Thermodynamics Lecture Series

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Combustion

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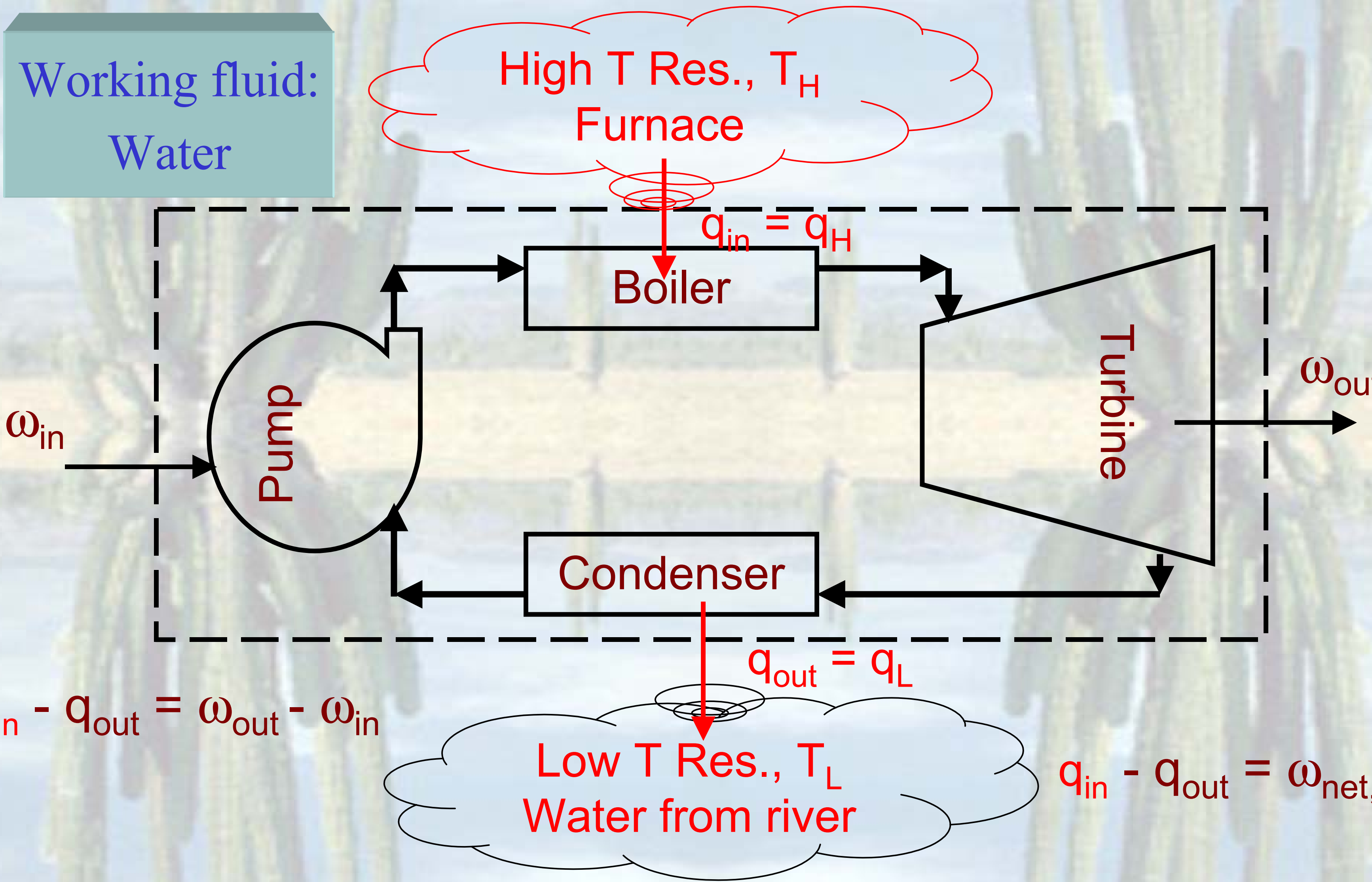
Review – Steam Power Plant

