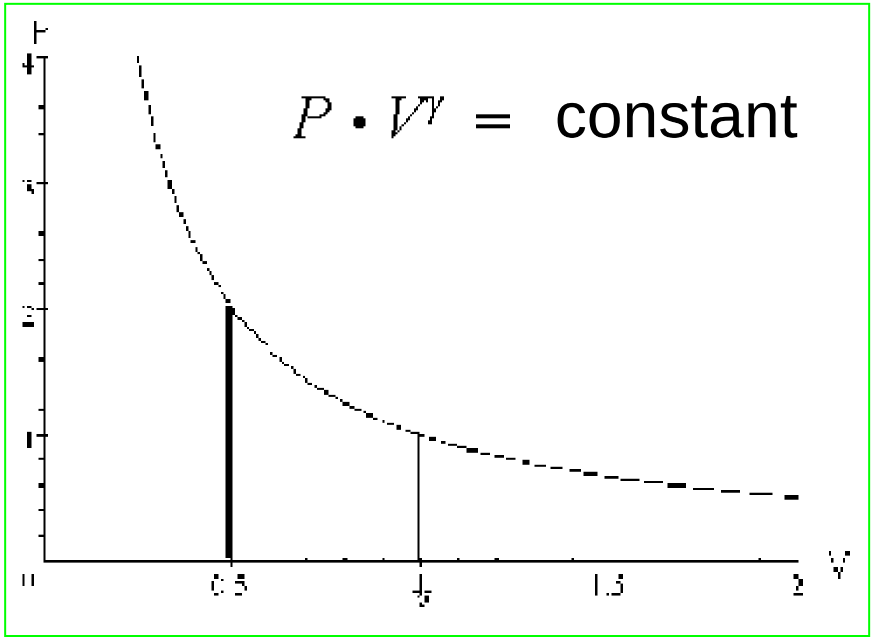
Work done by a gas (**Expansion**)
Work inserted into a gas (**Compression**)
Example: Adiabates: dQ=0



$$P \bullet V^{\gamma} = P_1 \bullet V_1^{\gamma} \Rightarrow P = \frac{P_1 \bullet V_1^{\gamma}}{V^{\gamma}}$$

Work done: $dW = P \bullet dV$

$$W = P_1 \bullet V_1^{\gamma} \int_{V_1}^{V_2} \frac{dV}{V^{\gamma}} = P_1 \bullet V_1^{\gamma} \left[\frac{1}{1-\gamma} V^{-\gamma+1} \right]_{V_1}^{V_2} = P_1 \bullet V_1^{\gamma} \frac{1}{1-\gamma} \left[\frac{1}{V_2^{\gamma-1}} - \frac{1}{V_1^{\gamma-1}} \right]$$

$$W = \frac{P_1 \bullet V_1}{\gamma-1} \left[1 - \left(\frac{V_1}{V_2} \right)^{\gamma-1} \right]$$

$$\gamma - 1 \succ 0; \frac{V_1}{V_2} \prec 1; \Rightarrow W \succ 0$$

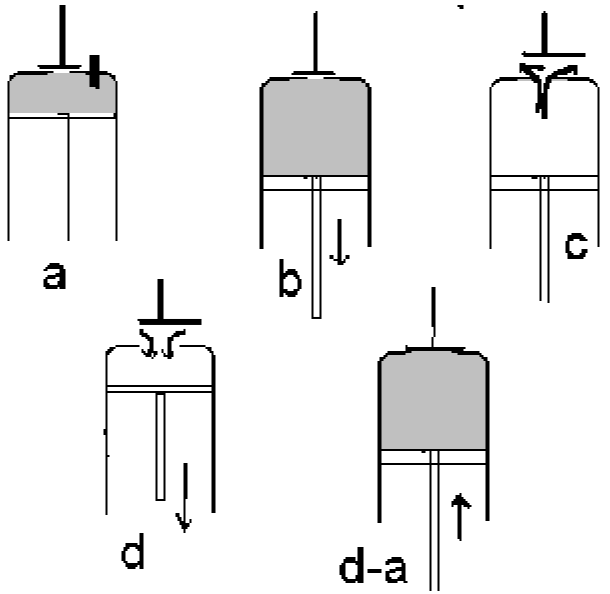
Reversely: $W = -\frac{P_1 \bullet V_1}{\gamma-1} \left[1 - \left(\frac{V_1}{V_2} \right)^{\gamma-1} \right]$

