Ideal gases

$pv = RT$

$u = f(T)$ only

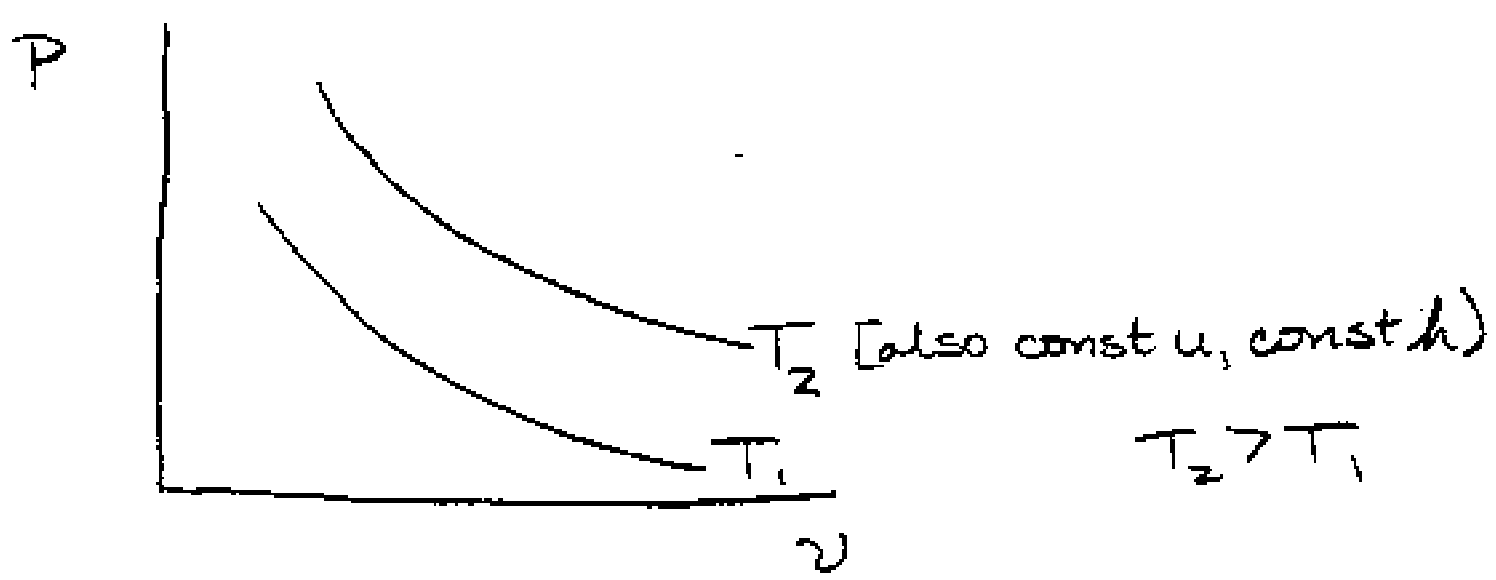
$h = f(T)$ only

for a closed system, Ideal Gas if T is const

then $pv = \text{const}$

$u = \text{const}$

$h = \text{const}$



$T_2 > T_1$

from last time

$$C_v \equiv \left(\frac{\partial u}{\partial T}\right)_v \qquad C_p \equiv \left(\frac{\partial h}{\partial T}\right)_p$$

for ideal gases

$$du = C_{v0}\,dT \qquad dh = C_{p0}\,dT$$

$$dU = mC_{v0}\,dT \qquad dH = mC_{p0}\,dT$$

Remember,

$$h = u + pv$$

for I.G. $pv = RT$

$$h = u + RT$$

$$dh = du + R\,dT$$

$$C_{p0}\,dT = C_{v0}\,dT + R\,dT$$

$$C_{p0} = C_{v0} + R \quad \text{or} \quad \boxed{C_{p0} - C_{v0} = R \text{ for I.G.}}$$

likewise $\boxed{\overline{C}_{p0} - \overline{C}_{v0} = \overline{R} \text{ for I.G.}}$

