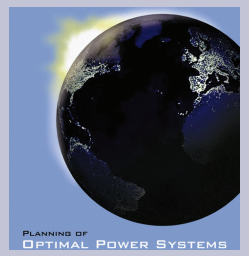
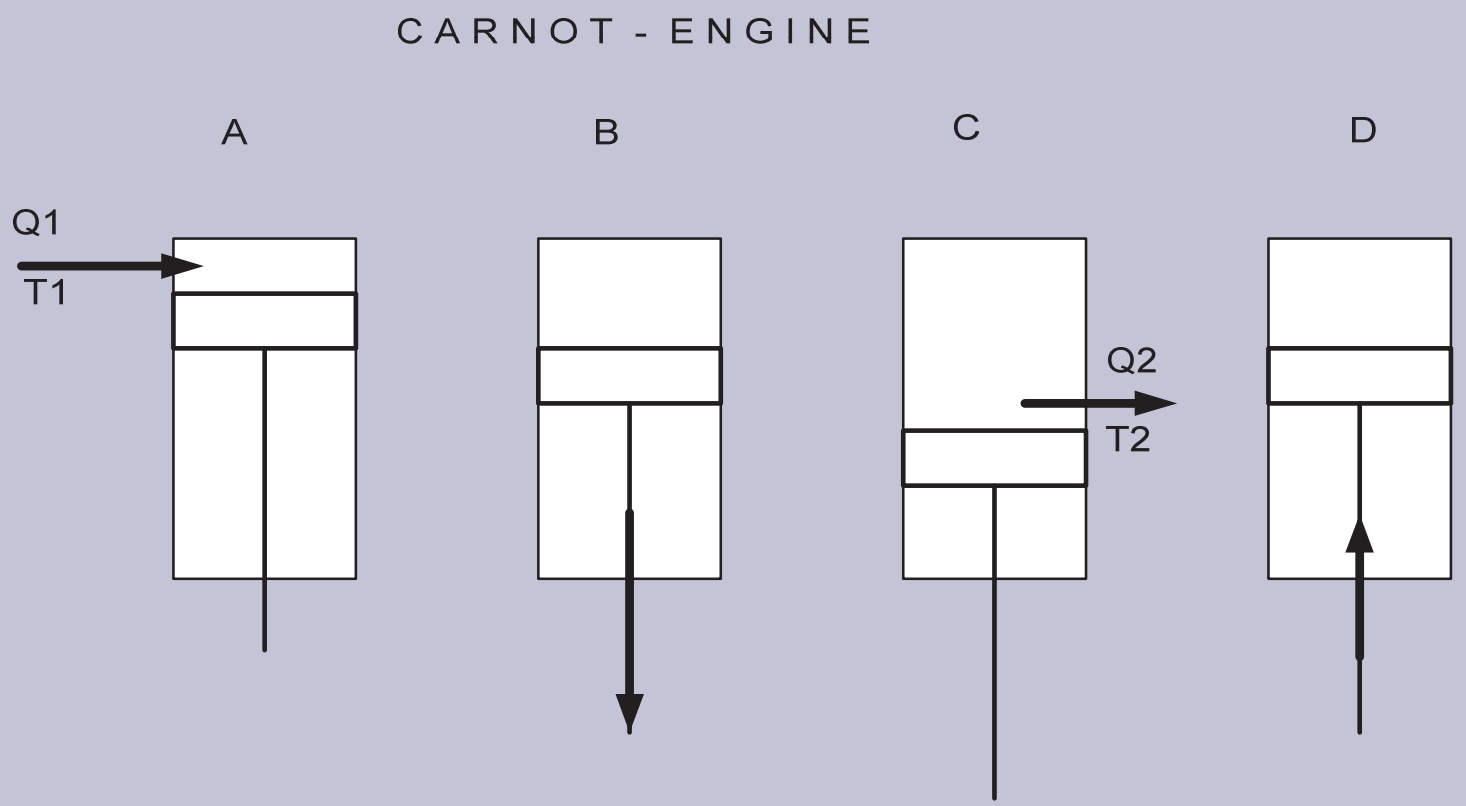


