

§13.5 卡诺过程

地热发电厂

一、卡诺正循环

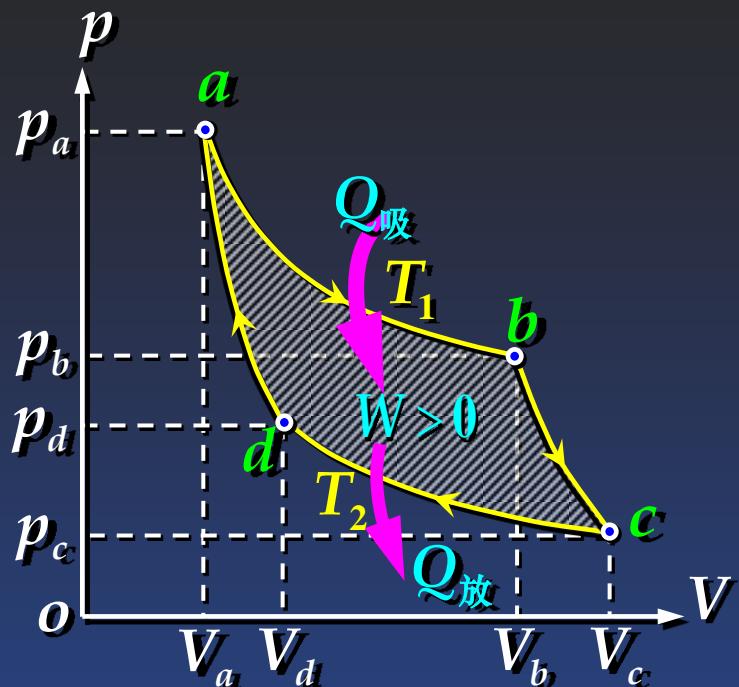
$a \rightarrow b$: 等温膨胀 (T_1)

$b \rightarrow c$: 绝热膨胀

$c \rightarrow d$: 等温压缩 (T_2)

$d \rightarrow a$: 绝热压缩

$$\left. \begin{aligned} Q_{\text{吸}} &= vRT_1 \ln \frac{V_b}{V_a} \\ Q_{\text{放}} &= vRT_2 \ln \frac{V_d}{V_c} \end{aligned} \right\} \quad \eta_{\text{卡诺}} = 1 - \frac{|Q_{\text{放}}|}{Q_{\text{吸}}}$$



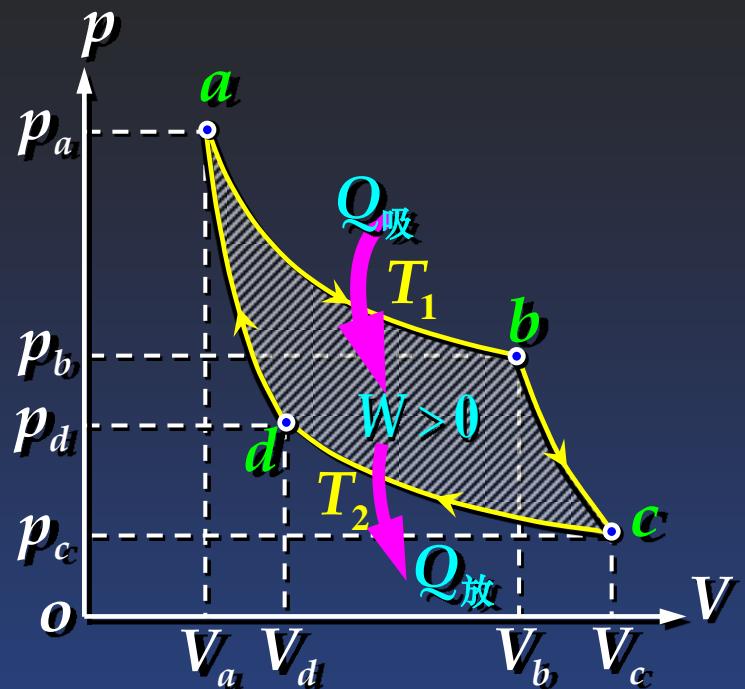
T_1 高恒温热源



T_2 低恒温热源

$$\eta_{\text{卡诺}} = 1 - \frac{T_2}{T_1} \cdot \frac{\ln(V_c/V_d)}{\ln(V_b/V_a)}$$

$$\left. \begin{array}{l} T_1 V_b^{\gamma-1} = T_2 V_c^{\gamma-1} \\ T_1 V_a^{\gamma-1} = T_2 V_d^{\gamma-1} \end{array} \right\} \quad \left. \begin{array}{l} \frac{V_b}{V_a} = \frac{V_c}{V_d} \end{array} \right.$$



$$\left. \begin{array}{l} Q_{\text{吸}} = v R T_1 \ln \frac{V_b}{V_a} \\ Q_{\text{放}} = v R T_2 \ln \frac{V_d}{V_c} \end{array} \right\} \quad \eta_{\text{卡诺}} = 1 - \frac{|Q_{\text{放}}|}{Q_{\text{吸}}}$$



