

ME-251: Thermodynamics and energetics I Second Law V

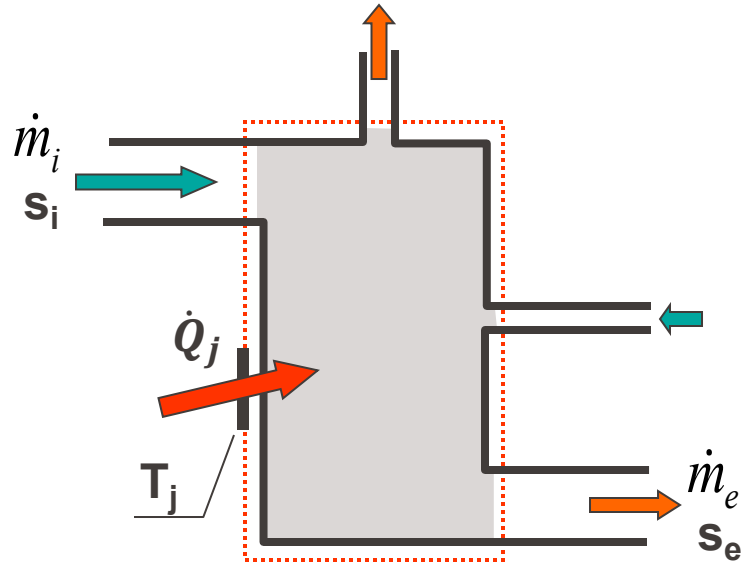
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2025 Fall Semester

Photo Credit: Trougnouf



- Open system entropy rate balance
- Isentropic process



**Mass
balance**

$$\frac{dm_{cv}}{dt} = \sum_i \dot{m}_i - \sum_e \dot{m}_e$$

**Energy
balance**

$$\frac{dE_{cv}}{dt} = \sum_j \dot{Q}_j - \dot{W}_{cv} + \sum_i \dot{m}_i \left(h_i + \frac{\vec{V}_i^2}{2} + gz_i \right) - \sum_e \dot{m}_e \left(h_e + \frac{\vec{V}_e^2}{2} + gz_e \right)$$

**Entropy
balance**

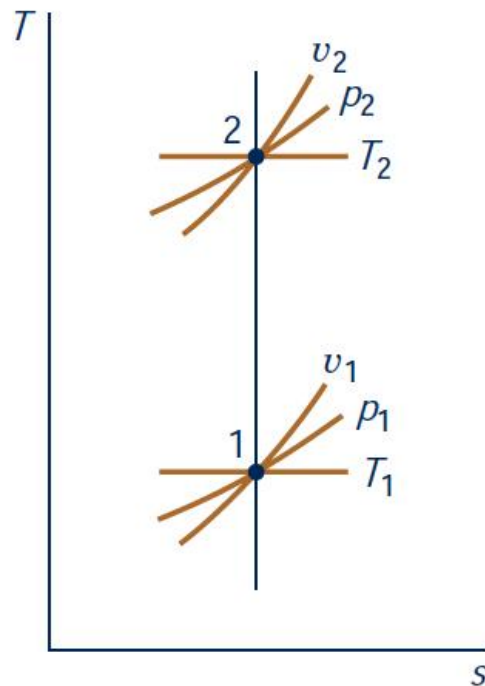
$$\frac{dS_{cv}}{dt} = \sum_j \frac{\dot{Q}_j}{T_j} + \underbrace{\sum_i \dot{m}_i s_i - \sum_e \dot{m}_e s_e}_{\text{Entropy transfer}} + \underbrace{\dot{\sigma}_{cv}}_{\text{Entropy generation}} \quad [\text{W/K}]$$

Entropy change

Entropy transfer

Entropy generation

Isentropic means constant entropy (typically constant specific entropy)



