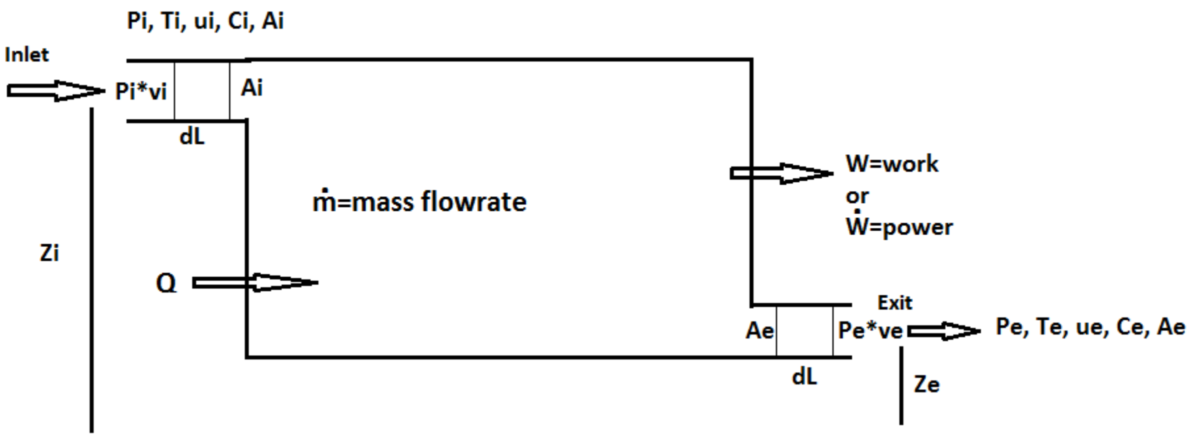
FIRST LAW OF THERMODYNAMICS

WORKING FLUID	**IDEAL GASES** ***State: Gas*** ***state does not change during a process*** 1. Monoatomic gases (Ar, He) $\gamma = 1.6$ 2. Diatomic gases (air, O_2, N_2, H_2) $\gamma = 1.4$ 3. Triatomic gases (CO_2, SO_2) $\gamma = 1.3$ **Equations** $P*V = m*R*T$ V = volume in m^3 $P*v = R*T$ v = specific volume in m^3/kg $u = c_v*T$ u = internal energy in kJ/kg c_v = specific heat kJ/kg.K (constant volume) $\Delta u = u_2 - u_1 = c_v*(T_2-T_1)$ $h = cp*T$ h = enthalpy in kJ/kg c_p = specific heat kJ/kg.K (constant pressure) $\Delta h = h_2 - h_1 = c_p*(T_2-T_1)$ $h = u + Pv$ Properties: P, T, V, v, u, h ***use equations***
	WATER ***State changes during a process*** 1. Liquid Water 2. Saturated Liquid Water (at boiling point) 3. Mixture (saturated liquid and saturated vapor) 4. Saturated Water Vapor Table: saturated water table (pressure or temperature table) 5. Superheated Water Vapor Table: superheated water vapor table Liquid or saturated liquid : subscript –f Saturated vapor: subscript –g Properties: P, T, v, u, h ***use tables*** Dryness fraction (***x***) in mixture region x = fraction of vapor present in mixture = kg vapor/kg mixture in mixture region v : specific volume $v = v_f + x*v_{fg}$ or sometimes vf is negligible use $v = x*v_g$ $u = u_f + x*u_{fg}$ $h = h_f + x*h_{fg}$ $h = u + Pv$ *****use tables*****

SYSTEMS

OPEN SYSTEMS

Consider an open system



It has an inlet and exit. Working fluid is flowing through system.

An energy balance around open system. Assume 1 kg of working fluid

Inlet energies:

$Q + ui + Pi*vi + ½*Ci^2 + gZi$

Exit energies

$W + ue + Pe*ve + ½*Ce^2 + gZe$

Energy balance:

$Q + ui + Pi*vi + ½*Ci^2 + gZi = W + ue + Pe*ve + ½*Ce^2 + gZe$

Arranging terms in the equation

$Q – W = \mathbf{(ue – ui) + (Pe*ve-Pi*vi)} + ½ (Ce^2 – Ci^2) + g(Ze-Zi)$ General steady flow energy equation

$h = u + p*v$

$Q – W = (he – hi) + ½ (Ce^2 – Ci^2) + g(Ze-Zi)$ Steady flow energy equation

Sometimes kinetic energy and potential energy changes are negligible, then simplified steady flow energy equation is used in the form of

$Q – W = (he – hi)$

$\dot{m}$ = mass flowrate (kg/sec) = constant

$\dot{m} = (A_i*C_i)/v_i = (A_e*C_e)/v_e$

A = area (m^2)

C = velocity (m/sec)

v = specific volume (m^3/kg)

