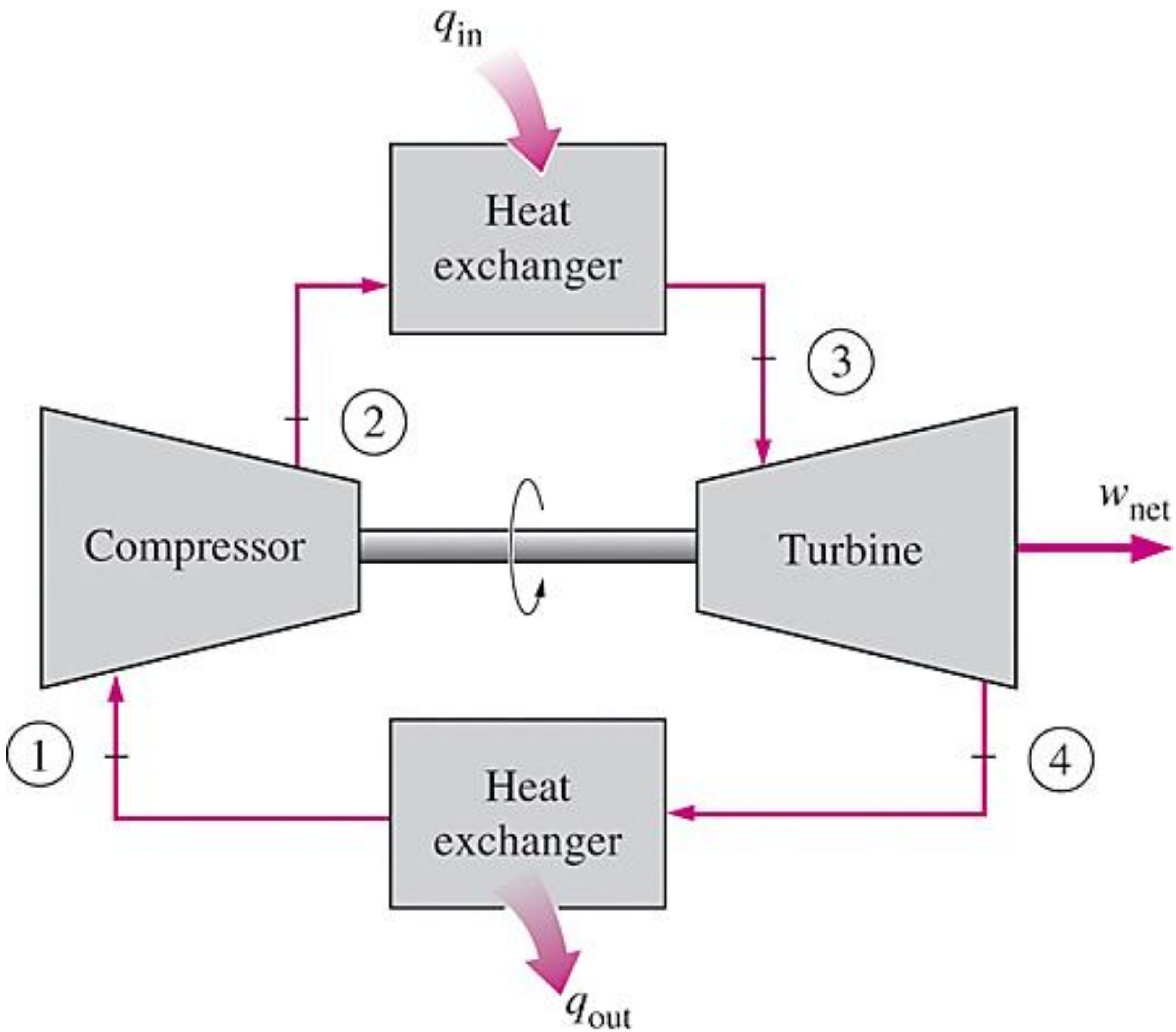
Gas Turbine

- Advantages
  - High power:weight ratio
  - Compact
  - One-direction motion – vibration
  - Fewer moving parts
  - Better reliability
  - Variety of fuels
  - Low emissions
- Disadvantages
  - Higher cost