For perfect gas

$$\frac{T_2}{T_1} = \left(\frac{v_1}{v_2} \right)^{k-1}$$

$$\frac{T_2}{T_1} = \left(\frac{p_2}{p_1} \right)^{\frac{k-1}{k}}$$

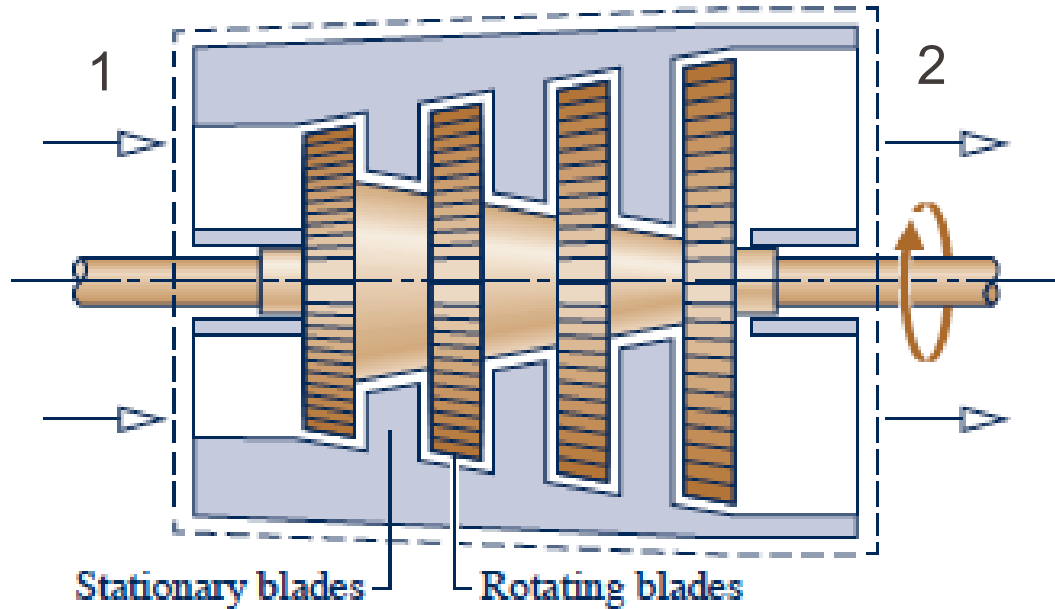
$$p_1 v_1^k = p_2 v_2^k$$

- Isentropic efficiency
- Internally reversible, steady-state flow processes
- Reading: 6.12 and 6.13

For turbines, nozzles, compressors, and pumps at steady states

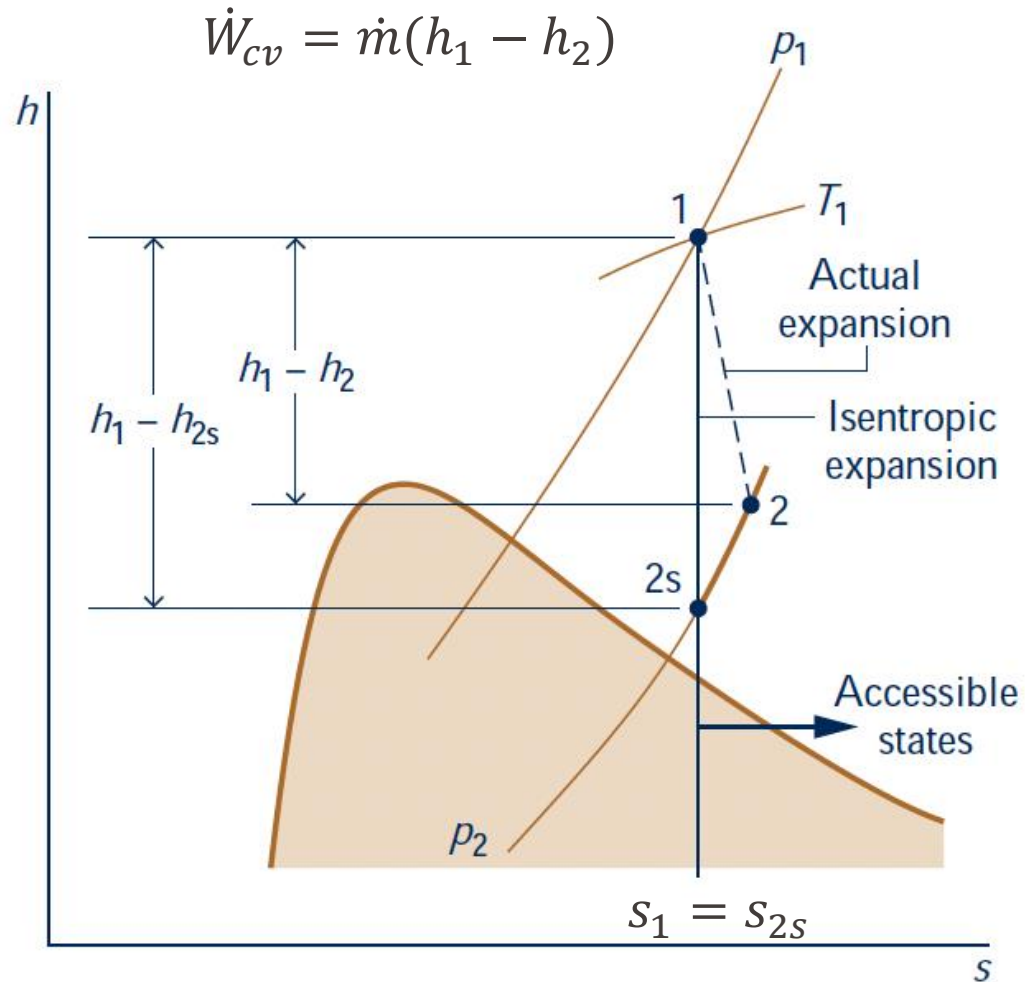
Isentropic efficiency is to compare the actual performance of a device to the performance that would be achieved under **idealized circumstances** for the **same inlet state** and the **same exit pressure**