Working fluid: Water



$q_{in} - q_{out} = \omega_{out} - \omega_{in}$

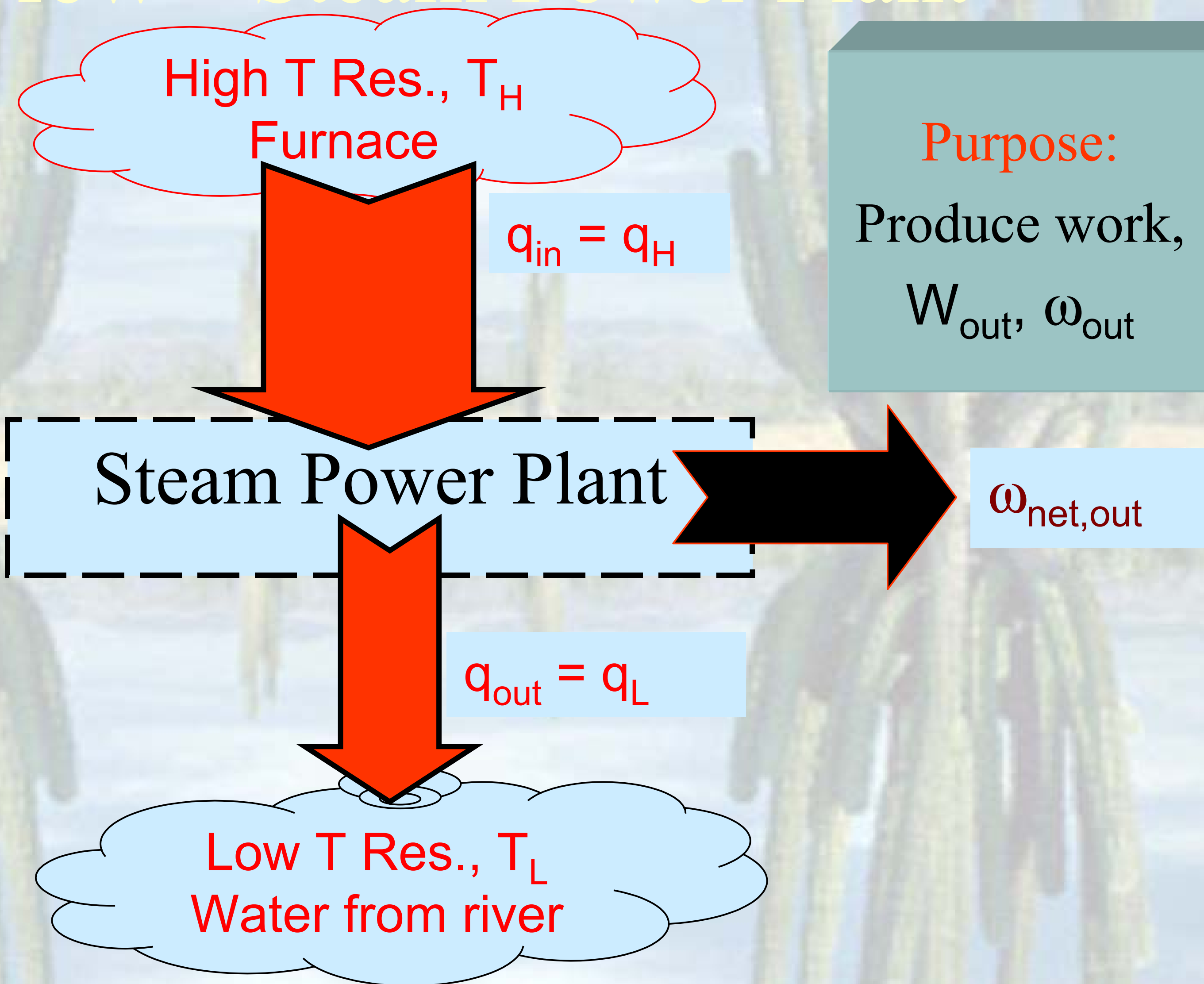
$q_{in} - q_{out} = \omega_{net,out}$

A Schematic diagram for a Steam Power Plant

Review - Steam Power Plant

Working fluid:
Water

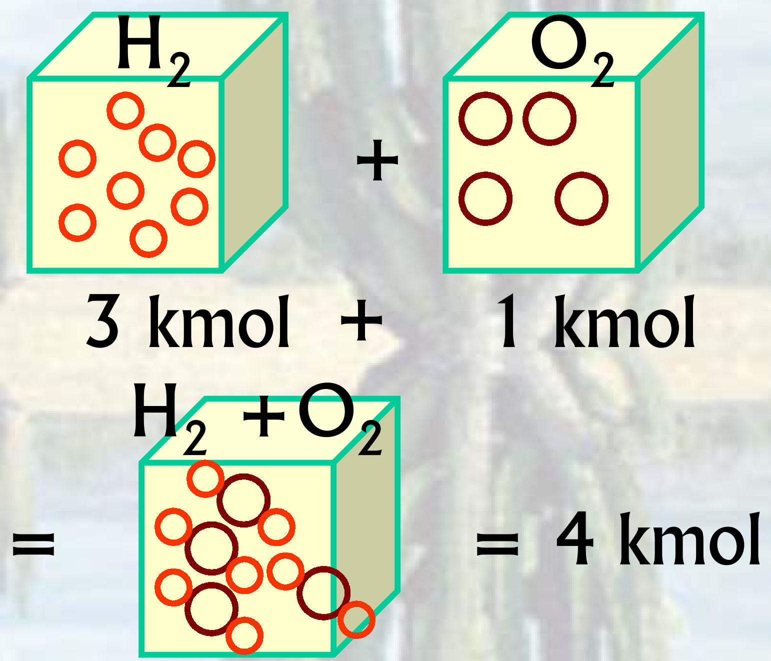
Purpose:
Produce work, W_{out}, ω_{out}



An Energy-Flow diagram for a SPP

Gas Mixtures – Composition by Moles

Composition Summary



Gravimetric Analysis

$$m_1 + m_2 = m_{mix}$$

$$mf_1 + mf_2 = 1 \text{ or } 100\%$$

where $$mf_i = \frac{m_i}{m_{mix}}$$