First Law as a rate equation:

$$\delta Q = dE + \delta W$$

$$\delta Q = dU + d(KE) + d(PE) + \delta W$$

$\div \delta t$

$$\frac{\delta Q}{\delta t} = \frac{dU}{\delta t} + \frac{d(KE)}{\delta t} + \frac{d(PE)}{\delta t} + \frac{\delta W}{\delta t}$$

in the limit as $\delta t \to 0$

$$\dot{Q} = \frac{dU}{dt} + \frac{d(KE)}{dt} + \frac{d(PE)}{dt} + \dot{W}$$

$$\dot{Q} = \frac{dE}{dt} + \dot{W}$$

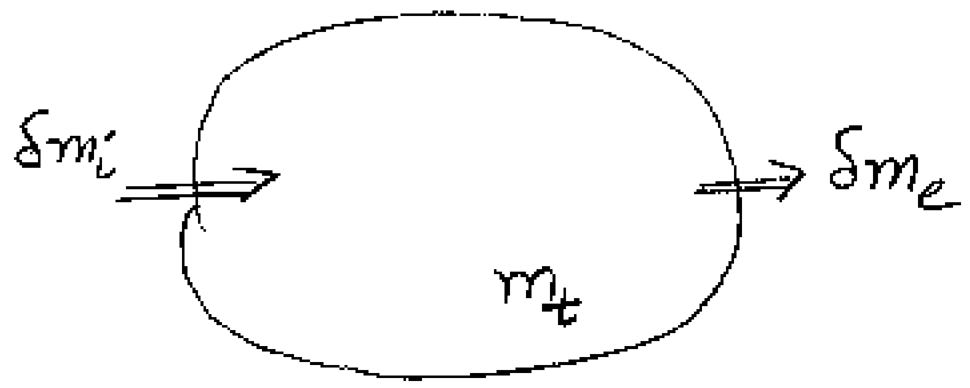
power $\frac{kJ}{s}$ or W ; $\frac{ft\,lbf}{s}$ or hp

rate of energy change

rate of heat transfer $\frac{kJ}{s}$ or W ; $\frac{Btu}{s}$ or $\frac{Btu}{hr}$

Open Systems:

mass conservation



a control volume (C.V.)
(region in space)

if what comes in is δm_i
& what (goes out) exits is δm_e
the accumulation is
$\delta m_i - \delta m_e$

in a time interval δt, for the C.V. $m \rightarrow m_{t+\delta t}$

the accumulation

$$(\delta m_i - \delta m_e) = m_{t+\delta t} - m_t$$

$\div$ by δt

$$\frac{\delta m_i}{\delta t} - \frac{\delta m_e}{\delta t} = \frac{m_{t+\delta t} - m_t}{\delta t} = \frac{dm_{c.v.}}{dt}$$

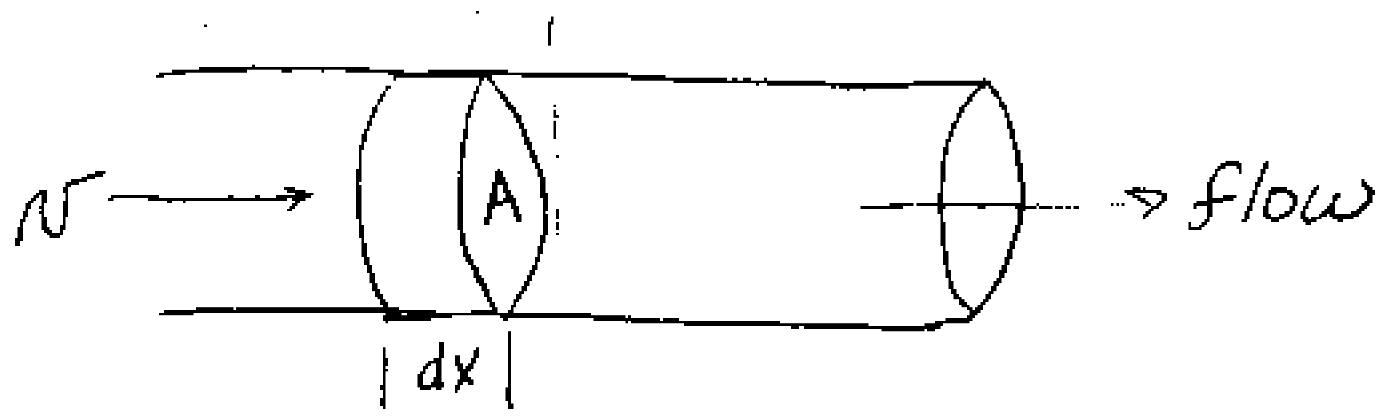
$$\frac{dm_{c.v.}}{dt} = \dot{m}_i - \dot{m}_e$$

where $\dot{m} = \frac{dm}{dt}$ mass flow rate $\frac{kg}{s}, \frac{lb}{s}$

or more generally

$$\boxed{\frac{dm_{c.v.}}{dt} = \Sigma \dot{m}_i - \Sigma \dot{m}_e = \dot{m}_{c.v.}}$$