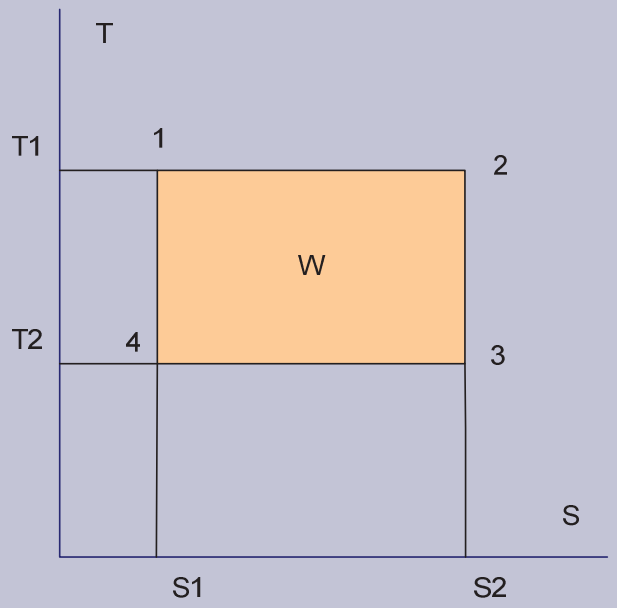
Engine cycles

- Carnot Cycle
- Otto Cycle
- Diesel Cycle
- Brayton Cycle
- Rankine Cycle
- Combined Cycles

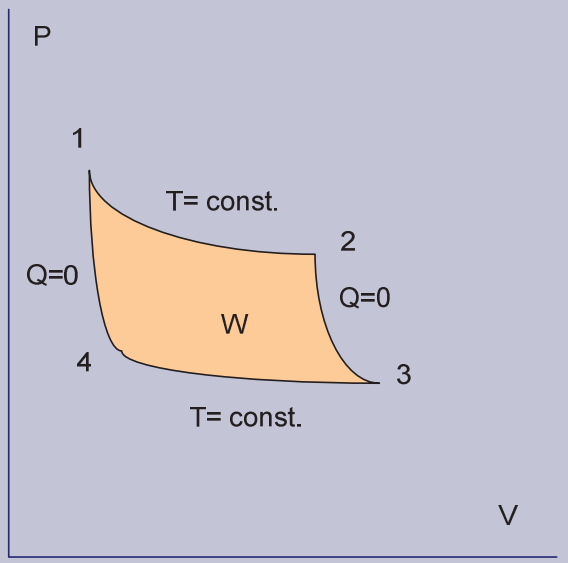
Carnot Engine



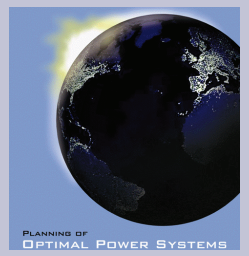
Carnot Cycle



T-S Diagram

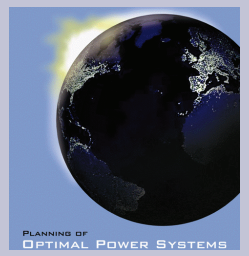


P-V Diagram



Carnot Cycle , continued

- Ideal gas cycle, discovered by French engineer Sadi Carnot in 1824
- Heat is added at constant temperature T_1
- Heat is discharged at constant temperature T_2