5.7.Thermal engines

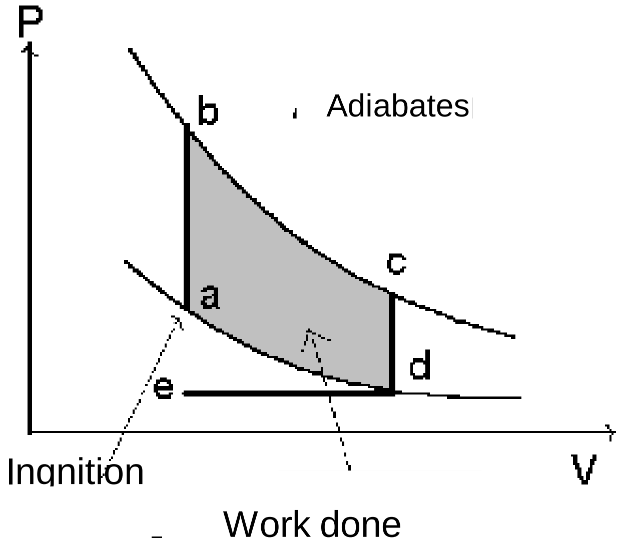
Heat energy<->mechanical work

Efficiency: $\eta = \frac{\Delta W}{\Delta Q}$

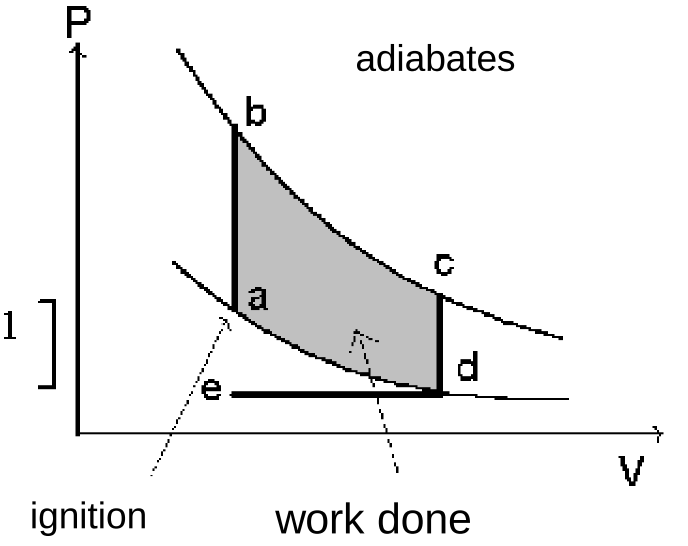
How large is the fraction of absorbed thermal energy that gets converted into mechanical work?
e.g: Otto-Motor



a) Ignition,
b) Rise of pressure, adiabatic expansion
c) Valve open,
c-d) Burned gas leaves cylinder
d) Intake of mixture of air and gasoline,
d-a) Valve closed,
adiabatic compression



Intermediate steps without relevance
for themodynamic cycle: d→e, e→d



Work done:

$$\Delta W = \frac{P_b \cdot V_1}{\gamma - 1}\left[1 - \left(\frac{V_1}{V_2}\right)^{\gamma-1}\right] - \frac{P_a \cdot V_1}{\gamma - 1}\left[1 - \left(\frac{V_1}{V_2}\right)^{\gamma-1}\right]$$

$$\Delta W = \frac{(P_b - P_a) \cdot V_1}{\gamma - 1}\left[1 - \left(\frac{V_1}{V_2}\right)^{\gamma-1}\right]$$

with $P \cdot V = \nu \cdot R \cdot T \Rightarrow P_a \cdot V_1 = \nu \cdot R \cdot T_a : \Delta T = T_b - T_a$

$$P_b \cdot V_1 = \nu \cdot R \cdot T_b \Rightarrow \Delta W = \frac{\nu \cdot R}{\gamma - 1} \cdot \Delta T\left[1 - \left(\frac{V_1}{V_2}\right)^{\gamma-1}\right]$$

$$\frac{\nu \cdot R}{\gamma - 1} = \frac{\nu \cdot R}{\frac{c_P}{c_V} - 1} = \frac{\nu \cdot R \cdot c_V}{c_P - c_V} = \nu \cdot c_V = \frac{\Delta Q}{\Delta T} \Rightarrow$$