What's typically assumed in the ideal case: adiabaticity and reversibility



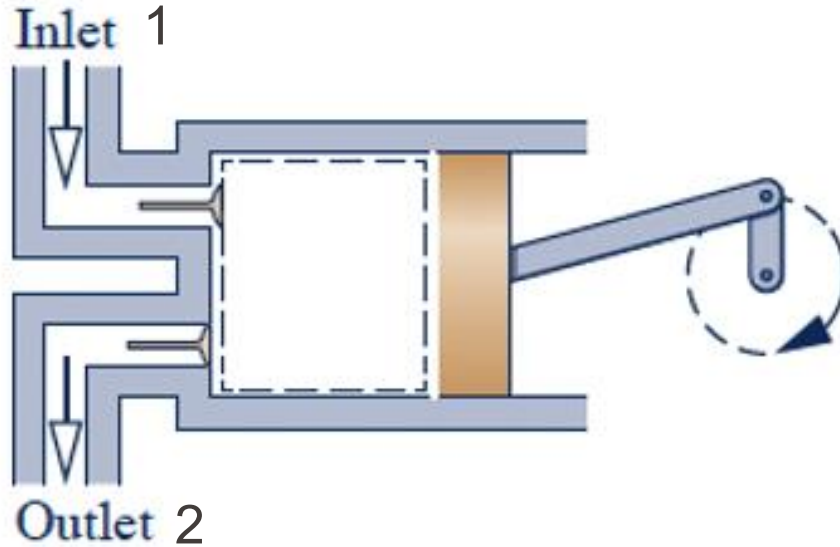
Idealized process ($1 \rightarrow 2_s$)
with no internal irreversibility

- Ignore kinetic and potential energy change
- Assume no heat exchange with the surrounding