Carnot Cycle , continued

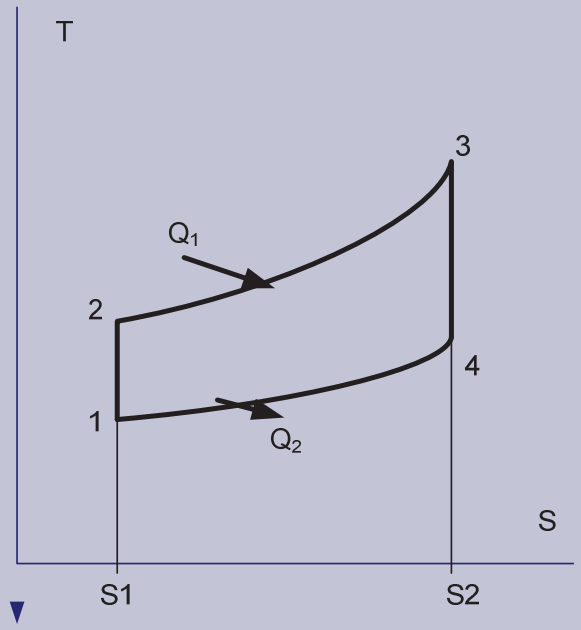
Efficiency

$$\eta = 1 - T_2/T_1$$

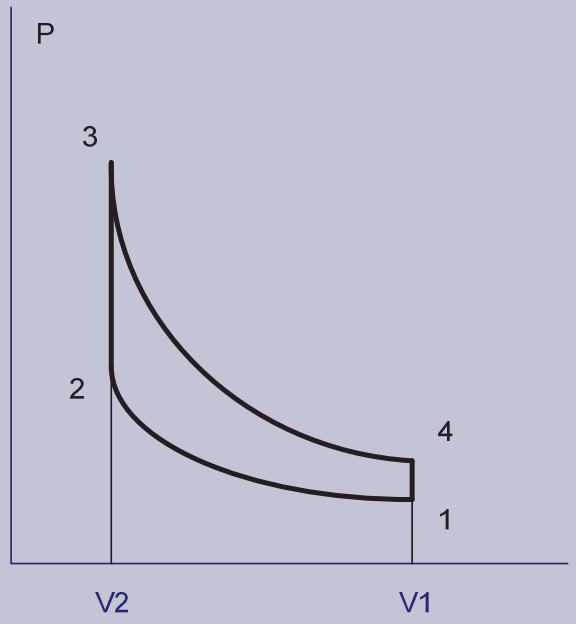
The work done is area W in diagram

Higher the T_1 and lower T_2 more work can be done by the Carnot engine

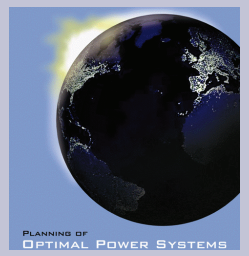
Otto Cycle



T-S Diagram

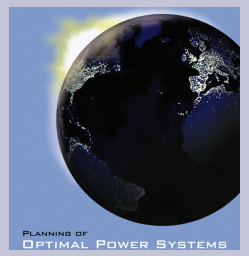


P-V Diagram



Otto Cycle, continued

- Nicolaus Otto discoverd spark ignition (SI) four stroke gas engine 1876
- Heat is added in constant volume V_1 at top dead center (TDC) by igniting gas air mixture by spark
- Heat is discharged at constant volume V_2 at botton dead center (BDC)



Otto Cycle, continued

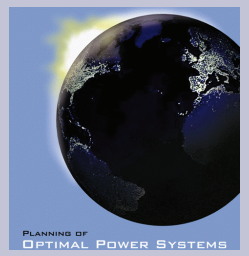
Efficiency of Otto Engine

$$\eta = 1 - 1/ r^{k-1}$$

where

r = compression ratio= V_2/V_1

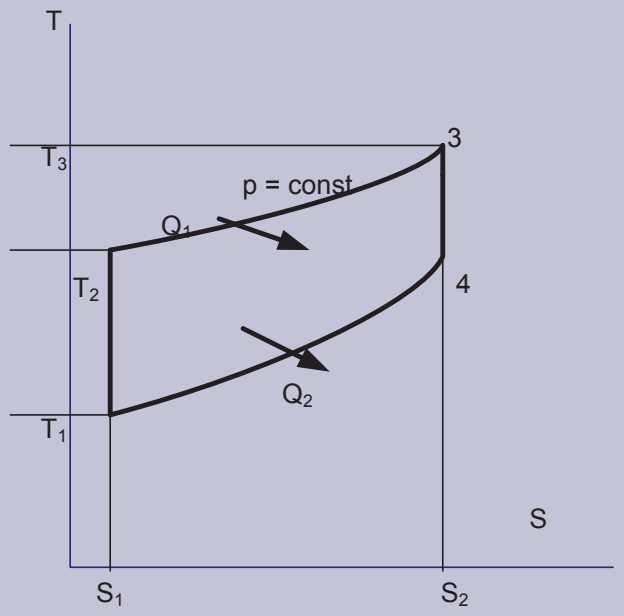
k= gas constant



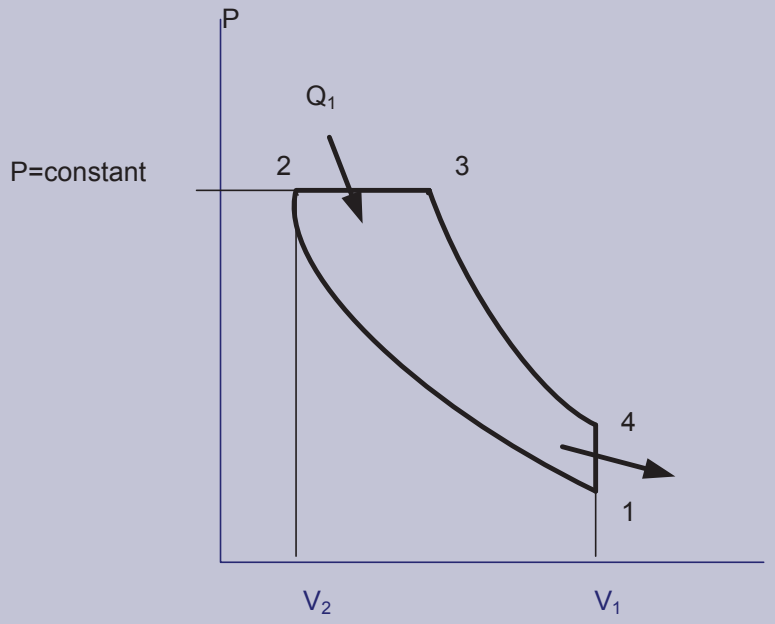
Otto Cycle, continued

- Spark ignition (SI) engines are most built engines in the world
- About 40 million engines/a for cars (200 000 MW)
- About 4000 engines/a for power plants (4000 MW/a)