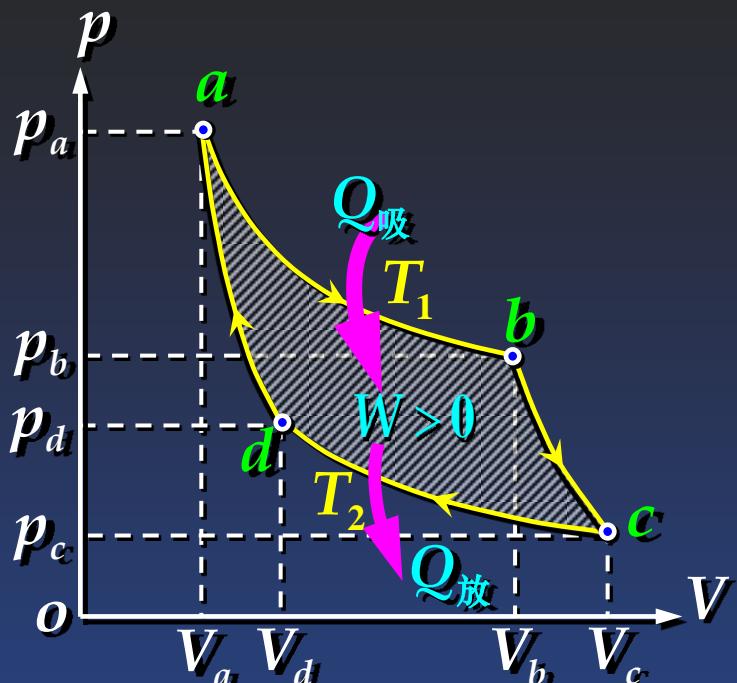
$$\eta_{\text{卡诺}} = 1 - \frac{T_2}{T_1} \cdot \frac{\ln(V_c/V_d)}{\ln(V_b/V_a)}$$

$$\left. \begin{aligned} T_1 V_b^{\gamma-1} &= T_2 V_c^{\gamma-1} \\ T_1 V_a^{\gamma-1} &= T_2 V_d^{\gamma-1} \end{aligned} \right\} \quad \left. \begin{aligned} \frac{V_b}{V_a} &= \frac{V_c}{V_d} \end{aligned} \right.$$

→ $\eta_{\text{卡诺}} = 1 - \frac{T_2}{T_1}$

注意

• 卡诺热机效率只与高、低温热源的温度有关，与工质无关！



T₁ 高恒温热源



T₂ 低恒温热源

二、卡诺逆循环

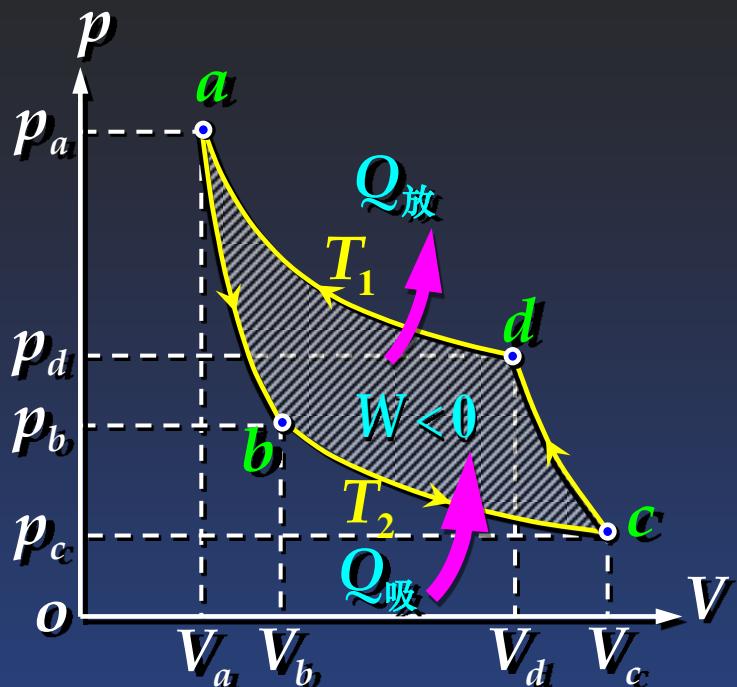
$$w_{\text{卡诺}} = \frac{Q_{\text{吸}}}{W'} = \frac{T_2}{T_1 - T_2}$$