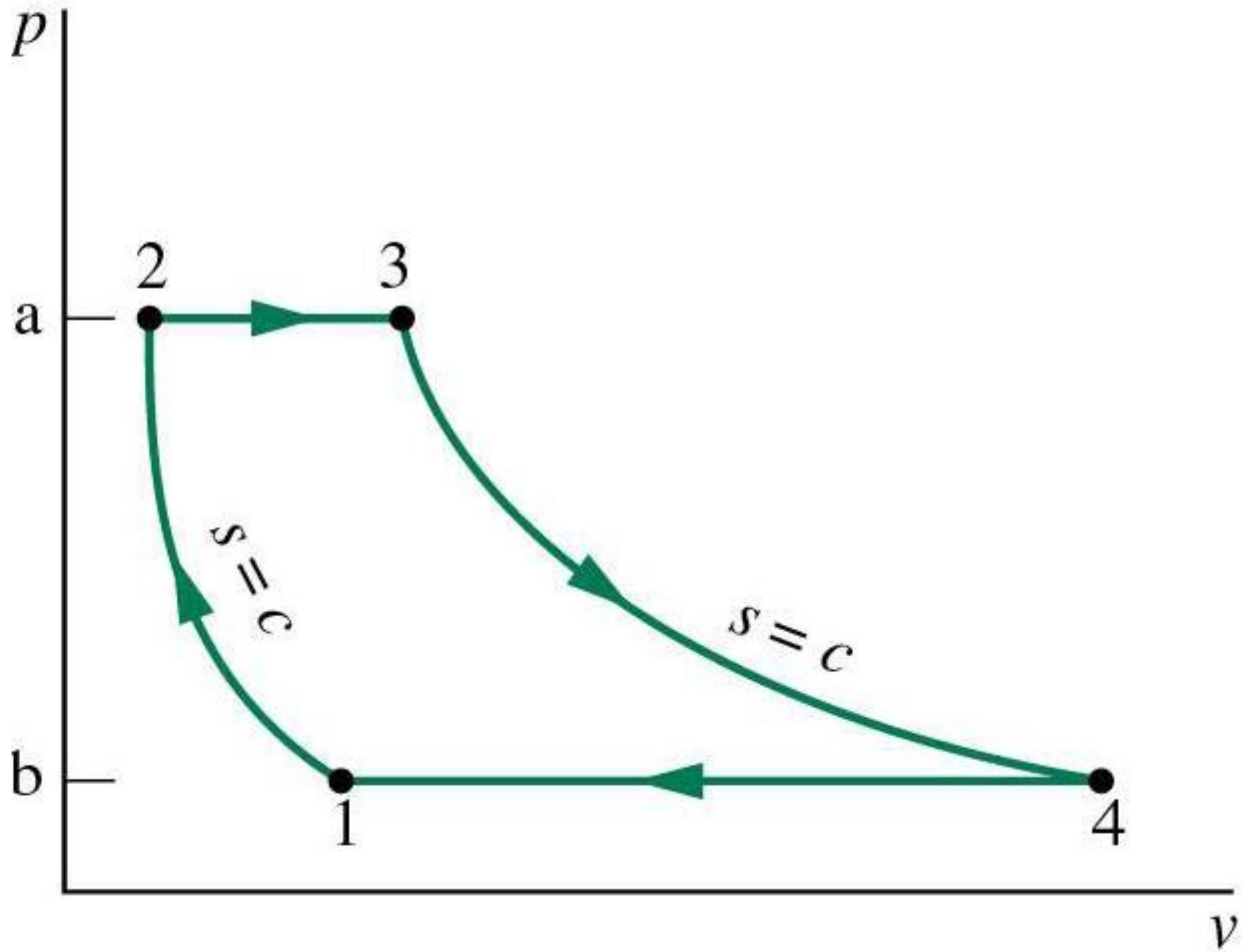
Brayton cycle

- Working fluid – air
- Ideal gas
- Specific heats steady or variable
- High temperature reservoir
- Open or closed model
- Steady pressure heat exchange


Fuel
Combustion chamber
2
3
Compressor
Turbine
w_{net}
1
Fresh air
Exhaust gases
4