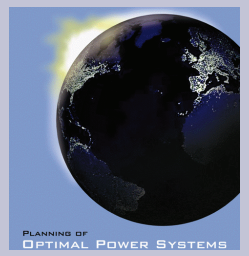
Diesel Cycle



T-S Diagram

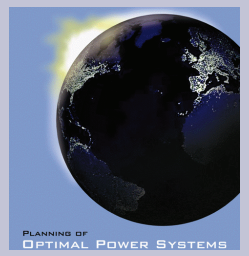


P-V Diagram



Diesel Cycle, continued

- Rudolf Diesel outlined Diesel engine in 1892 in his patent
- Heat is added at constant pressure and discharged at constant volume
- Ignition happens by self ignition by injecting fuel at top dead center
- Some call Diesel engines as compression ignion (CI) engines



Diesel Cycle, continued

Efficiency

$\eta = 1 - 1/r^{k-1} (r_c^k - 1)/(k(r_c-1))$

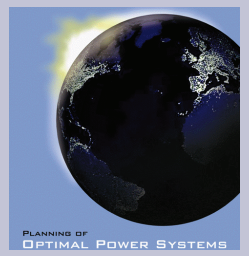
where

r = comperssion ratio = V_2/V_1

rc = cut off ratio = V_3/V_2

note

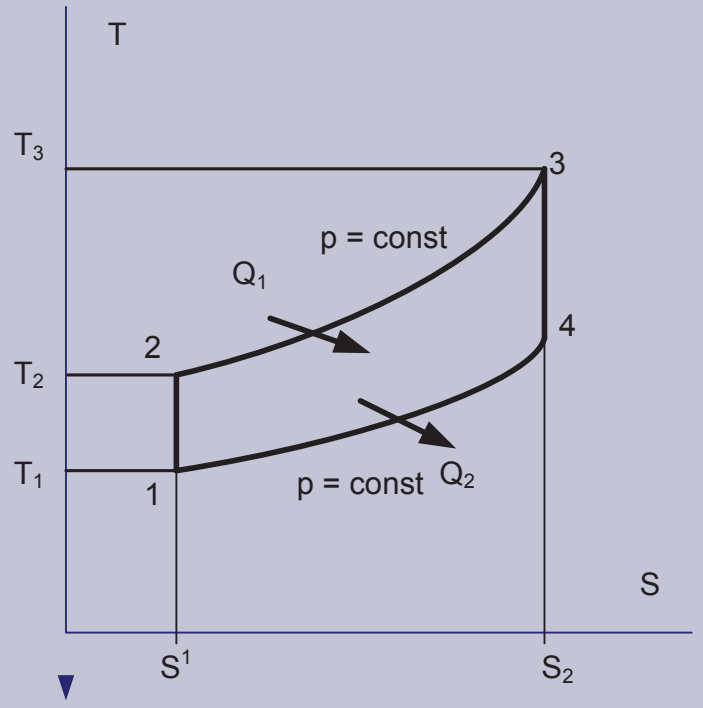
If r is the same, Diesel cycle has lower efficiency than Otto cycle



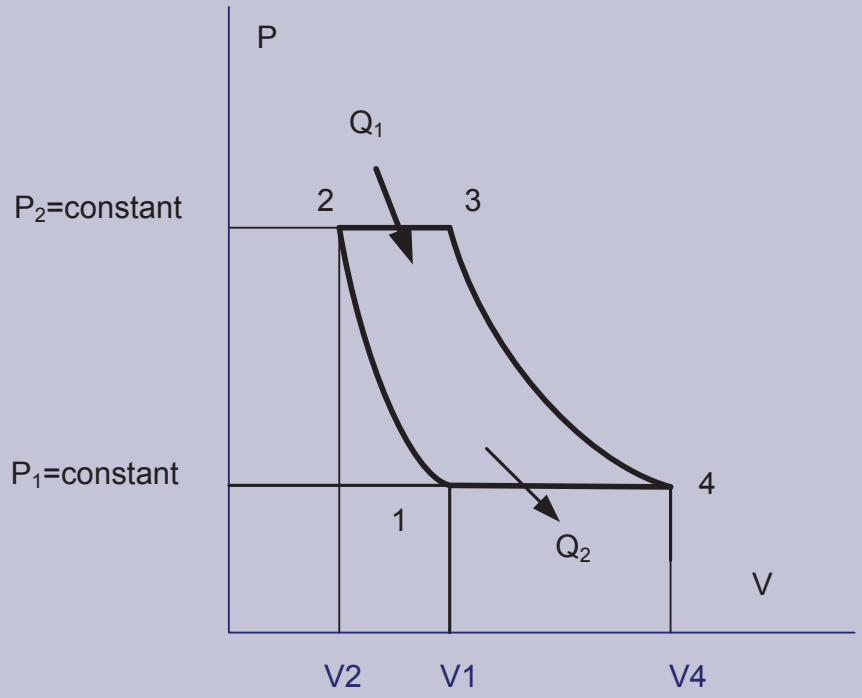
Diesel Cycle, continued

- Diesel engines are most built energy conversion machines after SI-engines
- Car industry builds about 20 million/a diesel cars and trucks (200000 MW/a)
- > 90 % market share in large ships
- Power plant orders are 30 000 MW/a

