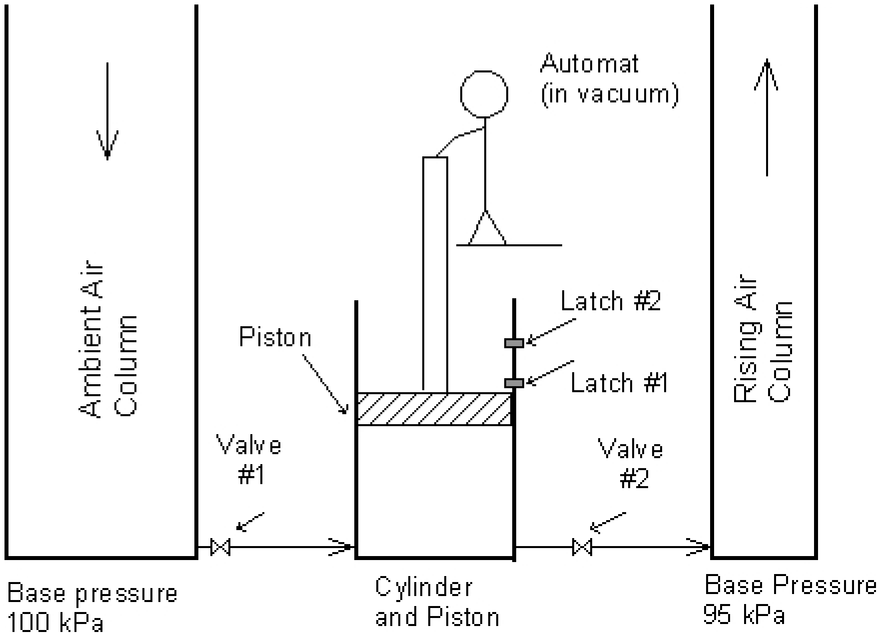
Mechanism permitting Constrained or Unconstrained air transfer



Constrained reversible transfer - Efficiency 10 to 30% (no latch)

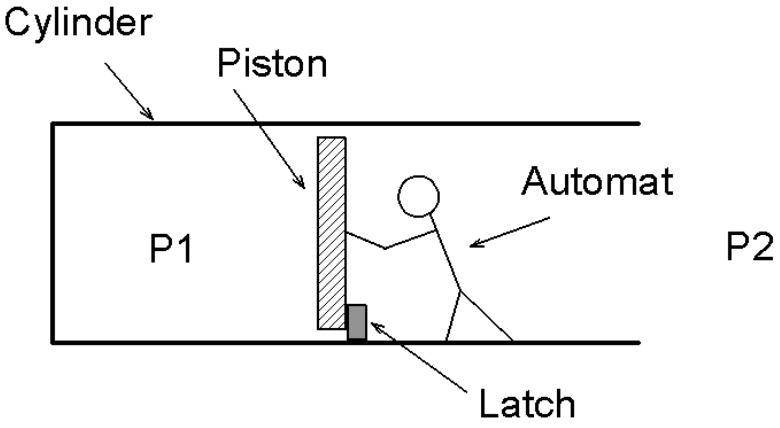
1. Start with piston at bottom of the cylinder, open valve #1,
2. Automat raises piston and let 1 kg of air at 100 kPa in cylinder,
3. Close valve #1,
4. Automat raises piston until cylinder pressure decreases to 95 kPa,
5. Open valve #2,
6. Automat pushes piston to the bottom of the cylinder.

Note: air temperature decreases - work is produced.

Unconstrained irreversible transfer- Efficiency 0% (2 latches)

As above except after step 3. set latch #1 and #2.
Automat lets go of the piston, release latch #1, piston snaps against latch #2 without doing any work.
Note: Position latch #1 to hold piston in place; position latch #2 so that the final pressure is 95 kPa by trial and error.
Note: Air temperature does not decrease - no work is produced.

Horizontal cylinder-piston system



P1 > P2

In the initial condition the piston is held in place by the latch.