Consider flow through a pipe



look @ a plug of fluid

$$\delta m = \frac{A\,dx}{v} \qquad \frac{A\,dx = V}{v} \qquad \frac{m^3}{\frac{m^3}{kg}} \rightarrow kg$$

If plug crosses plane A in time δt

$$\frac{\delta m}{\delta t} = \frac{A\frac{dx}{\delta t}}{v}$$

$$\boxed{\dot{m} = \frac{A v}{v}}$$

where
$\dot{m}$ mass flow rate
v velocity of the flow
A cross sectional area of the pipe (πr^2; $\pi \frac{d^2}{4}$)
v specific volume of the flowing substance

Also $m = \frac{V}{v}$

$$\frac{dm}{dt} = \frac{\frac{dV}{dt}}{v}$$

$$\dot{m} = \frac{\dot{V}}{v}$$

$\dot{V}$ volumetric flow rate $\frac{m^3}{s}$; $\frac{ft^3}{s}$

$$\boxed{\dot{V} = \dot{m} v}$$

comparing $\dot{m} = \frac{Av}{v}$ & $\dot{m} = \frac{\dot{V}}{v}$ $\Longrightarrow$ $\boxed{\dot{V} = Av \text{ or } \frac{\dot{V}}{A} = v}$

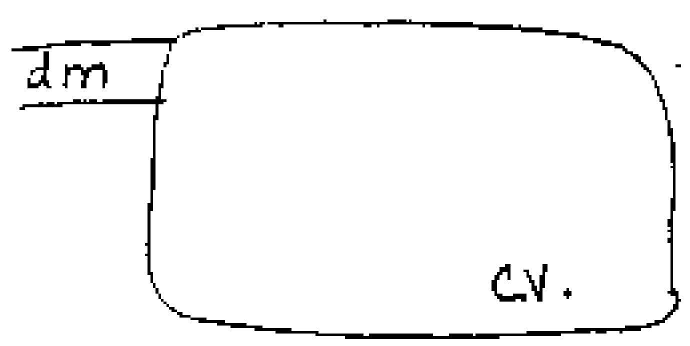
Steady State Steady Flow (SSSF)

No accumulation $\Longrightarrow \dot{m}_{c.v.} = 0$

$$\Sigma \dot{m}_i - \Sigma \dot{m}_e = 0 \Longrightarrow \Sigma \dot{m}_i = \Sigma \dot{m}_e$$

$\frac{dE_{cv}}{dt} = 0$ there is no change in the energy of the control volume with time
(but the may be a change in energy for the fluids)

Energy associated with a flowing fluid



$W_{fw} \equiv$ the flow work

– work required to move the fluid across the control boundary of the control volume

$$\delta W_{fw} = -p\,dV$$
$$= -p v\,dm$$

–ve because work is done ON system

$dV = m\,dv + v\,dm$

and assuming $dv = 0$

wrt t $\boxed{\dot{W}_{fw} = -p v \dot{m}}$

$$\dot{W}_{fw_i} = -p v \dot{m}_i$$

$$\dot{W}_{fw_e} = +p v \dot{m}_e$$

+ve because work is being done BY system to push fluid out

$$\boxed{\dot{W}_{fw} = \sum_e p v \dot{m}_e - \sum p v \dot{m}_i}$$

just the sum of all of the flow works.

for 1 inlet, 1 outlet, this reduces to

$$\dot{W}_{fw} = p_e v_e \dot{m}_e - p_i v_i \dot{m}_i$$

and for SSSF $\dot{m}_i = \dot{m}_e = \dot{m}$

$$\boxed{\frac{\dot{W}_{fw}}{\dot{m}} = p_e v_e - p_i v_i = w}$$

w specific work $= \frac{W}{m} = \frac{\dot{W}}{\dot{m}}$