q_{in}
Heat exchanger
3
2
Compressor
Turbine
w_{net}
1
4
Heat exchanger
q_{out}



p
2
3
a
s = c
s = c
b
1
4
v

Cycle Analysis

- Net work
- Heat in
- Thermal efficiency
- Back work ratio

Brayton cycle

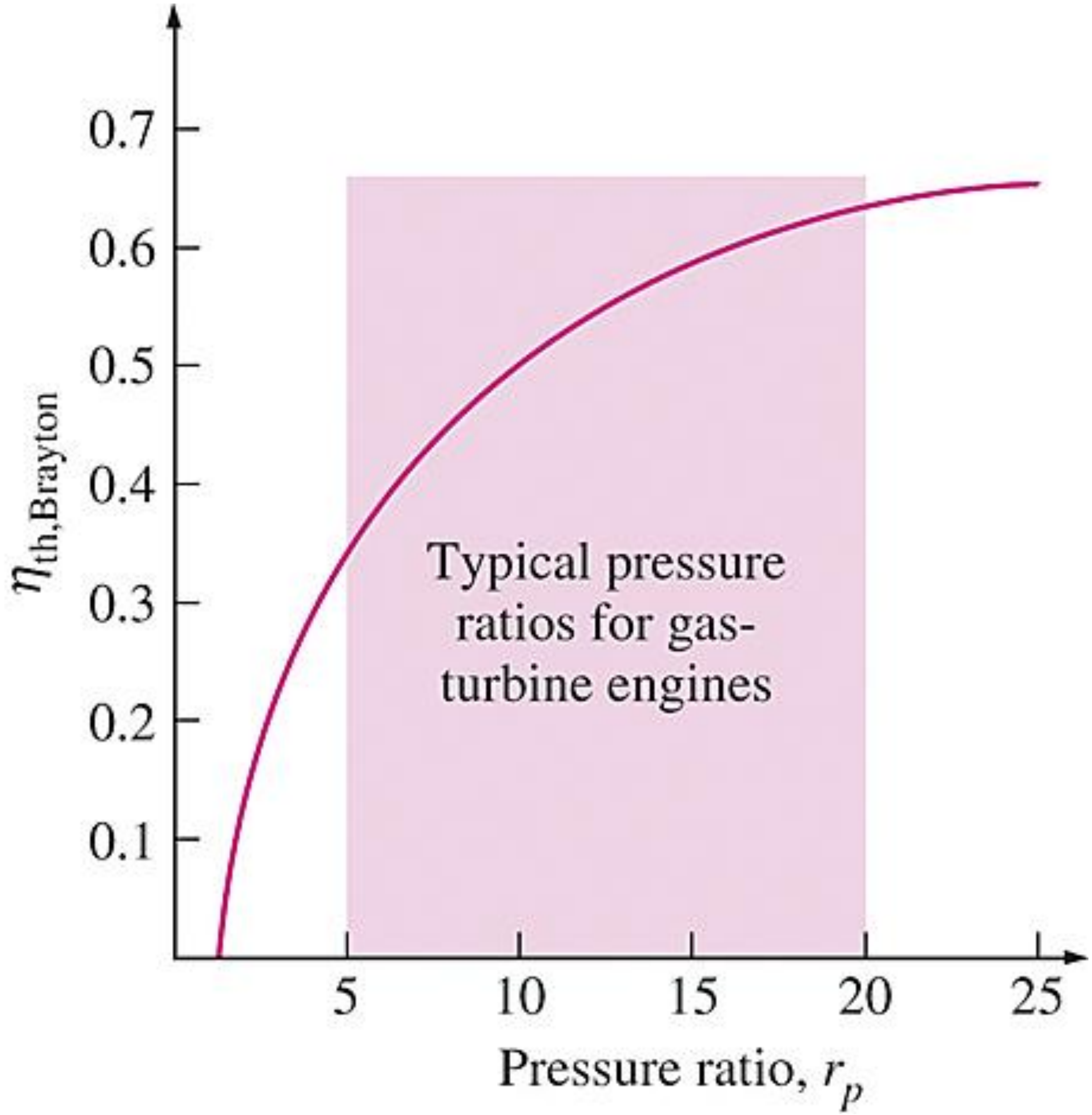
- 1→2 Isentropic compression
- 2→3 steady pressure heat addition
- 3→4 isentropic expansion
- 4→1 steady pressure heat rejection

Brayton cycle

- Work in & work out
- Heat in & heat out
- Thermal efficiency
- Pressure ratio
- Back work ratio