Brayton Cycle

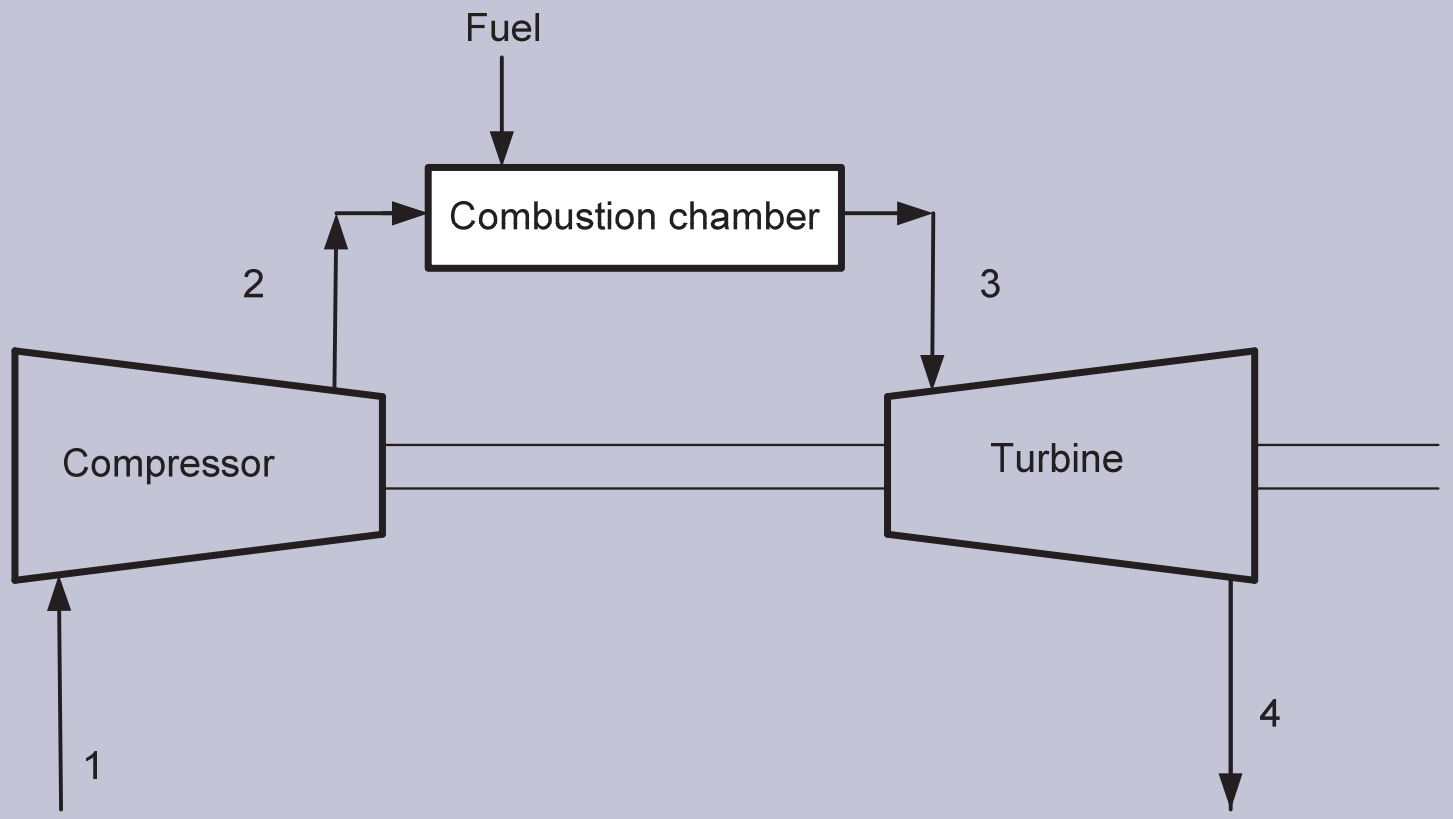


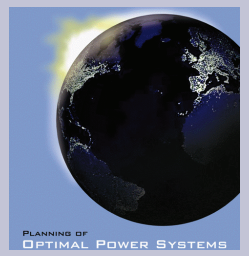
T-S Diagram



P-V Diagram

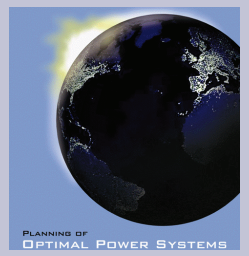
Brayton Cycle





Brayton Cycle

- Developed by Georg Brayton (1832 - 1890)
- Heat is added and discharged at constant pressure
- Applied in Gas Turbines (GT) (Combustion Turbines in US)



