Steady-Flow Engineering Devices

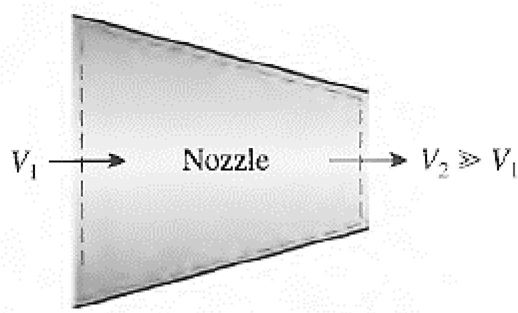
Many engineering devices operate under the **same conditions** for long periods of time. Therefore, these devices can be conveniently analyzed as **steady-flow** devices. Some common steady-flow devices are:

- Nozzles and Diffusers
- Turbines and Compressors
- Heat Exchangers.

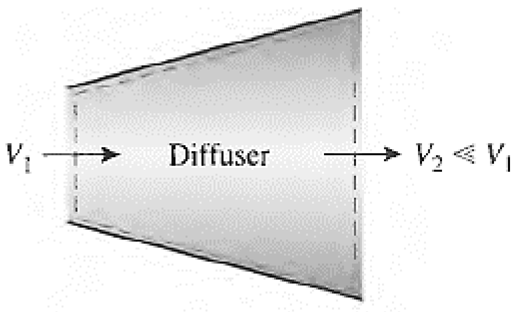
Nozzles and Diffusers

Nozzles and diffusers perform opposite tasks.

Nozzle is a device that ***increases the velocity*** of a fluid at the expense of ***pressure.***



Diffuser is a device that ***decrease the velocity*** of a fluid by increasing its ***pressure.***



Recall the Energy Balance Equation

$$\dot{Q}_{in} + \dot{W}_{in} + \dot{m}\left(h_1 + \frac{V_1^2}{2} + gZ_1\right) = \dot{Q}_{out} + \dot{W}_{out} + \dot{m}\left(h_2 + \frac{V_2^2}{2} + gZ_2\right)$$

Thermodynamic analysis

- The rate of heat transfer between the fluid flowing through a nozzle or a diffuser and the surroundings is usually very small (can be neglected) since the fluid has high velocities, and thus it does not spend enough time in the device for any significant heat transfer to take place.
- Nozzles and diffusers typically involve neither work ***(W =** 0*) nor any change in potential energy because Z_2& Z_1 lies on the same reference line.

Thus the energy balance equation applied to Nozzles and diffusers reduces to

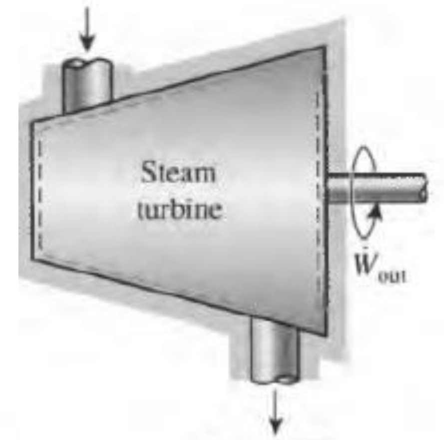
$$\boxed{h_1 + \frac{V_1^2}{2} = h_2 + \frac{V_2^2}{2}}$$

Ex_1) Air at 10°C and 80 Kpa enters the diffuser of a jet engine steadily with a velocity of 200 m/s. The inlet area of the diffuser is 0 .4 m^2. The air leaves the diffuser with a velocity that is very small compared with the inlet velocity. Determine the mass flow rate of the air and the temperature of the air leaving the diffuser.

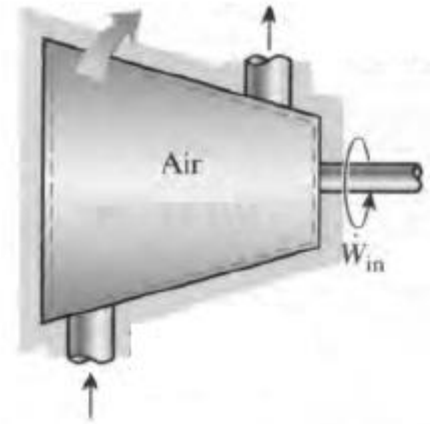
Ex_2) Steam at 16 bar and 370 ^{0}C steadily enters a nozzle whose inlet area is 0.02 m^2. The mass flow rate of steam through the nozzle is 4.5 kg/s. Steam a leaves the nozzle at 14 bar with a velocity of 275 m/s. Heat losses from the nozzle per unit mass of the steam are estimated to be 2.8 KJ/Kg. Determine the inlet velocity and the exit temperature of the steam.

Turbines and Compressors

In steam, gas or hydroelectric power plants, the device that drives the electric generator is the turbine. As the fluid passes through the turbine, work is done against the blades, which are attached to the shaft. As a result, the shaft rotates and the turbine ***produces work***.



Compressors are devices used to **increase** the pressure of a fluid. Work is supplied to these devices from an external source through a rotating shaft. Therefore, compressors ***involve work inputs.***



Thus, turbines produce **power output** whereas compressors require **power input**.

- Heat transfer for turbines and compressors are usually negligible ***(Q*** $= 0$) since they are typically well insulated.
- Potential energy changes are negligible for all of these devices (Δpe $= 0$).
- The velocities involved in these devices, are usually too low to cause any significant change in the kinetic energy (Δke $= 0$).

Ex_3) Air at 100 Kpa and 280 K is compressed steadily to 600 Kpa and 400 K. The mass flow rate of the air is 0.02 kg/s, and a heat loss of 16 kJ/kg occurs during the process. Assuming the changes in kinetic and potential energies are negligible, determine the necessary power input to the compressor.