Brayton Cycle

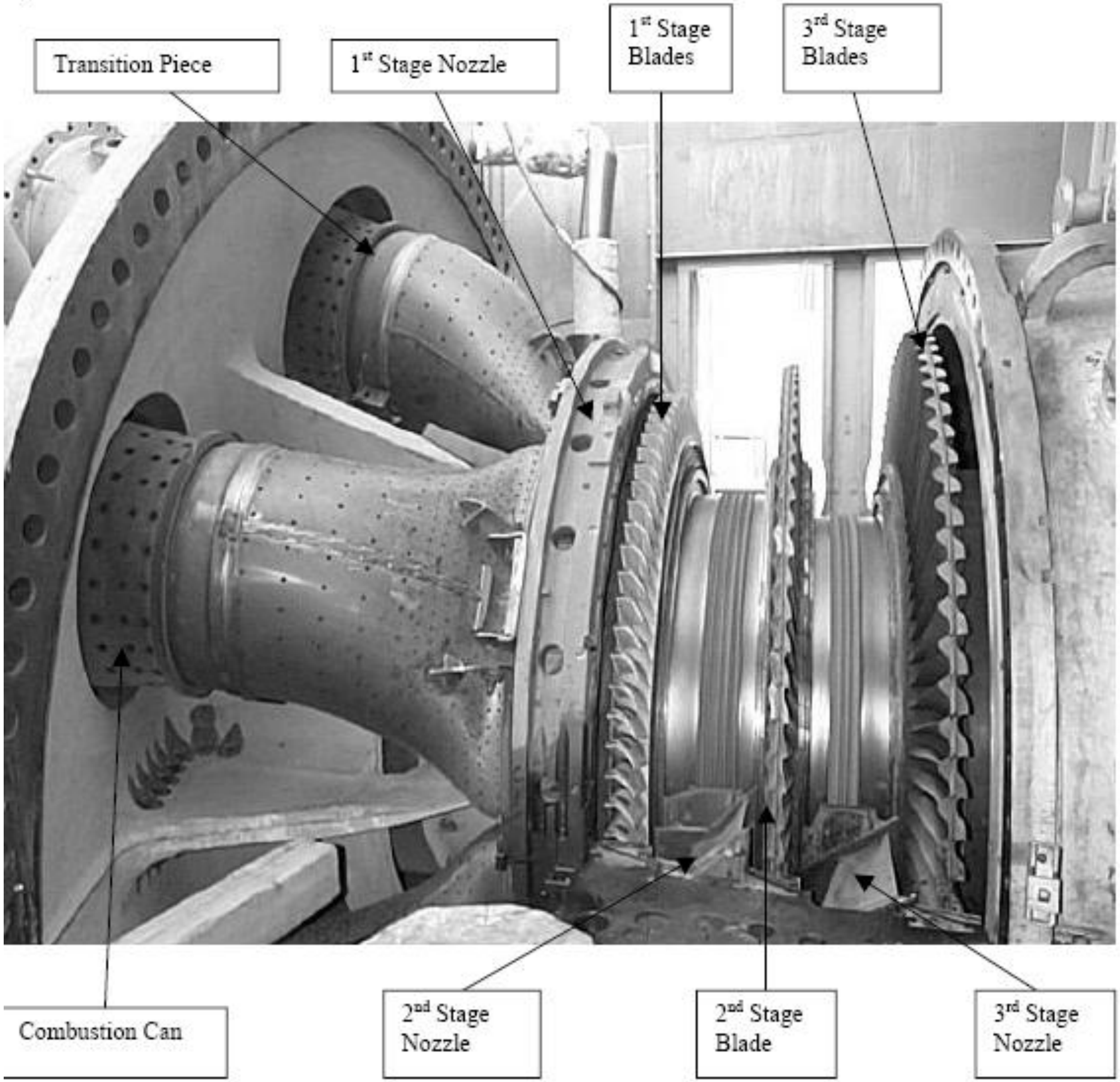
- Approaches
- Variable specific heats: Table: h, p_r
- Steady specific heats: $\Delta h = C_p \Delta T$
- P,v,T relationships: $T_2 = T_1(P_2/P_1)^{(k-1)/k}$



0.7
0.6
0.5
0.4
0.3
0.2
0.1
$\eta_{th,Brayton}$
Typical pressure ratios for gas-turbine engines
5
10
15
20
25
Pressure ratio, r_p

Compressor

- Essential to compress large volumes of air for efficiency of cycle
- Centrifugal
- Axial: more common; rotor and stator blades


Transition Piece
1st Stage Nozzle
1st Stage Blades
3rd Stage Blades
Combustion Can
2nd Stage Nozzle
2nd Stage Blade
3rd Stage Nozzle

Example

- A simple Brayton cycle has a r_p = 12, a compressor inlet at 300K, and a turbine inlet at 1000K. Determine the mass flow of air needed when the net power output is 70MW. Specific heats are constant.