When the latch is let go, the work required to push away the ambient air is less than the work that could be produced by isentropic expansion, therefore the excess work becomes heat.

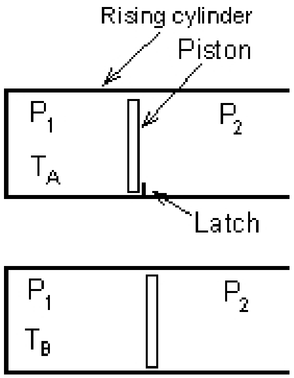
Capturing the work requires that the expansion take place in mechanical equilibrium.

Without the automat to capture the work any work beyond the work required to push the ambient air away is lost.

Work loss form lack of mechanical equilibrium calculation

Initial Condition

Final Condition



Reversible Expansion

$$T_{BR} = T_A (P_2 / P_1)^k \qquad \text{where} \qquad k = R / C_p = 2/7$$

$$W_R = c_p (T_A - T_{BR})$$

Irreversible Expansion

$$T_{BI} = T_A (k (P_2 / P_1) + 1) / (k + 1) \qquad \text{from} \qquad \Delta h = P_2 (\Delta V)$$

$$W_I = c_p (T_A - T_{BI})$$

Loss Work

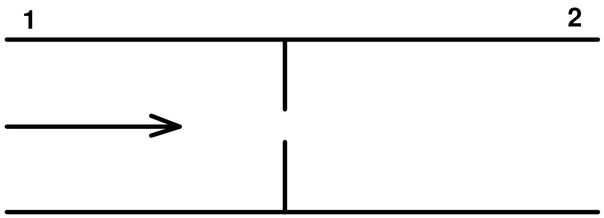
$$W_{loss\%} = 100 (W_R - W_I) / W_R$$

$$W_{loss\%} = 100 ((k R + 1)/(k + 1) - (R)^k) / (1 - (R)^k) \qquad \text{where} \qquad R = P_2 / P_1$$

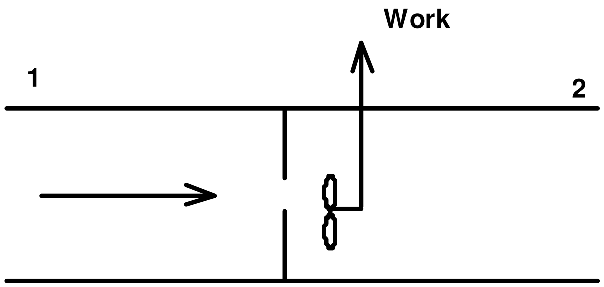
Limit $W_{loss\%}$ as R approaches 1 is 22.2%

Therefore 22.2 % of the work that would be produced if the expansion were carried out at mechanical equilibrium is lost as the cylinder is raised irrespective of how small the friction between the cylinder and piston.

