

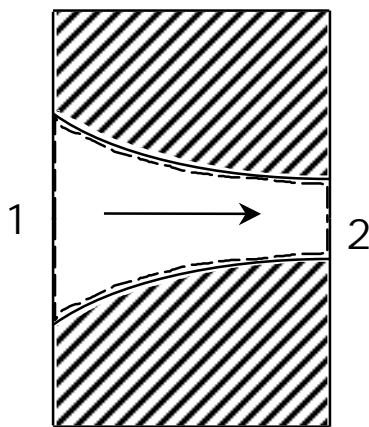
### 3.5. Applications of the steady flow energy equation

#### (a) Nozzle and diffuser

##### Nozzle

Accelerates the flow and expands the gas.

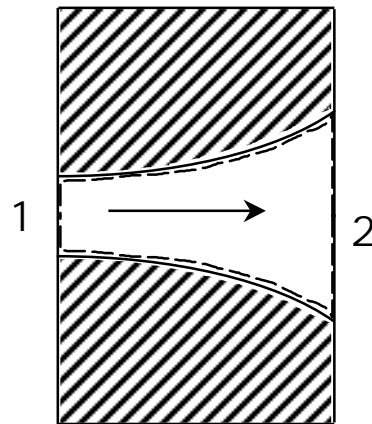
Typical applications:  
turbine passages, propelling  
nozzles



##### Diffuser

Decelerates the flow and compresses the gas.

Typical applications:  
compressor passages, aircraft  
engine intakes.



Steady flow energy equation:

$$q + w_s = \frac{1}{2}(c_2^2 - c_1^2) + g(z_2 - z_1) + (h_2 - h_1)$$

In this case, for adiabatic flow,  $q = 0$ ,  $w_s = 0$ ,  $z_2 = z_1$  (no appreciable change in height)

$$\therefore (h_2 - h_1) = \frac{1}{2}(c_1^2 - c_2^2)$$

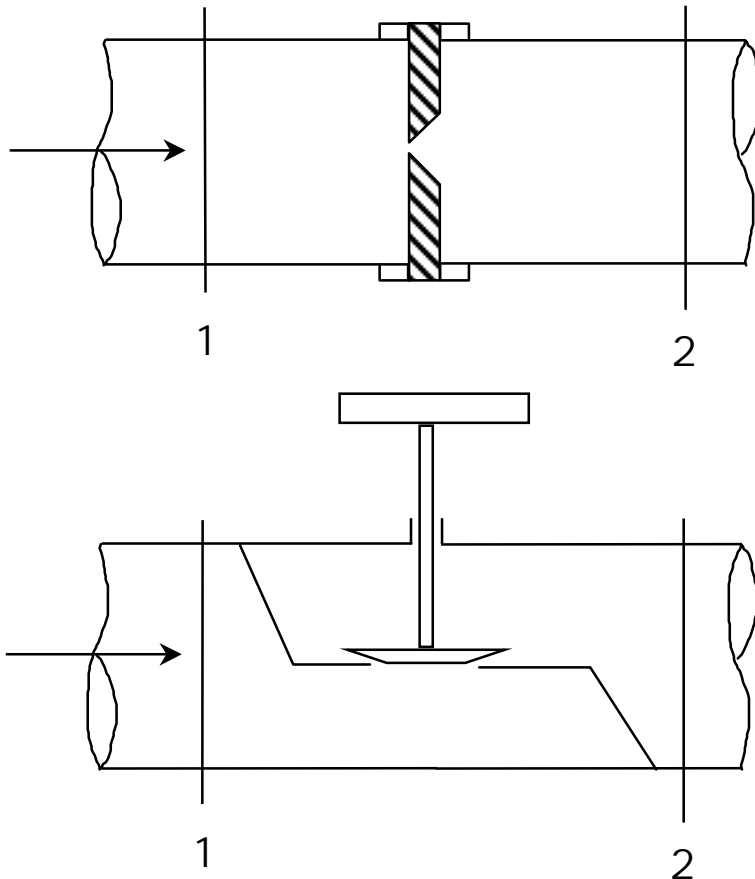
So, as the velocity increases (in the nozzle) the enthalpy decreases, and for a perfect gas  $h_2 - h_1 = c_p(T_2 - T_1)$ , so the temperature falls.

In the diffuser, however, as the velocity decreases, the enthalpy, and therefore temperature, rises.

(b) **Throttle**

Flow through a small orifice reduces gas pressure.

Typical applications: pressure regulators, pneumatic circuits, valves, measurement of steam condition.



$$\text{SFEE:} \quad q + w_s = \frac{1}{2}(c_2^2 - c_1^2) + g(z_2 - z_1) + (h_2 - h_1)$$

If it happens rapidly, there is no time for heat transfer,  $q = 0$ .