Volumetric Analysis

$$N_1 + N_2 = N_{mix}$$

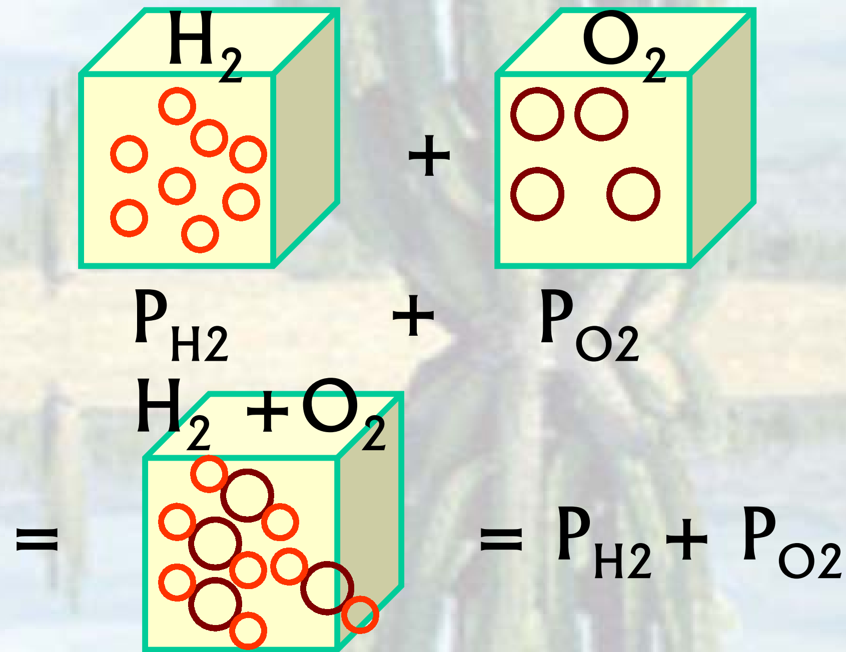
$$y_1 + y_2 = 1 \text{ or } 100\%$$

where $$y_i = \frac{N_i}{N_{mix}}$$

Gas Mixtures – Additive Pressure

Dalton's Law

- The total pressure exerted in a container at volume V and absolute temperature T, is the sum of component pressure exerted by each gas in that container at V, T.



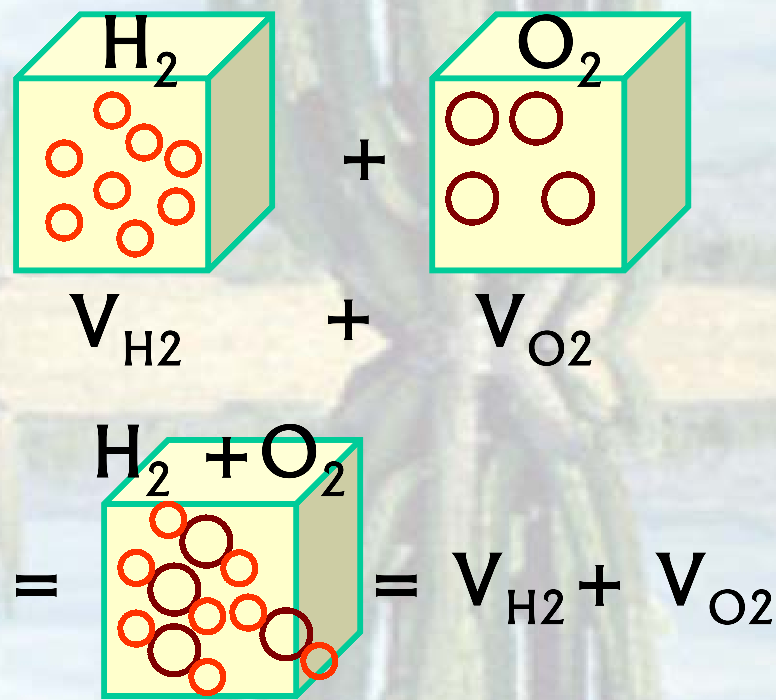
$$P_{mix} = P_1 + P_2$$

$$P_{mix} = \sum_{i=1}^{k} P_i\,(V_{mix}, T_{mix});$$ k is total number of components