例 保持冰箱内温度为 -3°C ,
则由于:

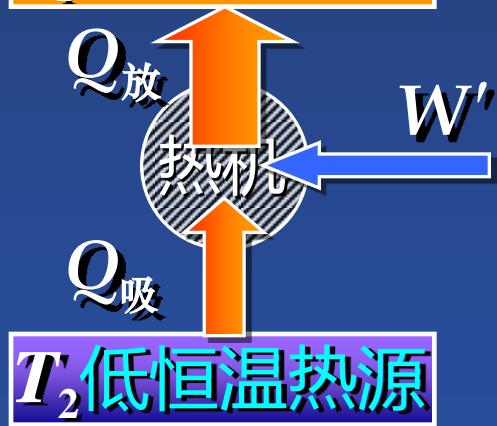
$$T_2 = 273 - 3 = 270(\text{K})$$

$$T_1 = 273 + 27 = 300(\text{K})$$

$$w_{\text{卡诺}} = \frac{T_2}{T_1 - T_2} = 9$$



T_1 高恒温热源



三、其他循环

奥托循环 (Otto cycle):

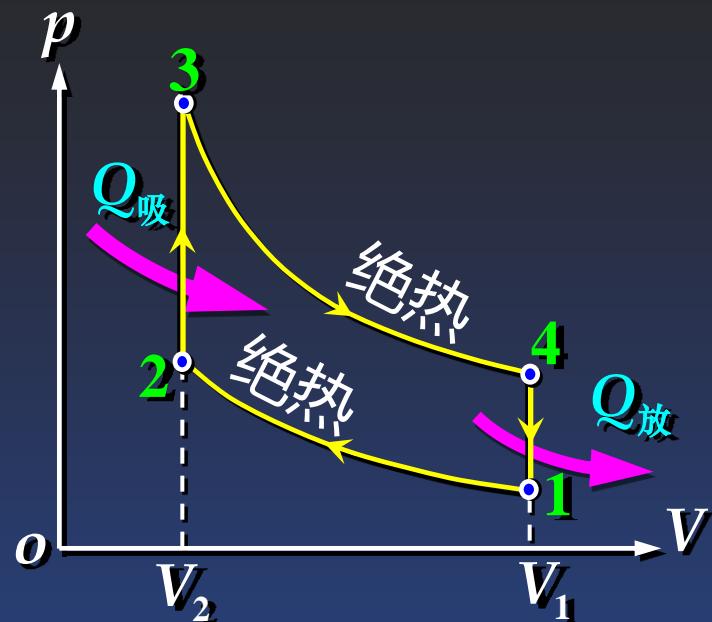
$$\eta_{\text{otto}} = 1 - q^{1-\gamma}$$

$q = V_1/V_2$: 绝热压缩比

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$$T_1 = 273 + 27 = 300 \text{ (K)}$$

$$w_{\text{卡诺}} = \frac{T_2}{T_1 - T_2} = 9$$



三、其他循环

☺ 奥托循环 (Otto cycle):

