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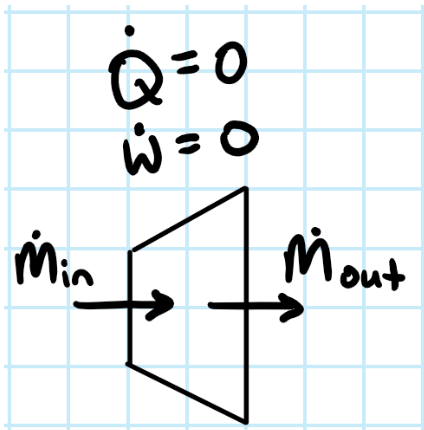
## **Device:** Diffuser for HVAC System

**Schematic of a diffuser**

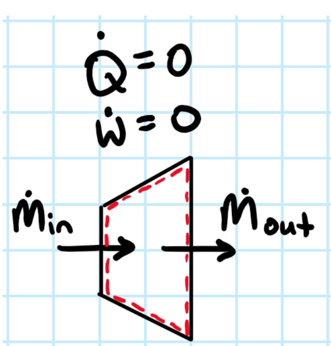



**Picture of a diffuser**

## Description of Diffuser

A diffuser is a type of thermodynamic device that decreases the speed of a fluid as it passes. In this example, the fluid is air, and the diffuser slows the air down as it exits the vent, which helps distribute the air more evenly throughout a room. This slowing process is due to the change in cross-sectional area of the diffuser. The air travels through a smaller cross-sectional area inside the duct, and when it reaches the diffuser vent, the cross-sectional area becomes larger. This increase in area is responsible for reducing the speed of the air and allowing it to spread gently into the space.

## System Diagram




This setup is treated as a control volume because we are only concerned with the fluid inside the diffuser. The gas enters through the smaller cross-sectional area and exits through the larger one. Since the diffuser is adiabatic, there is no heat transfer, and it does not produce or require work.

**Assumptions**: Steady-state and adiabatic.

**Mass Balance:**

$$\sum \dot{m}_{in} = \sum \dot{m}_{out}$$

$$\rho A_{in} \vec{v}_{in} = \rho A_{out} \vec{v}_{out}$$

**Energy Balance:**

$$\underbrace{\dot{E}}_{\substack{=0 \\ \text{Steady-state}}} = \underbrace{\dot{Q}_{cv}}_{\substack{=0 \\ \text{Adiabatic}}} - \underbrace{\dot{W}_{cv}}_{\substack{=0 \\ \text{Nozzle does no work}}} + \sum_i \dot{m}_i \left(h_i + \frac{|v_i|^2}{2} + \underbrace{g z_i}_{\substack{=0 \\ \text{Neglect PE}}}\right) - \sum_o \dot{m}_o \left(h_o + \frac{|v_o|^2}{2} + \underbrace{g z_o}_{\substack{=0 \\ \text{Neglect PE}}}\right)$$

Resulting Equation:

$$0 = \dot{m}\left(h_i - h_o + \frac{|v_i|^2}{2} - \frac{|v_o|^2}{2}\right)$$

**Entropy Balance:**

$$\underbrace{\dot{S}}_{\substack{=0 \\ \text{Steady-state}}} = \underbrace{\sum \frac{\dot{Q}}{T_b}}_{\substack{=0 \\ \text{Adiabatic}}} + \dot{\sigma} + \sum \dot{m}_{in} s_{in} - \sum \dot{m}_{out} s_{out}$$

Resulting Equation:

$$\dot{\sigma} = \sum \dot{m} \left(s_{out} - s_{in}\right)$$

## Change and Effect

Many different changes can be made depending on the goal of the diffuser. For a diffuser on an air-conditioning vent, we don't want the air exiting at a very high speed, because fast-moving air would create drafts and make the room uncomfortable. Instead, the diffuser is designed to slow the air down so it can spread gently throughout the space. However, in other systems, like a duct into a large room, we may want a diffuser that reduces the speed more gradually to maintain good airflow while still increasing the pressure. One way to control how much the airflow slows down is to increase the exit cross-sectional area.

## Example with Numbers

Air enters a steady, adiabatic diffuser at $T_{in}$= 20°C, $V_{in}$ = 12 m / s, and density $\varrho$ = 1.2 kg / m$^3$. The duct area upstream is $A_{in}$ = 0.02 m$^2$ and the diffuser expands to $A_{out}$ = 0.10 m$^2$. Assume steady, adiabatic, isentropic operation and neglect potential energy changes. Find the mass flow rate m dot, the exit velocity $V_{out}$, the exit temperature $T_{out}$, and the entropy generation rate $S_{gen}$ dot.

**Solution:**

m dot = $\varrho$*$A_{in}$*$V_{in}$ = (1.2 kg / m$^3$)(0.02 m$^2$)(12 m / s) = 0.288 kg / s

Steady-state, so, $A_1V_1 = A_2V_2 \rightarrow V_{out} = A_{in}V_{in} / A_{out}$ = (0.02 m$^2$)(12 m / s) / (0.10 m$^2$) = 2.4 m /s

$$h_i + \frac{|V_i|^2}{2} = h_o + \frac{|V_o|^2}{2}$$

$$C_pT_i + \frac{|V_i|^2}{2} = C_pT_o + \frac{|V_o|^2}{2}$$

$$T_o = T_i + \frac{V_i^2 - V_o^2}{2C_p}$$

$$T_{out} = (20^\circ C + 273.15) + \frac{(12\,\frac{m}{s})^2 - (2.4\,\frac{m}{s})^2}{2(1005\ J/kgK)}$$

$$T_{out} = 293.219\ K = 20.07^\circ C$$

$S_{gen} = 0$ because of isentropic assumption