3.1 INTRODUCTION

- First Law of Thermodynamics (also known as conservation of energy principle) states that energy can be neither created nor destroyed during a process but can only change forms.
- Conservation of Energy Principle ➔ the net change (increase or decrease) in the total energy of the system during a process is equal to the difference between the total energy entering and the total energy leaving the system during that process:

$$\begin{pmatrix}\text{Total energy}\\ \text{entering the system}\end{pmatrix} - \begin{pmatrix}\text{Total energy}\\ \text{leaving the system}\end{pmatrix} = \begin{pmatrix}\text{Net change in the total}\\ \text{energy of the system}\end{pmatrix}$$

$$E_{\text{in}} - E_{\text{out}} = \Delta E_{\text{system}}$$

- This relation is applicable to any kind of system undergoing any kind of process.

Energy Balance for closed systems

(closed tank, rigid tank, piston-cylinder device)

$$Q - W = \Delta U + \Delta KE + \Delta PE \quad \left(\text{with,} \quad W = W_b + W_{other}\right)$$

STATIONARY SYSTEMS ($\Delta KE = \Delta PE = 0$)

$$Q - W = \Delta U \quad \left(\text{with,} \quad W = W_b + W_{other}\right)$$

CONSTANT VOLUME PROCESS / ISOCHORIC PROCESS ($\Delta V=0$)

RIGID TANK / PISTON-CYLINDER DEVICE

$\Delta V=0 \rightarrow W_b=0$

$\therefore Q=\Delta U$

CONSTANT PRESSURE PROCESS / ISOBARIC PROCESS ($\Delta P=0$)

PISTON-CYLINDER DEVICE ($W=W_b$)

$$Q - W_b = \Delta U$$

$$Q = \Delta U + W_b$$

$$Q = \underbrace{\Delta U + P\Delta V}_{\text{Entalphy definition}}$$

$$\therefore Q = \Delta H$$

Energy Balance for control volumes

$$Q_{in} + W_{in} + \sum_{in} \underbrace{\dot{m}\left(h + \frac{\vec{V}^2}{2} + gz\right)}_{\text{for each inlet}} = Q_{out} + W_{out} + \sum_{out} \underbrace{\dot{m}\left(h + \frac{\vec{V}^2}{2} + gz\right)}_{\text{for each outlet}}$$

$$\Downarrow$$

$$\dot{Q}_{in} + \dot{W}_{in} + \sum \underbrace{\dot{m}\left(h_i + \frac{\vec{V}_i^2}{2} + gz_i\right)}_{\text{for each inlet}} = \dot{Q}_{out} + \dot{W}_{out} + \sum \underbrace{\dot{m}\left(h_e + \frac{\vec{V}_e^2}{2} + gz_e\right)}_{\text{for each outlet}}$$

$$\dot{Q}_{net} = \sum \dot{Q}_{in} - \sum \dot{Q}_{out}$$

$$\Downarrow$$

$$\dot{Q}_{net} - \dot{W}_{net} = \sum \underbrace{\dot{m}\left(h_e + \frac{\vec{V}_e^2}{2} + gz_e\right)}_{\text{for each inlet}} - \sum \underbrace{\dot{m}\left(h_i + \frac{\vec{V}_i^2}{2} + gz_i\right)}_{\text{for each outlet}}$$

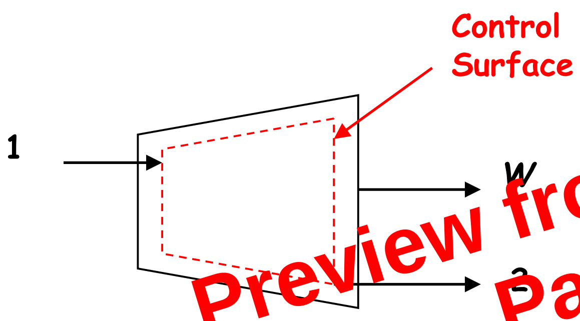
$$\dot{W}_{net} = \sum \dot{W}_{out} - \sum \dot{W}_{in}$$

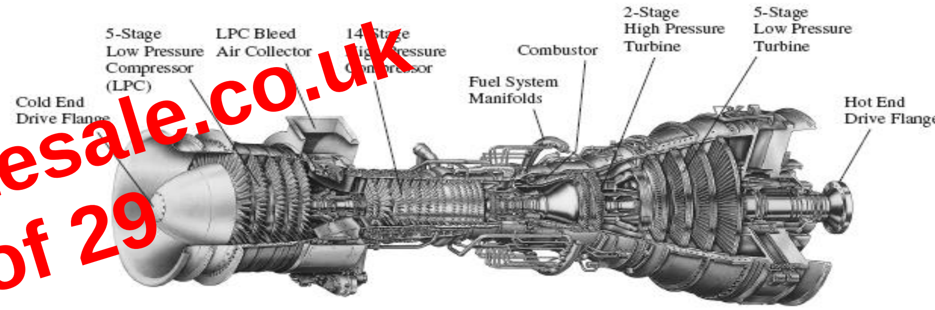
$$\Updownarrow$$

$$\boxed{\dot{Q} - \dot{W} = \Delta\dot{H} + \Delta\dot{KE} + \Delta\dot{PE}}$$

Overall 1st Law of thermodynamics for CV undergoing steady-flow process

Turbines





- In steam, gas, or hydroelectric power plants, the device that drives the electric generator ➔ TURBINE. As the fluid passes through the turbine, work is done against the blades, which are attached to the shaft ➔ shaft rotates, and the turbine produces work ➔ produce power output.
- By ignoring the change in *KE* and *PE* energies ($\Delta ke = \Delta pe = 0$) through an adiabatic turbine ($Q=0$) with a single stream (one inlet-one outlet) that undergoes a steady flow process:

$$\boxed{\begin{gathered}\text{Mass balance: } \dot{m}_{in} = \dot{m}_{out} \Rightarrow \dot{m}_1 = \dot{m}_2 = \dot{m} \\ \text{Energy balance: } \dot{E}_{in} = \dot{E}_{out} \\ \dot{m}h_1 = \dot{m}h_2 + \dot{W} \\ \therefore \dot{W} = \dot{m}(h_1 - h_2)\end{gathered}}$$