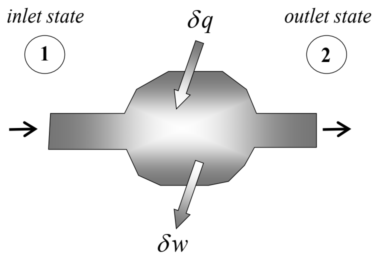
7-10 REVERSIBLE STEADY-FLOW WORK

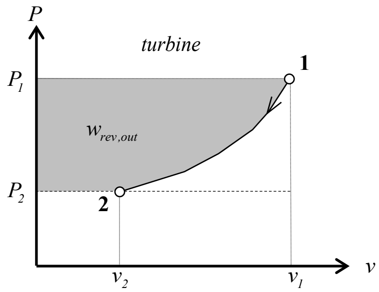


$\delta q_{rev} - \delta w_{rev} = dh + dke + dpe$	*Energy balance*
$\delta q_{rev} = Tds = dh - vdP$	*2nd Gibbs equation*

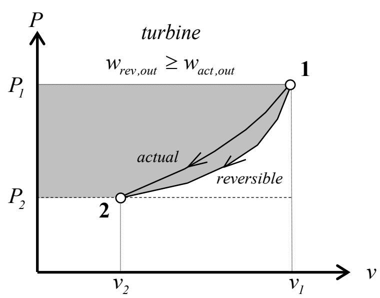
$$\delta w_{rev} = -vdP - dke - dpe$$

$$w_{rev,net,out} = -\int_1^2 vdP - \Delta ke - \Delta pe \quad (7\text{-}51)$$

Reversible work output for steady-flow and closed systems



$w_{rev,out} = -\int_1^2 vdP$ *turbine*	(7-52)	*turbine* $\left(for\ \Delta ke = \Delta pe = 0\right)$
$w_{rev,in} = \int_1^2 vdP$ *compression*		*compressor*



$$w_{rev,net,out} \geq w_{act,net,out}$$

$w_{rev,out} \geq w_{act,out}$ *turbine*

$w_{rev,in} \leq w_{act,in}$ *compression*

Steady-flow devices deliver the most and consume the least work when the process is reversible

In derivation, we assume that both processes are between the same states

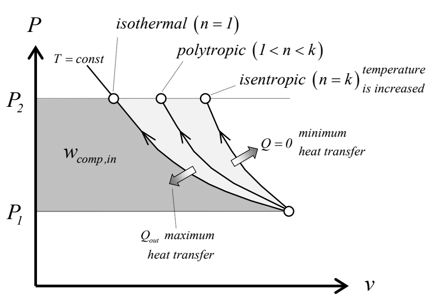
$$\begin{aligned} &\delta q_{act} - \delta w_{act} = dh + dke + dpe \\ -\ &\delta q_{rev} - \delta w_{rev} = dh + dke + dpe \\ \hline &\delta q_{act} - \delta q_{rev} - \delta w_{act} + \delta w_{rev} = 0 \end{aligned}$$

$$\delta w_{rev} - \delta w_{act} = \underbrace{\delta q_{rev}}_{Tds} - \delta q_{act}$$

$$\frac{\delta w_{rev} - \delta w_{act}}{T} = ds - \frac{\delta q_{act}}{T} = s_{gen} \geq 0 \quad \text{Eq.7-9}$$

$$\Rightarrow \delta w_{rev} \geq \delta w_{act}$$

7-11 *Compression work for ideal gas* *(p.364)*

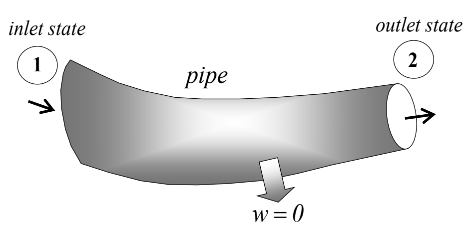


By cooling compressor, the requiered work input can be minimized to achive the same pressure increase

Ideal gas $Pv = RT$		*Equations 7-57 a,b,c*
Isentropic process $Pv^k = const$	$v = cP^{\frac{-1}{k}}$	$w_{comp,in} = \dfrac{k}{k-1}R\left(T_2 - T_1\right) = \dfrac{kRT_1}{k-1}\left[\left(\dfrac{P_2}{P_1}\right)^{\frac{k-1}{k}} - 1\right]$
Polytropic process $Pv^n = const$	$v = cP^{\frac{-1}{n}}$	$w_{comp,in} = \dfrac{n}{n-1}R\left(T_2 - T_1\right) = \dfrac{nRT_1}{n-1}\left[\left(\dfrac{P_2}{P_1}\right)^{\frac{n-1}{n}} - 1\right]$
Isothermal process $Pv = const$	$v = cP^{-1}$	$w_{comp,in} = RT\ln\dfrac{P_2}{P_1}$

Incompressible fluid ($v = const$, 7-51) $\Rightarrow$ $w_{rev} = -v\left(P_2 - P_1\right) - \Delta ke - \Delta pe$ (7-54)

Bernoulli equation *(steady flow of incompressible fluid through the simple pipe without friction)*



Flow through the pipe which involves no work interaction

$$\frac{P_2 - P_1}{\rho} + \frac{V_2^2 - V_1^2}{2} + g \cdot \left(z_2 - z_1\right) = 0 \quad (7\text{-}55)$$

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(1700 – 1782)