Actual process: same inlet state and exit pressure, with irreversibility

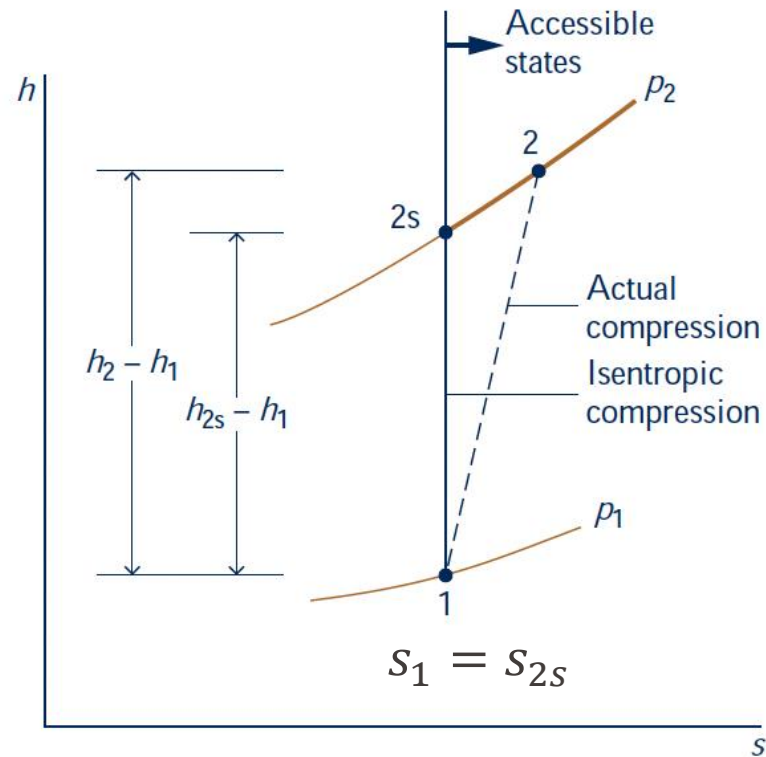
Isentropic efficiency for turbine



Idealized process ($1 \rightarrow 2_s$)
with no internal irreversibility

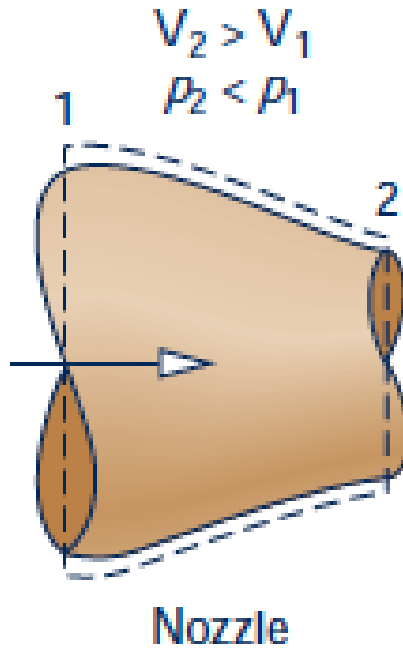
- Ignore kinetic and potential energy change
- Assume no heat exchange with the surrounding

$$-\dot{W}_{cv} = \dot{m}(h_2 - h_1)$$



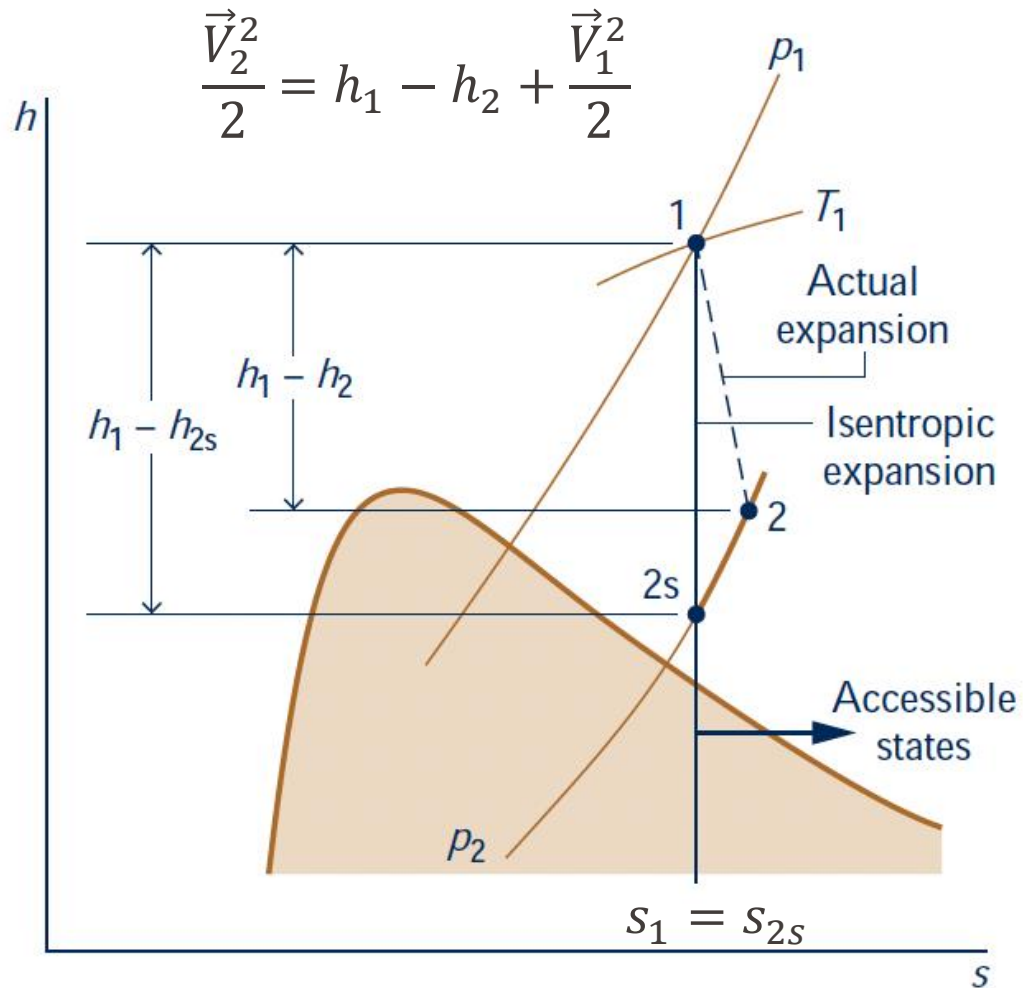
Actual process: same inlet state and exit pressure, with irreversibility