Expander Types

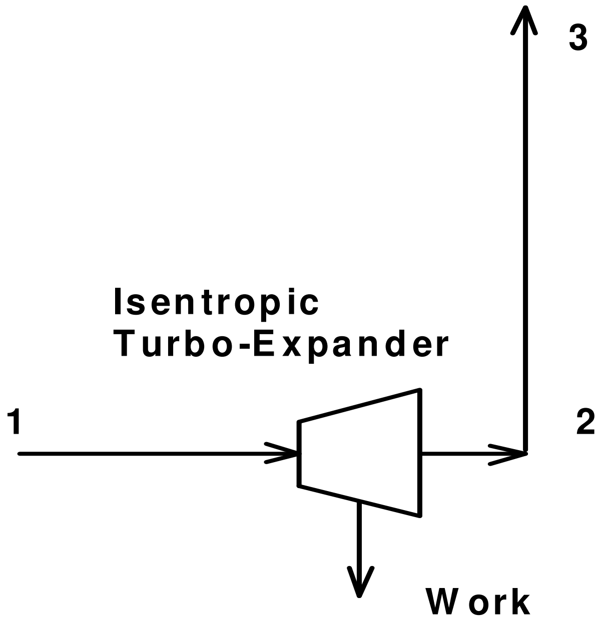


Isenthalpic Expander   h2 = h1, T2 = T1



Isentropic Expander s2 = s1

Isentropic Lifting



Isentropic Lifting

$s3 = s2 = s1$

$T3 < T2 < T1$

$Work = h1 - h2$

$h3 = h2 - gz$

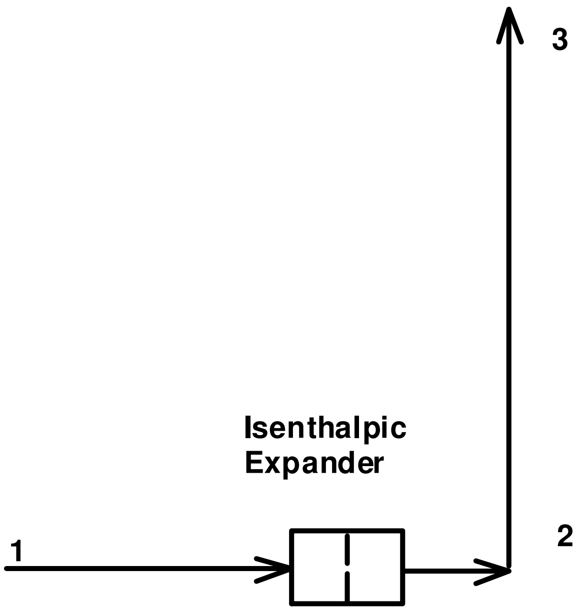
- Isentropic lifting requires an isentropic expander (except in the special case where W=gz).

- Isentropic expansion is widely used in meteorology.

- Isentropic expansion implies that work has been produced and taken out of the system.

- No shaft, no isentropic expansion.

Isenthalpic Lifting



Isenthalpic Lifting

Work = 0 = h1 - h2

s2 > s1, s3 = s2

T2 = T1, T3 < T1

h3 = h2 - gz

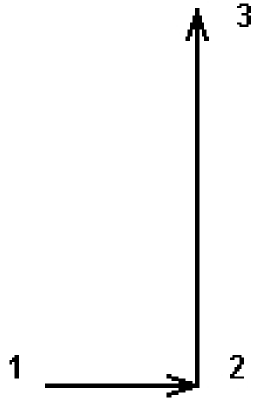
If there is no work taken from the system (no shaft), entropy must increase.

Static energy (h+gz) is what is conserved.

The isenthalpic expander is not esential. A plain tube without an isentropic expander is all that is necessary for the expansion to be constant a constant static energy one.

(Adiabatic lifting with no mixing assumed in both cases)

Three types of continuous lifting processes

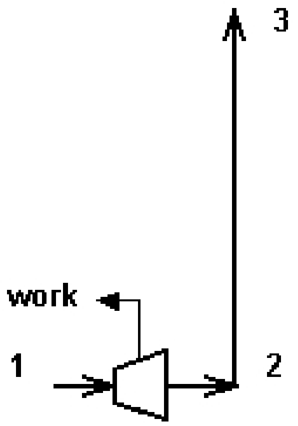


USUAL

Isenthalpic Lifting

h3 = h2 - gz
s3 > s1

Irrespective of where dissipation occurs. Irrespective of whether of whether dissipation is due to resistance to flow or unrestrained expansion.

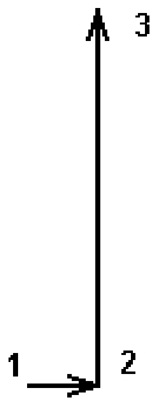


APPROCHABLE

Isentropic Lifting

s3 = s2 = s1
w = h1 - h2

Requires an isentropic expander. Requires a shaft to get the work out of the system .



IMPOSSIBLE

Isentropic Lifting

s3 = s2 = s1
w = 0

Isentropic expansion without device for taking work out of the system is impossible except in one case (w=0).
It is the basis of most atmospheric models.