$$\Delta W = \Delta Q\left[1 - \left(\frac{V_1}{V_2}\right)^{\gamma-1}\right] = \Delta Q \cdot \eta$$

e.g.: Compression ratio 8:1,

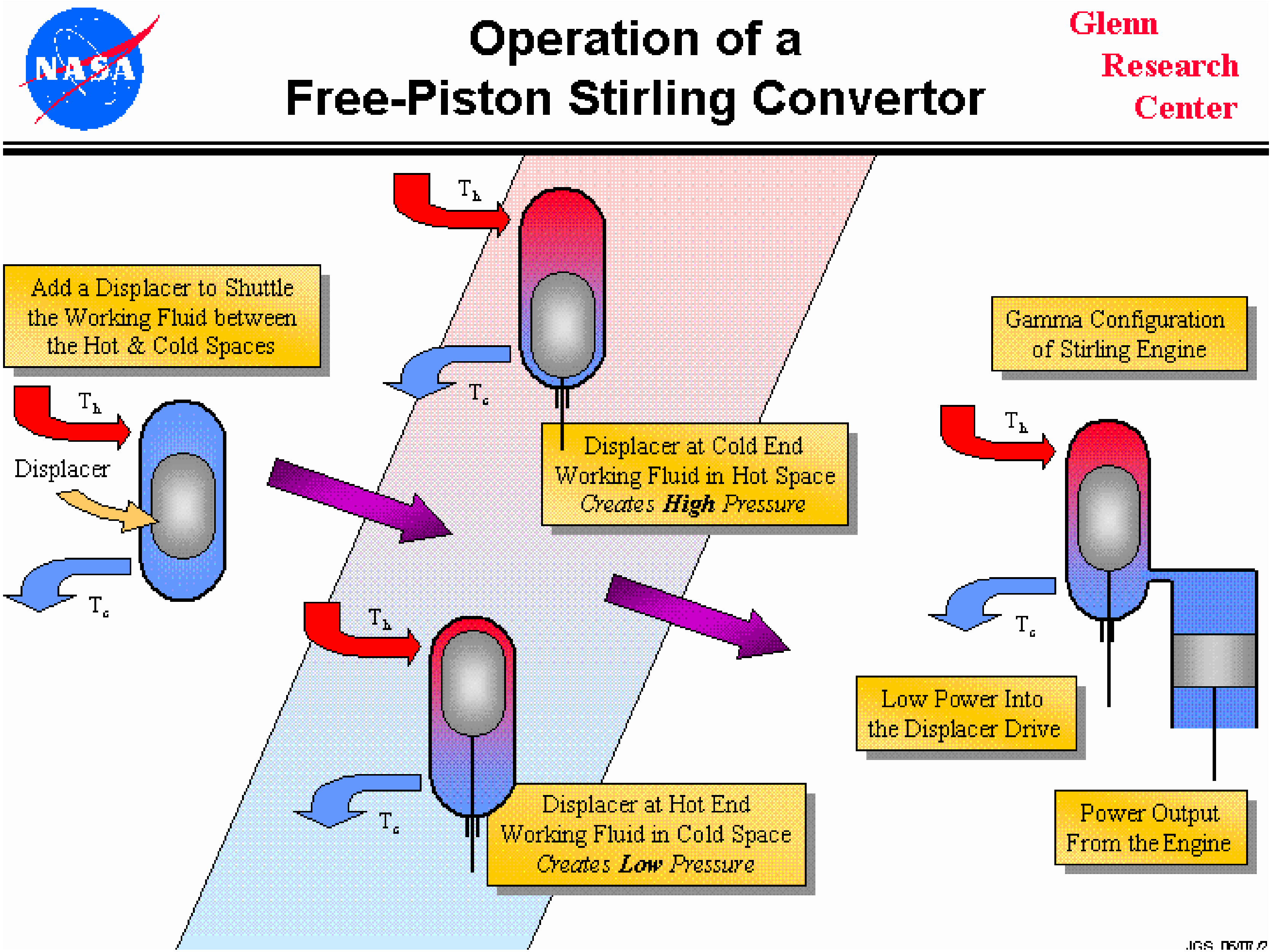
$\gamma = 1.4$(Two atomic molecule)

$$\eta = 1 - \left(\frac{1}{8}\right)^{0.4} = .56 \Rightarrow 56\%$$

Theoreticaly!!