Example

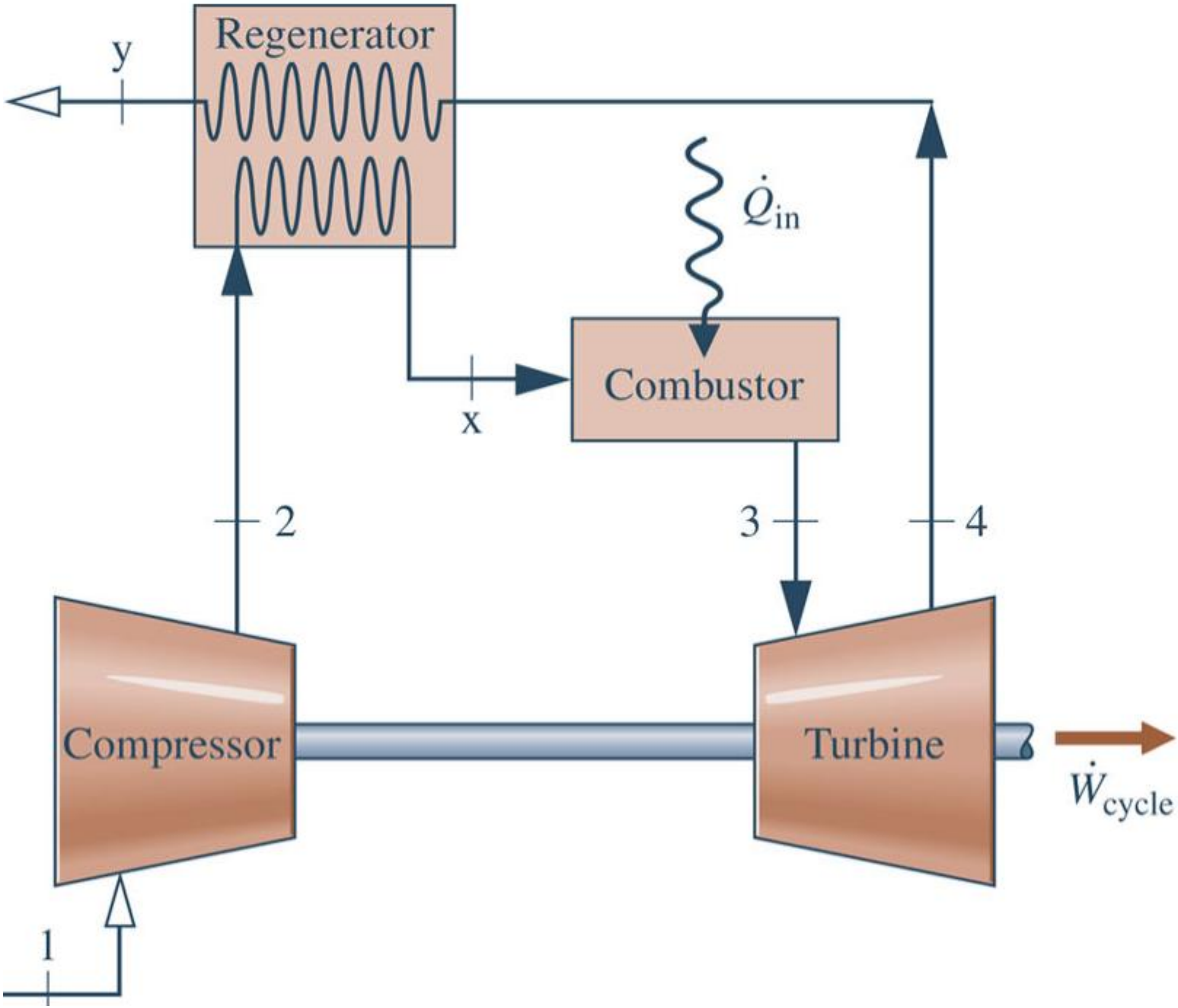
- An ideal air-standard Brayton cycle has air entering the compressor at 100kPa,300K, & $5m^3/s$. The compressor ratio is 10; the turbine inlet is at 1400K.
- Find power generated, bwr, and thermal efficiency.

Brayton cycle

- Irreversibilities: isentropic efficiency
- Gas turbine power plant operating at steady state receives air at 100kpa & 300K. Air is compressed to 500kPa and reaches a maximum cycle temperature of 920K. The isentropic efficiencies of the compressor and turbine are both at 83%.
- Find the thermal efficiency and bwr of the cycle.