Isentropic efficiency for compressors and pumps



Idealized situation ($1 \rightarrow 2_s$) with no internal irreversibility

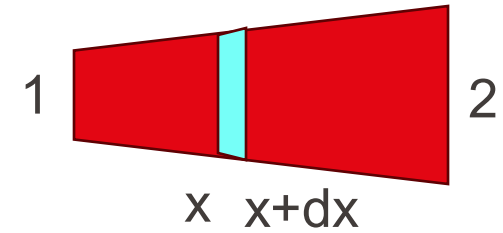
Ignore PE change and heat transfer



Actual process: same inlet state and exit pressure, with irreversibility

Isentropic efficiency for nozzles

One-inlet, one-exit control volumes at steady state



Heat transfer

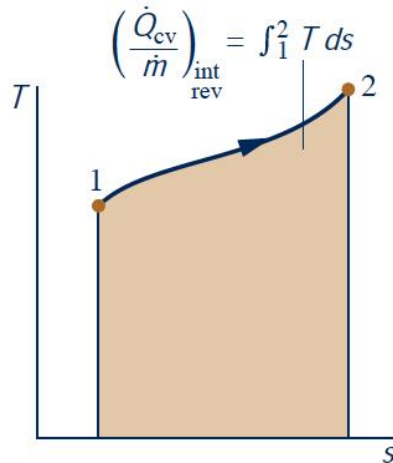


Fig. 6.13 Area representation of heat transfer for an internally reversible flow process.

Work transfer

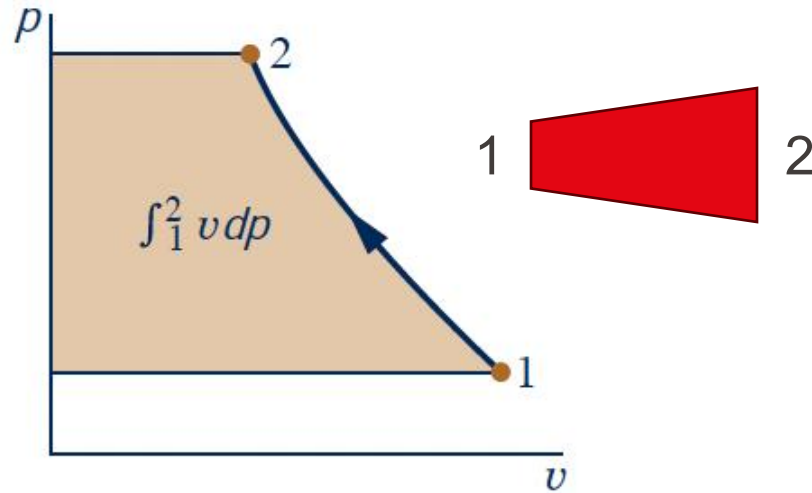
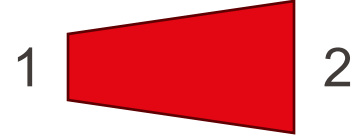


Fig. 6.14 Area representation of $\int_1^2 v dp$.

$$\int_1^2 v dp + \frac{\vec{V}_2^2 - \vec{V}_1^2}{2} + g(z_2 - z_1) = 0$$





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Question: This football is going *upward* while spinning *counterclockwise*. Based on your understanding, it will:

- A) curve to the left
- B) go along a straight line
- C) curve to the right
- D) I don't know

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luepfl