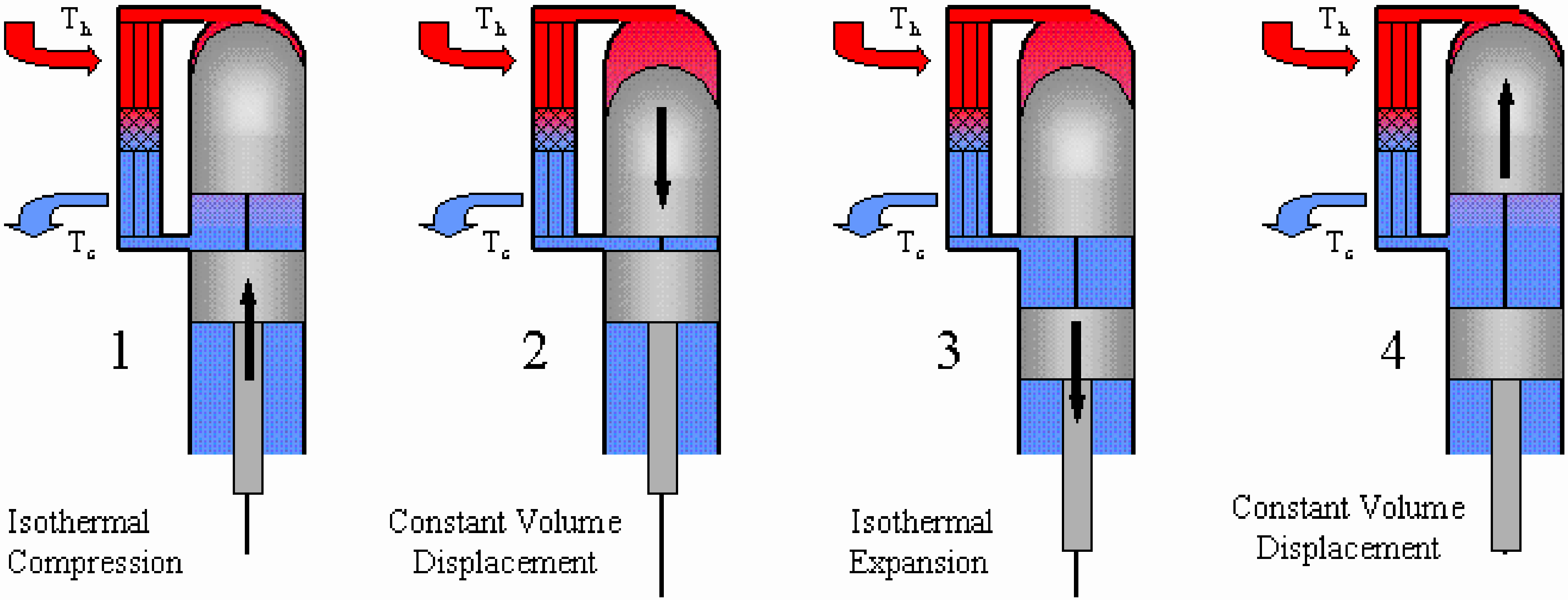
In practice ~ 30%

Hot air motor: Stirling cycle

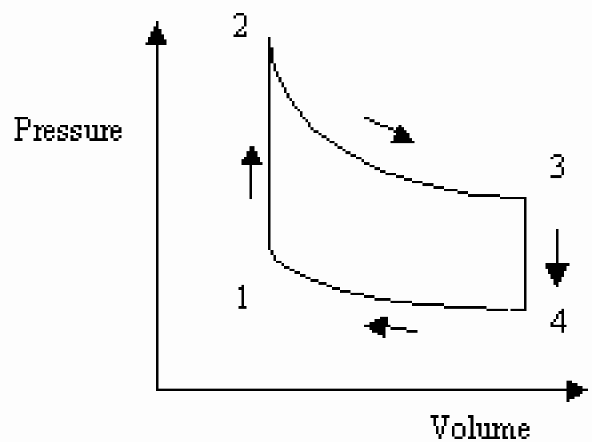


Operation of a Free-Piston Stirling Convertor

Glenn Research Center



Beta Configuration - with the addition of heat exchangers *Heater/Regenerator/Cooler*