Brayton Cycle, continued

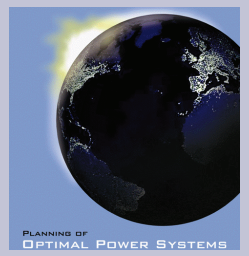
Efficiency

$$\eta = 1 - 1/ r_p^{(k-1)/k}$$

where

r_p = compressor pressure ratio = p_2/p_1

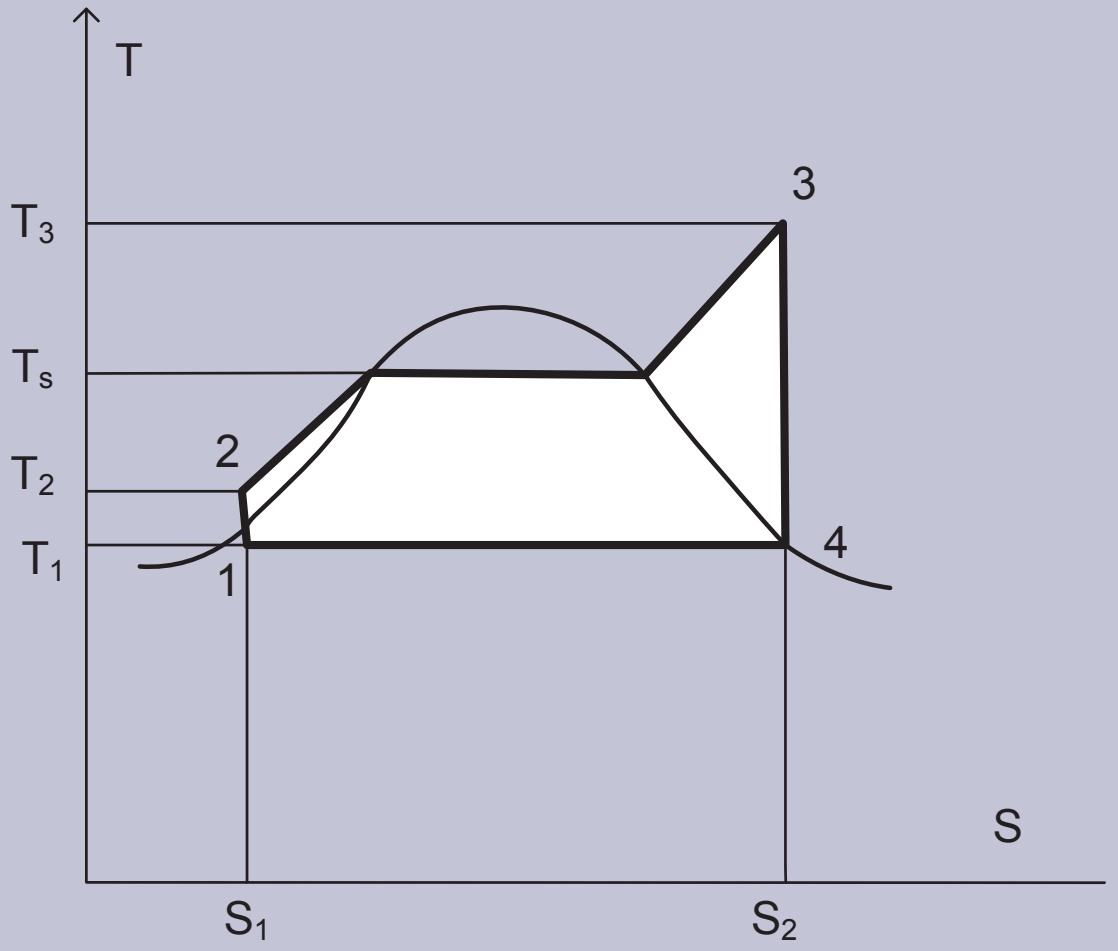
k = gas constant



Brayton cycle, continued

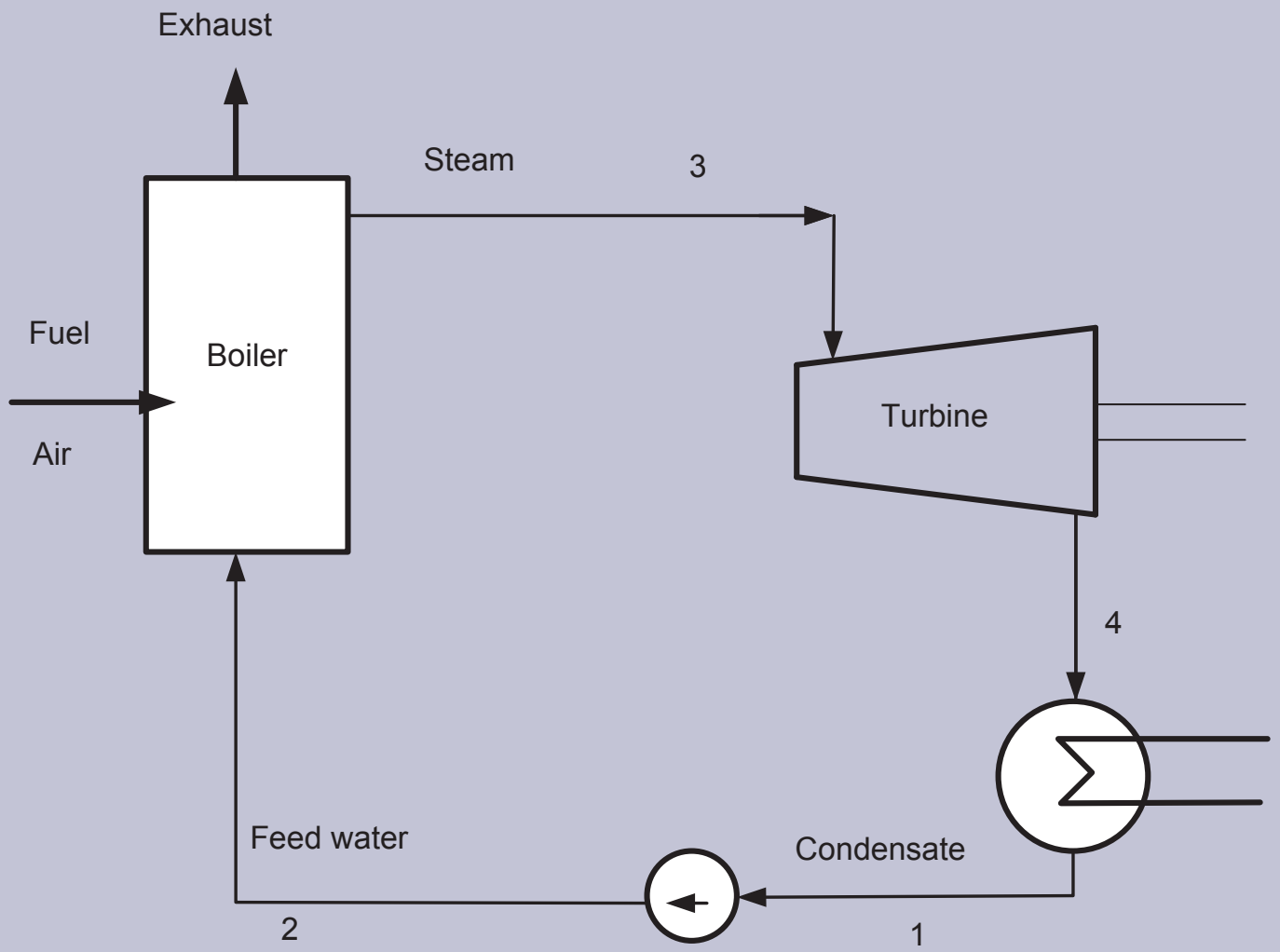
- Gas turbines are number third power conversion machines after SI- and CI-engines
- > 90 % market share in large airplanes
- Power plant orders are 40 000 MW/a

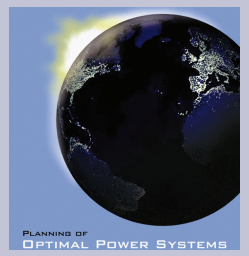
Rankine Cycle



T-S Diagram

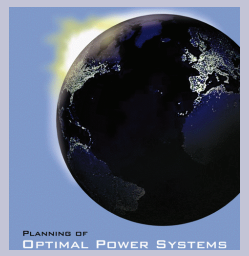
Rankine Cycle, continued





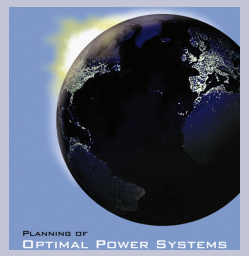
Rankine Cycle, continued

- Scottish engineer William Rankine (1820-1872) developed a theory of steam cycles
- Heat is added in a water boiler, where the water becomes steam
- Steam is fed to a steam turbine, which generates mechanical energy
- After turbine the steam becomes water again in a condenser