Also  $w_s = 0$ , and  $z_2 = z_1$  (no appreciable change in height)

$$\therefore (h_2 - h_1) = \frac{1}{2}(c_1^2 - c_2^2)$$

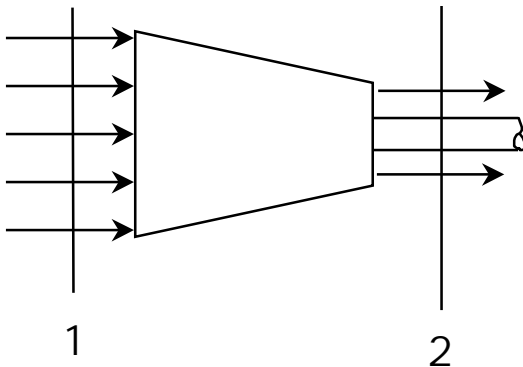
But  $c_2 \approx c_1$  – not exactly, because by continuity,  $\rho_1 A_1 c_1 = \rho_2 A_2 c_2$ , and although  $A_1 = A_2$ ,  $\rho_1 \neq \rho_2$ , because there has been a change in pressure. Usually the change is small, however, so that  $h_2 = h_1$  approximately.

A throttle is normally modelled as an **isenthalpic** (constant enthalpy) device.

(c) **Compressor and turbine**

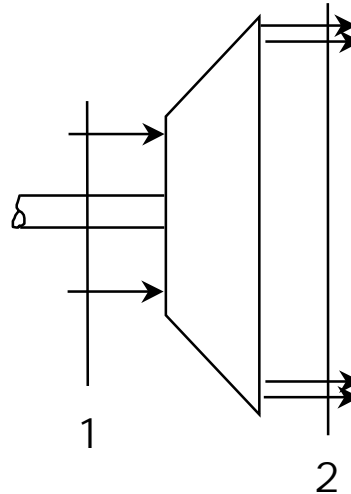
**Compressor**

work is done on the fluid to increase the pressure



**Turbine**

work is produced by the fluid, as it expands to a lower pressure.



These devices are usually modelled as adiabatic, because the flow rate is too rapid for heat transfer to take place.

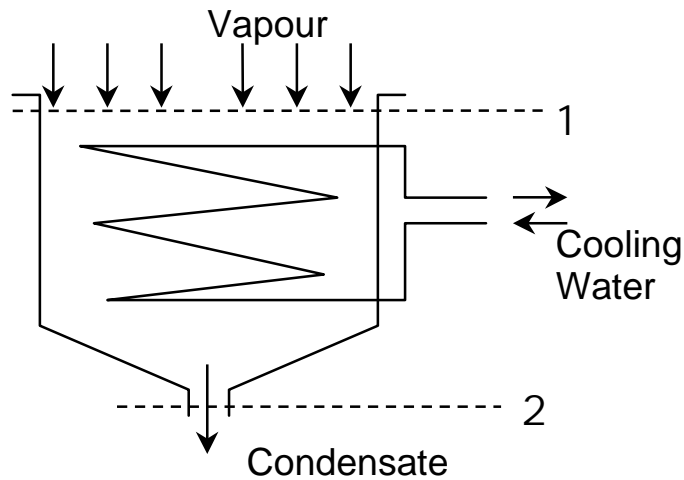
Thus the SFEE:  $q + w_s = \frac{1}{2}(c_2^2 - c_1^2) + g(z_2 - z_1) + (h_2 - h_1)$

with  $q = 0$  and  $z_2 = z_1$  (no appreciable change in height), gives:

$$w_s = \frac{1}{2}(c_2^2 - c_1^2) + (h_2 - h_1)$$

So, in the compressor, the work input produces a change in enthalpy and a change in velocity, while in the turbine, shaft work output is produced by utilising the kinetic energy of the incoming fluid and reducing the enthalpy of the fluid.

(d) Condenser and evaporator



Condenser

$$\text{SFEE: } q + w_s = \frac{1}{2}(c_2^2 - c_1^2) + g(z_2 - z_1) + (h_2 - h_1)$$

In these devices,  $w_s = 0$ , and changes in kinetic and potential energy are normally negligible, so that:

$$q = h_2 - h_1$$

An evaporator works in a similar way, but in reverse. Heat is supplied to a liquid causing it to vaporise. This means that  $q$  is positive for an evaporator, but negative for a condenser.

Other constant pressure devices, are heat exchanges in which energy from one fluid is transferred to another at constant pressure.

Further reading:

Bacon and Stephens, Mechanical Technology

23.11

Rogers, G and Mayhew, Y,

Engineering Thermodynamics Work and Heat Transfer

Ch 4.2

The Open University, T236 Introduction to thermofluid mechanics

Block 6