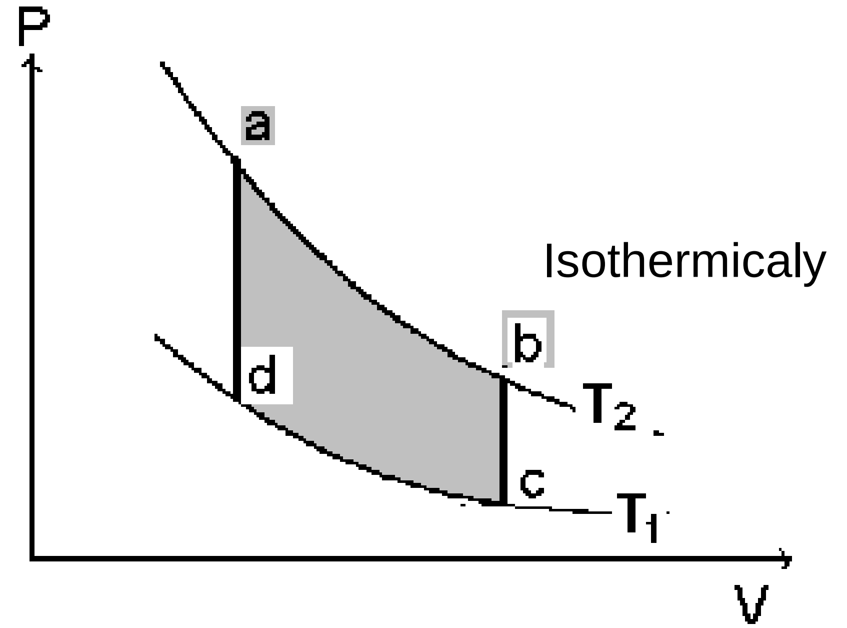


The regenerator stores heat as the working fluid flows from the hot (expansion) space to the cool (compression) space, and returns the heat to the fluid when the flow is reversed

Cycle with experiment:

a) Gas gets heated

a-b) Gas expands, working piston down



b-c) Upward movement displacing piston gas cools, gets pressed through copper wool

c-d) Compressed : Heat output towards cooling water

d-a) Downward motion of displacing piston $T_1 \rightarrow T_2$ out of copper wool, too.

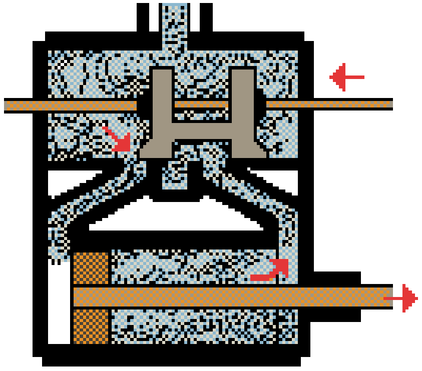


Bild 1a

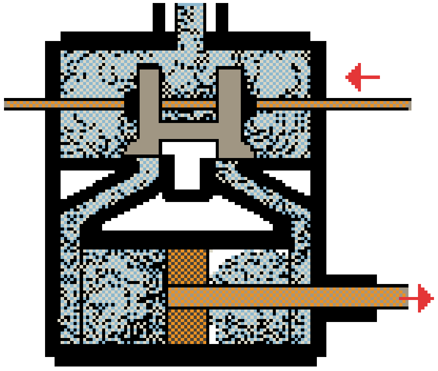


Bild 1b

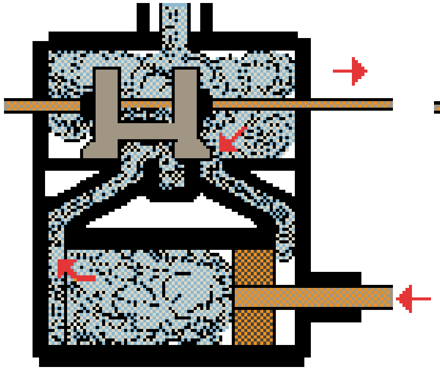


Bild 1c

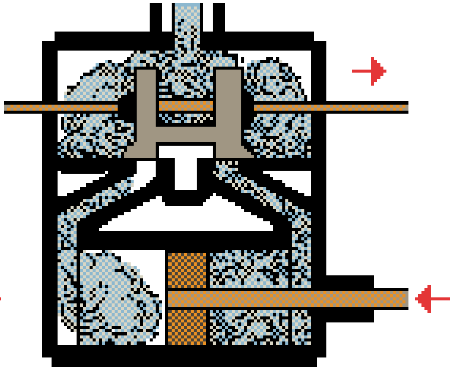


Bild 1d