Rankine cycle, continued

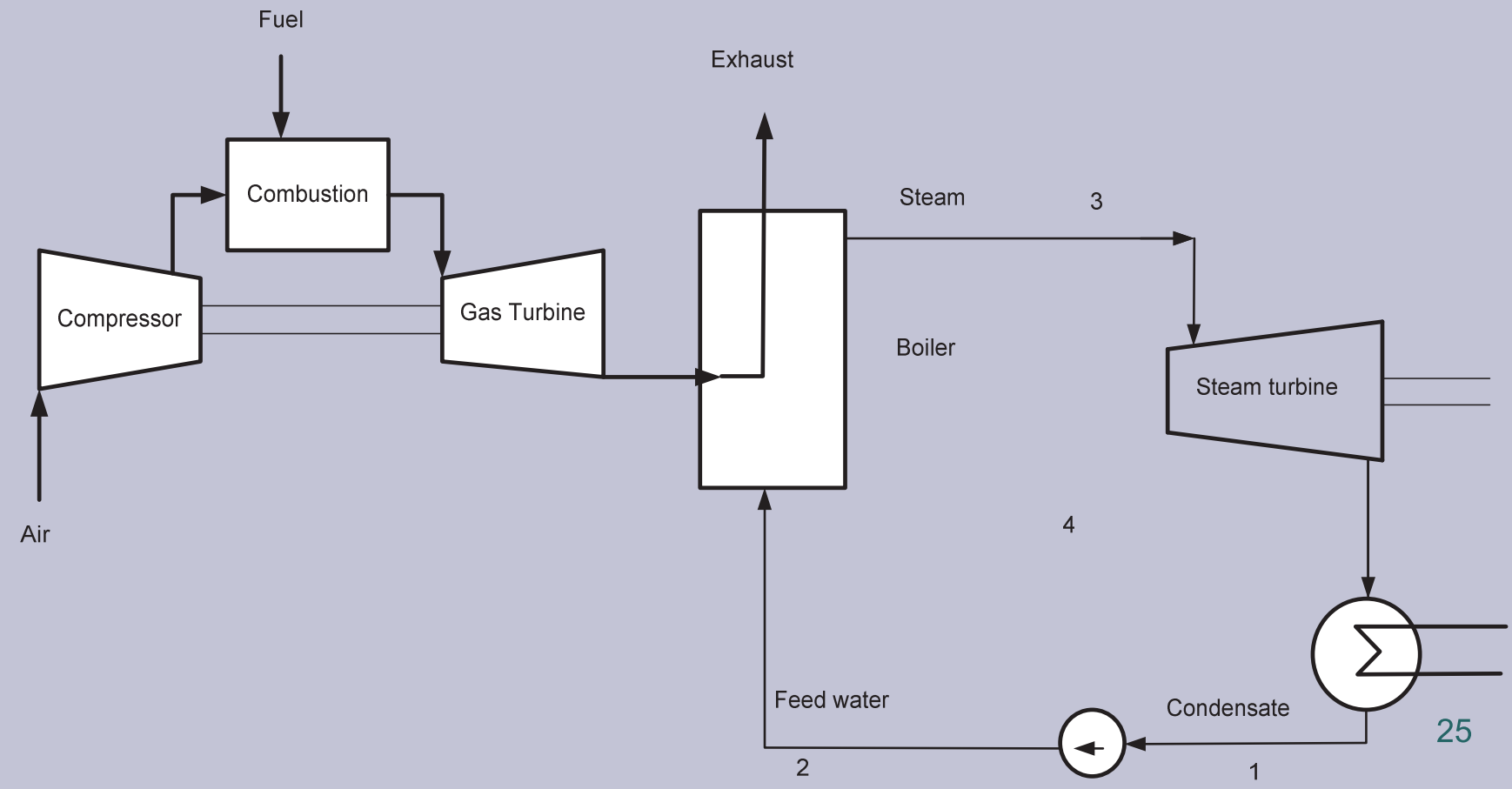
- The efficiency varies from 20 % in small subcritical steam turbines to 45 % in large double reaheat supercritical steam turbines
- The rankine cycle is ideal for solid fuel (coal, wood) power plants

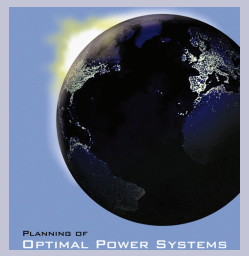


Rankine cycle, continued

- Steam turbines are most sold machines for power plants as measured in output (100 000 MW/a)
- They are used in coal fired, nuclear and combined cycle power plants
- Coal and nuclear plants generate about 50 % of world electricity

Gas turbine combined cycle





Gas Turbine Combined Cycle

- Combines a gas turbine (Brayton cycle) and steam turbine (Rankine Cycle)
- About 66 % of power is generated in gas turbine and 34 % in steam turbine
- Efficiency of GTCC plant is typically 1.5 times the efficiency of the single cycle gas turbine plant