Steady flow energy equation in rate form

Q = heat transfer

$\dot{Q}$ = rate of heat transfer = $\dot{m}$*Q

W = work

$\dot{W}$ = power = $\dot{m}$*W

$\dot{m}*(Q - W) = \dot{m}*[(he - hi) + \frac{1}{2}(Ce^2 - Ci^2) + g(Ze-Zi)]$

$\dot{Q} - \dot{W} = \dot{m}*[(he - hi) + \frac{1}{2}(Ce^2 - Ci^2) + g(Ze-Zi)]$

If kinetic energy and potential energy changes are negligible

$\dot{Q} - \dot{W} = \dot{m}*(he - hi)$

Flow systems or open systems

Flow systems have fixed size and shape (control volume)

1. work producing device

Turbine

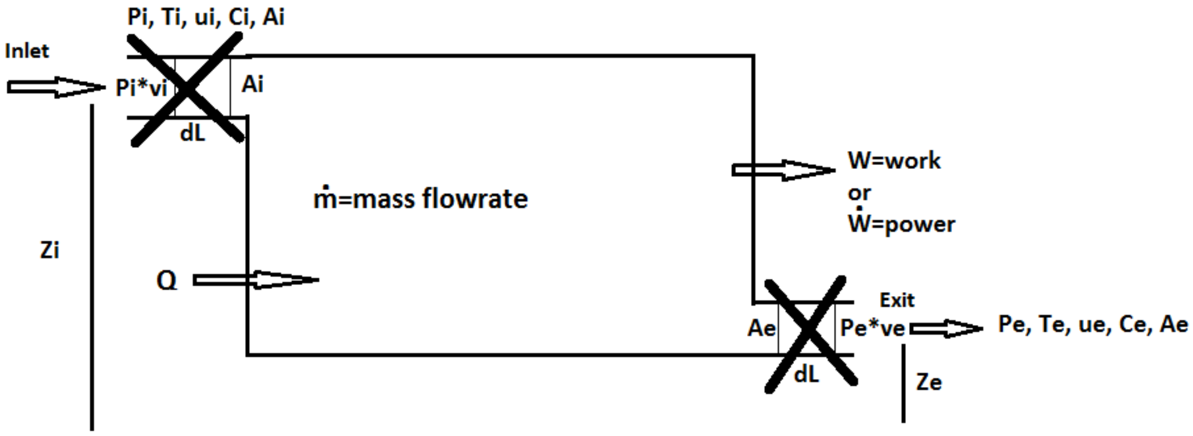
2. work consuming device

Compressor

3. other flow devices (no work)

Nozzle

CLOSED SYSTEMS



Now the system is a closed system

A non-flow process occurs in a closed system. There are initial and final states of the working fluid during a non-flow process

Mass of the working fluid is constant in closed system and during non-flow process.

Mass = m = constant

Simplification on general flow energy equation by neglecting some energy terms

Kinetic energy and potential energy changes are zero in a closed system.

Also, no need to use P*v since no inlet no exit of the closed system.

General steady flow energy equation becomes

$Q - W = \mathbf{(ue - ui)} + \mathbf{(Pe*ve-Pi*vi)} + \mathbf{\tfrac{1}{2}(Ce^2 - Ci^2)} + \mathbf{g(Ze-Zi)}$

$\mathbf{Q - W = (u2 - u1) = \Delta u}$ Non-flow energy equation

Non-flow processes

1. Reversible constant volume
2. Reversible constant pressure
3. Reversible constant temperature (isothermal)
4. Reversible adiabatic
5. Polytropic

PROCESSES	
FLOW **Flow energy equation** $Q - W = (h_2-h_1) + \frac{1}{2}(C_2^2 - C_1^2) + g(Z_2-Z_1)$	NON-FLOW **Non-flow energy equation** $Q - W = U_2-U_1$ Non-flow processes

in rate form $\dot{m} *(Q - W) = \dot{m}*[(he - hi) + ½ (Ce^2 - Ci^2) + g(Ze-Zi)]$ $\dot{Q} - \dot{W} = \dot{m}*[(he - hi) + ½ (Ce^2 - Ci^2) + g(Ze-Zi)]$ If kinetic energy and potential energy changes are negligible $\dot{Q} - \dot{W} = \dot{m}*(he - hi)$ $\dot{m}$ = mass flowrate (kg/sec) = constant $\dot{m} = (A_i*C_i)/v_i = (A_e*C_e)/v_e$ A = area (m^2) C = velocity (m/sec) v = specific volume (m^3/kg) **Flow systems or open systems** Flow systems have fixed size and shape (control volume) 1. work producing device Turbine 2. work consuming device Compressor 3. other flow devices (no work) Nozzle Diffuser Throttling Adiabatic mixing chamber	1. Reversible constant volume 2. Reversible constant pressure 3. Reversible constant temperature (isothermal) 4. Reversible adiabatic 5. Polytropic Mass is constant Non-flow systems or closed devices 1. Piston cylinder (boundary work) 2. Rigid vessel or constant volume vessel (no boundary work)
Work : Mechanical work or shaft work	Work: Boundary work ($W_{boundary}$) due to volume change during a process