Brayton cycle

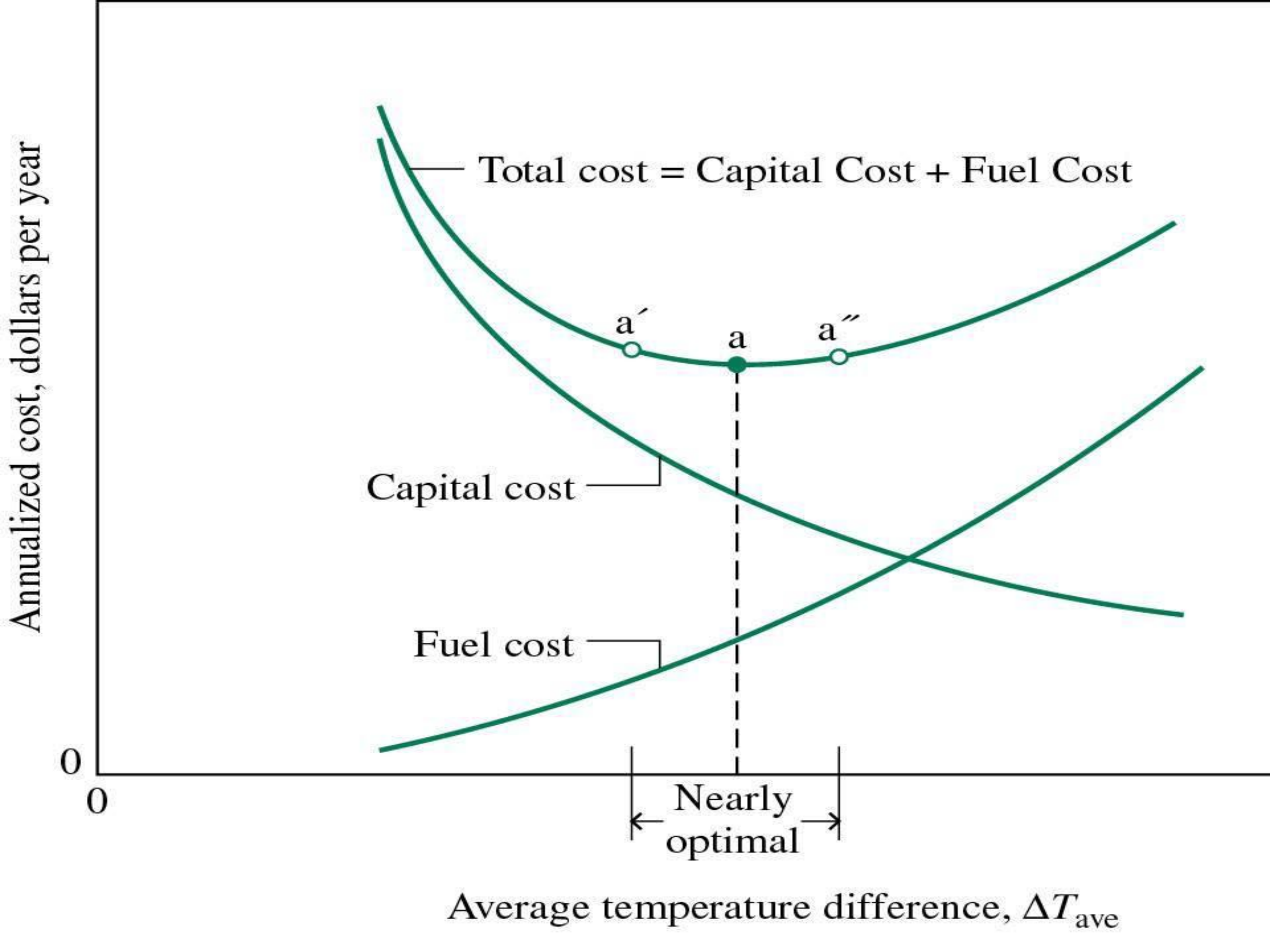
- Regenerator
- Effectiveness



Regenerator
y
$\dot{Q}_{in}$
Combustor
x
2
3
4
Compressor
Turbine
$\dot{W}_{cycle}$
1

Regeneration

- Capital costs
- Pressure losses


Total cost = Capital Cost + Fuel Cost
a´
a
a″
Capital cost
Fuel cost
0
0
Nearly optimal
Annualized cost, dollars per year
Average temperature difference, ΔT_{ave}