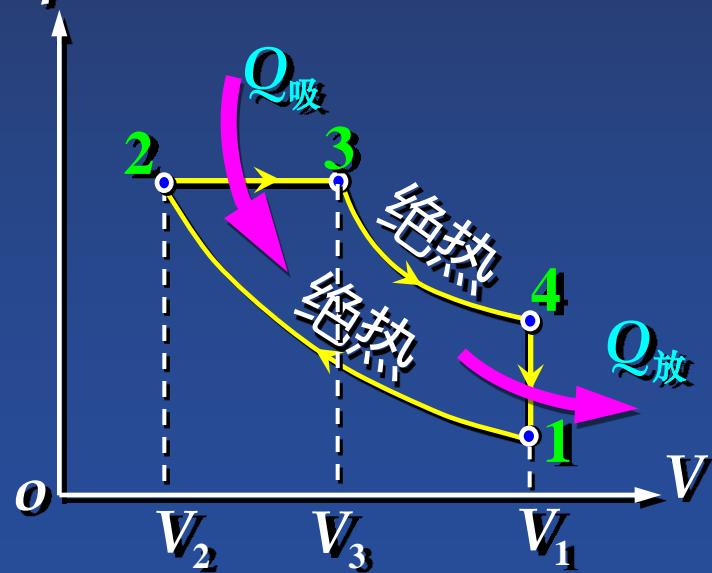
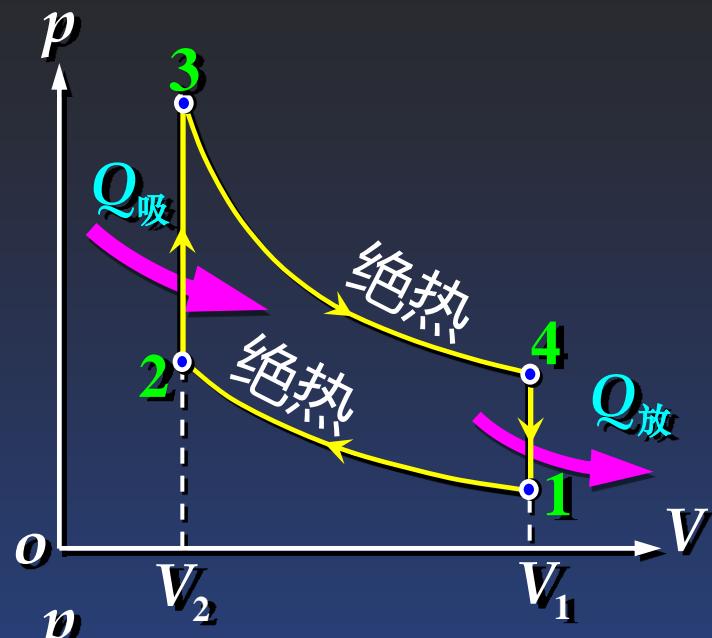
$$\eta_{\text{otto}} = 1 - q^{1-\gamma}$$

$q = V_1/V_2$: 绝热压缩比

☺ 狄塞尔循环 (Diesel cycle):

$$\eta_{\text{diesel}} = 1 - \frac{1}{\gamma} q^{1-\gamma} \cdot \frac{\beta^{\gamma} - 1}{\beta - 1}$$

$\beta = V_3/V_2$: 定压膨胀比



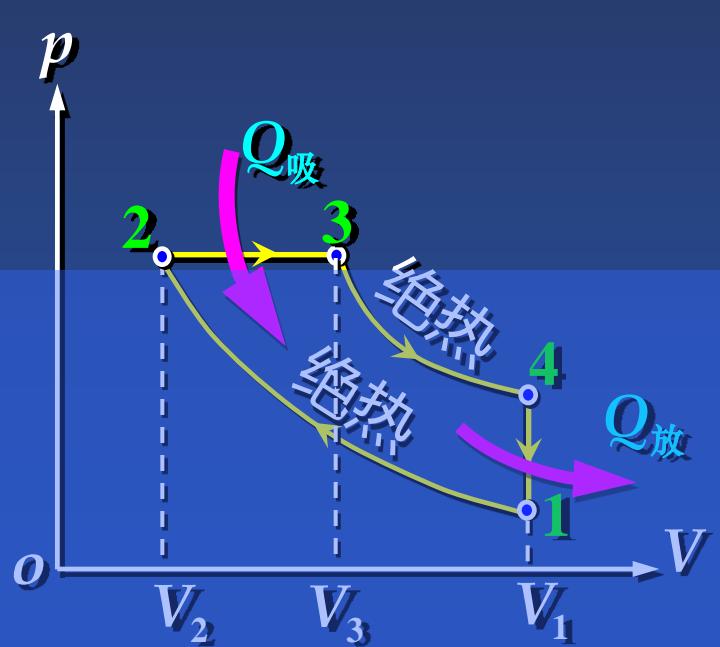
归纳:

😊 $\eta_{\text{卡诺}} = 1 - \frac{|Q_{\text{放}}|}{Q_{\text{吸}}} = 1 - \frac{T_2}{T_1}$

😊 $w_{\text{卡诺}} = \frac{T_2}{T_1 - T_2}$

$$\eta_{\text{diesel}} = 1 - \frac{1}{\gamma} q^{1-\gamma} \cdot \frac{\beta^{\gamma} - 1}{\beta - 1}$$

$\beta = V_3/V_2$: 定压膨胀比



归纳:

☺ $\eta_{\text{卡诺}} = 1 - \frac{|Q_{\text{放}}|}{Q_{\text{吸}}} = 1 - \frac{T_2}{T_1}$

☺ $w_{\text{卡诺}} = \frac{T_2}{T_1 - T_2}$

☺ $\eta \leq \eta_{\text{卡诺}} = 1 - T_2 / T_1$

(The end)