Brayton cycle

- Ideal
- η_{th} =45.6%

❑ With regenerator

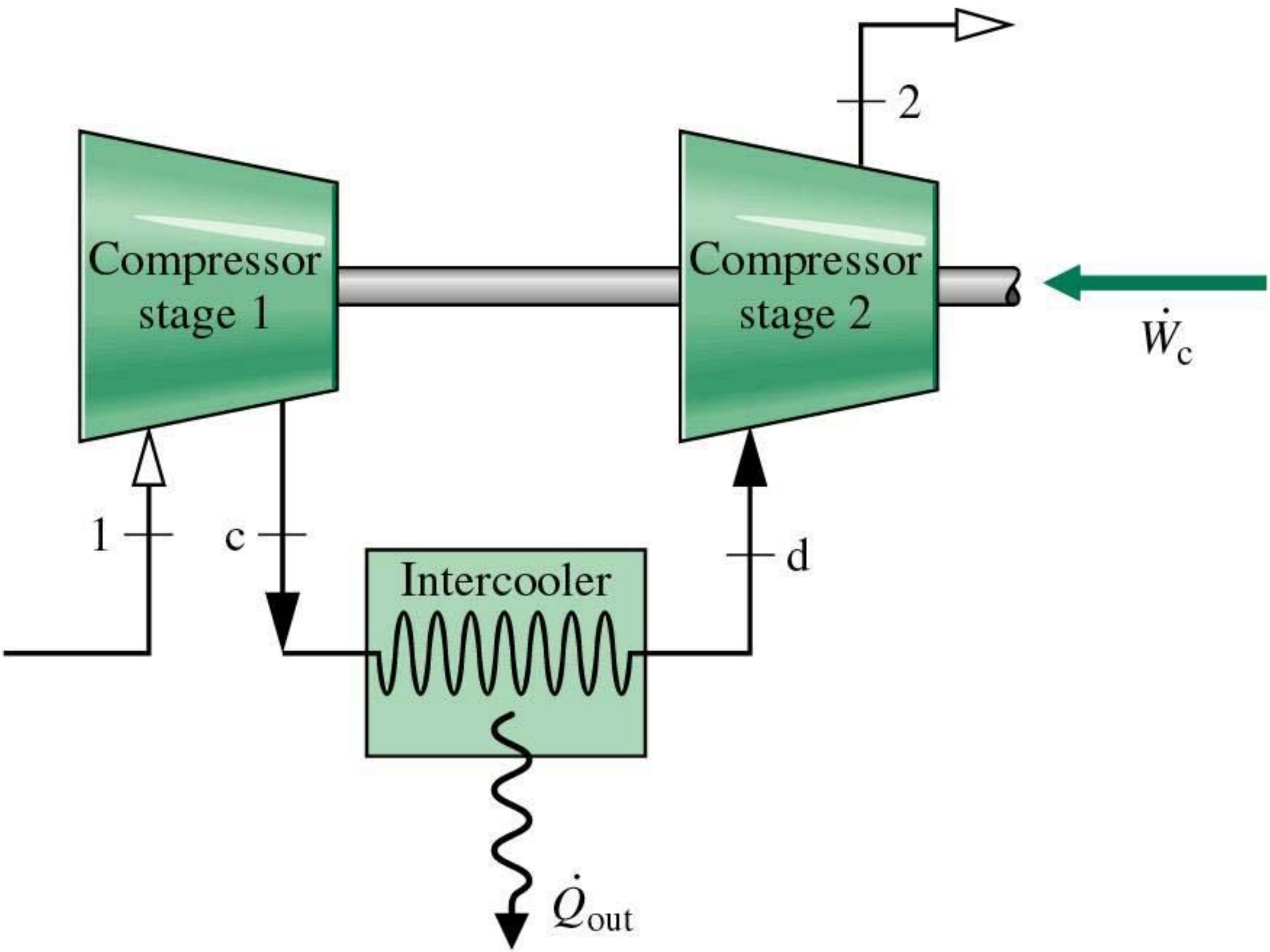
- η_{th} =57%

Assignment

- Chapter 9: sections 9.5 through 9.10

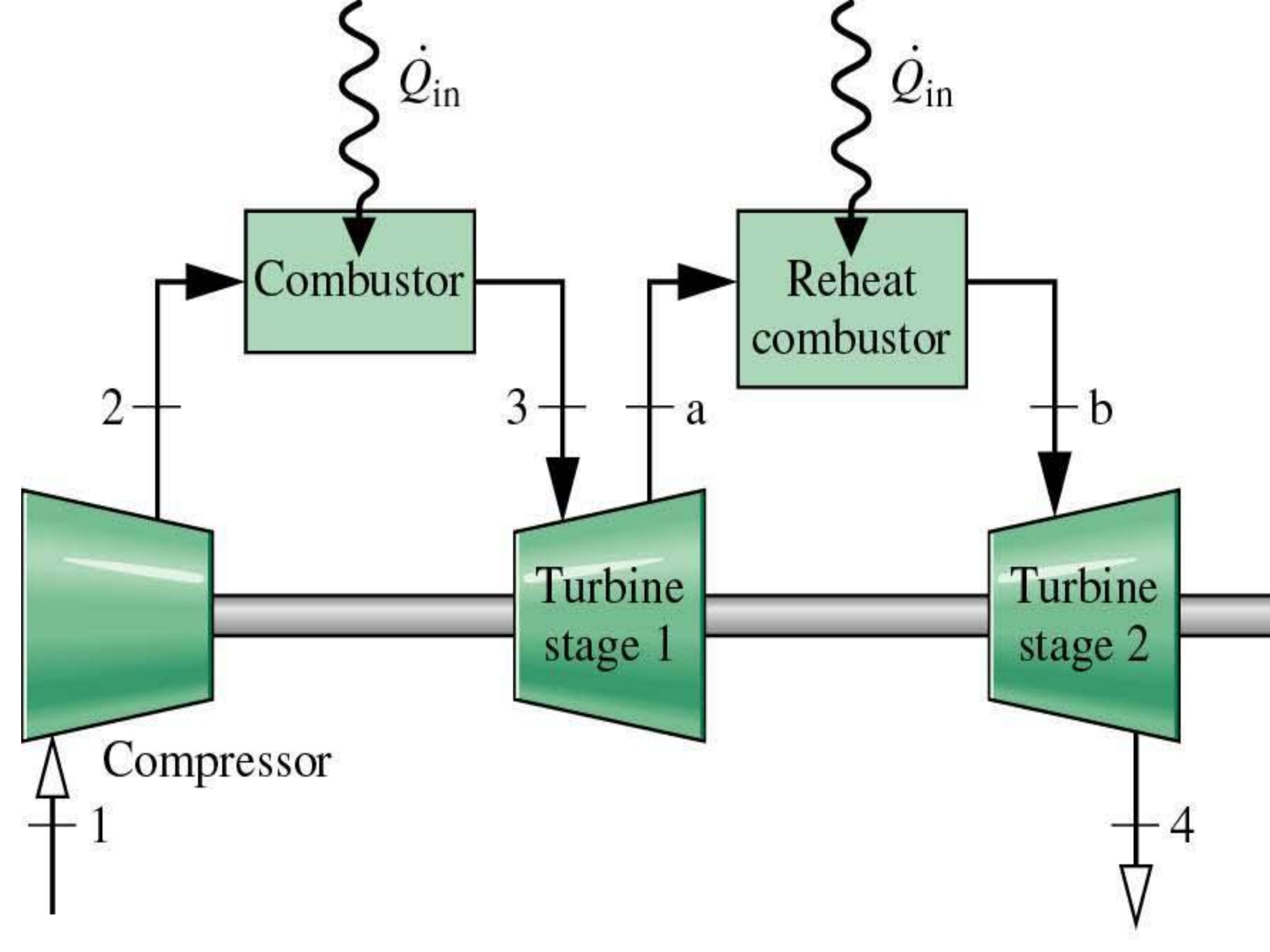
Brayton cycle

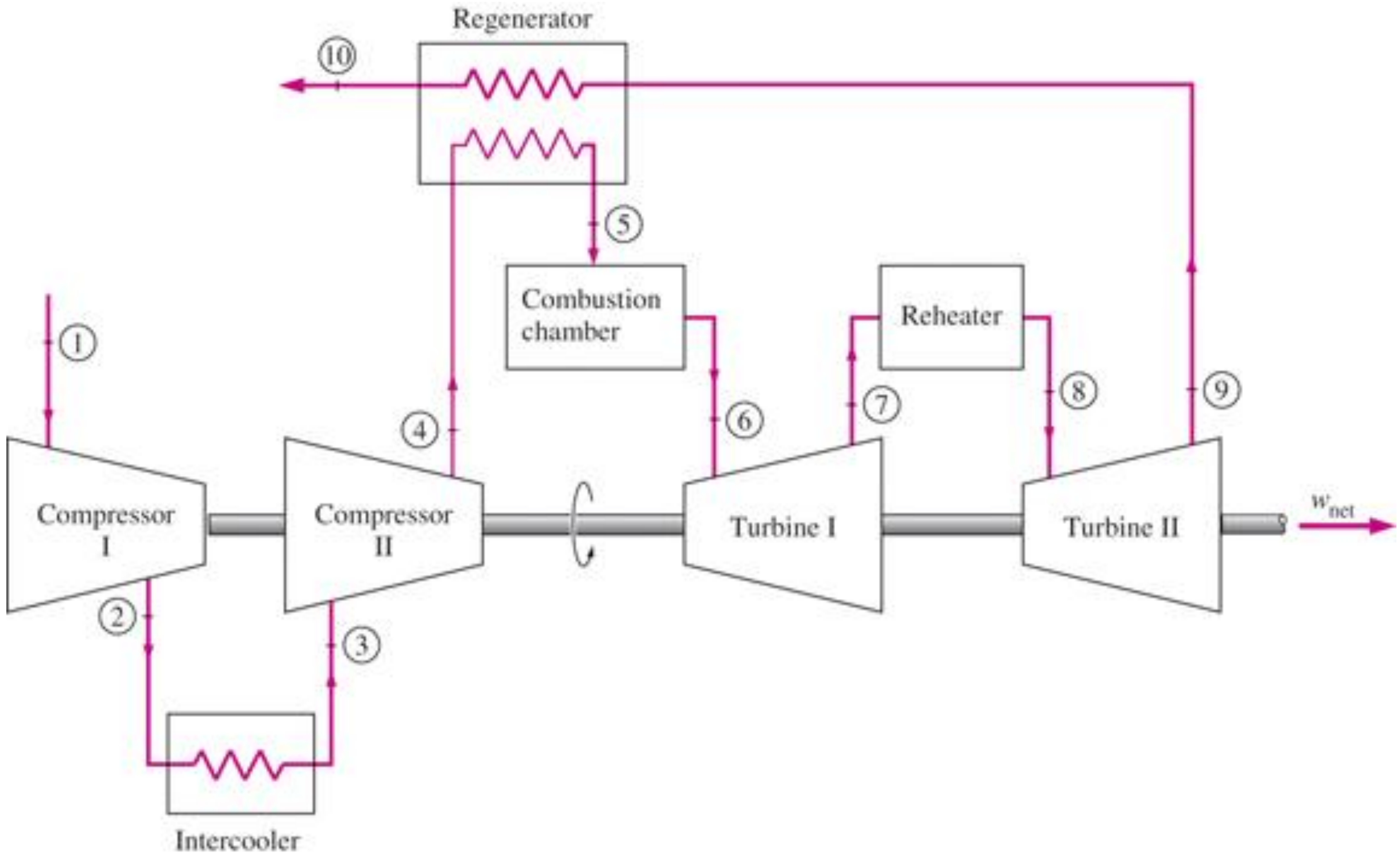
- Isentropic compression power
- Isothermal power
- Intercooler


Compressor
stage 1
Compressor
stage 2
2
$\dot{W}_c$
1
c
d
Intercooler
$\dot{Q}_{out}$

Brayton cycle

- Reheat


$\dot{Q}_{in}$
$\dot{Q}_{in}$
Combustor
Reheat combustor
2
3
a
b
Turbine stage 1
Turbine stage 2
Compressor
1
4



Regenerator
10
5
Combustion chamber
Reheater
1
7
8
9
4
6
Compressor I
Compressor II
Turbine I
Turbine II
w_{net}
2
3
Intercooler

Brayton cycle

- Ideal
- η_{th} =45.6%

❑With irreversibilities

- η_{th} =24.9%

❑With regenerator

* η_{th} =56.8%