Gas Mixtures – Additive Volume

Amagat's Law

- The total volume occupied in a container at pressure P_{mix} and absolute temperature T_{mix}, is the sum of component volumes occupied by each gas in that container at P_{mix}, T_{mix}.



$$V_{mix} = V_1 + V_2$$

$$V_{mix} = \sum_{i=1}^{k} V_i\ (P_{mix}, T_{mix});$$ k is total number of components

Gas Mixtures –Pressure Fraction

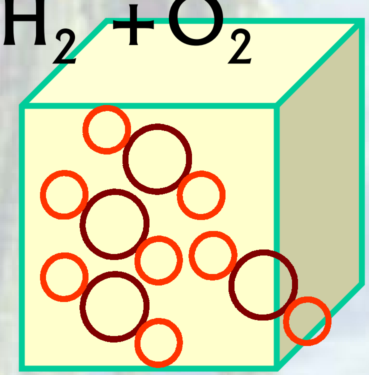
Partial Pressure

Since $P_{mix} V_{mix} = N_{mix} R_U T_{mix}$; $P_1 V_{mix} = N_1 R_U T_{mix}$

- The pressure fraction for each gas inside the container is

$$\frac{P_1}{P_{mix}} = \frac{N_1 R_u \frac{T}{V}}{N_{mix} R_u \frac{T}{V}} = \frac{N_1}{N_{mix}} = y_1$$

$H_2 + O_2$



Hence the partial pressure is $P_1 = y_1 P_{mix}$

In general, $P_i = y_i P_{mix}$

Gas Mixtures –Volume Fraction

Partial Volume

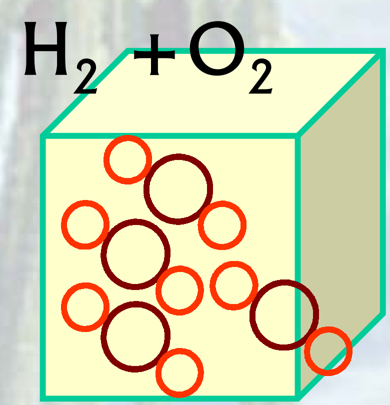
Since $P_{mix} V_{mix} = N_{mix} R_U T_{mix}$; $P_{mix} V_1 = N_1 R_U T_{mix}$

- The volume fraction for each gas inside the container is

$$\frac{V_1}{V_{mix}} = \frac{N_1 R_u \frac{T}{P}}{N_{mix} R_u \frac{T}{P}} = \frac{N_1}{N_{mix}} = y_1$$

Hence the partial volume is $V_1 = y_1 V_{mix}$

In general, $V_i = y_i V_{mix}$



Gas Mixtures –Combustion

Converting gravimetric to volumetric

Mixture by weight is: 13.3% CO_2; 0.95% CO; 8.35% O_2; 77.4% N_2. Let the mixture mass be 1 kg.

Constituent	% By weight	Mass fraction $mf_i = m_i/m_{mix}$	Mass, kg $m_i = mf*m_{mix}$	Molar mass M_i, kg/kmol
CO_2	13.3	0.1330	0.13	44
CO	0.95	0.0095	0.01	28
O_2	8.35	0.0835	0.08	32
N_2	77.4	0.7740	0.77	28
Total	100.00	1.0000	1.00	-

Gas Mixtures –Combustion

Converting gravimetric to volumetric

Mixture by weight is: 13.3% CO_2; 0.95% CO; 8.35% O_2; 77.4% N_2. Let the mixture mass be 1 kg.

Constituent	# of kilomoles $N_i = m_i/M_i$	Mole fraction $y_i = N_i/N_{mix}$	% By volume
CO_2	0.0030	0.090	9.0
CO	0.0003	0.010	1.0
O_2	0.0026	0.078	7.8
N_2	0.0276	0.822	82.2
Total	0.0336	1.00	100.0

Gas Mixtures –Combustion

Converting volumetric to gravimetric

Mixture by volume is: 85% C; 7% H_2; 5% O_2; 3% S. Let the mixture volume be 1 kilomole.

Constituent	% By volume	Mole fraction $y_i = N_i/N_{mix}$	# of kilomoles $N_i = y_i{*}N_{mix}$
C	85	0.85	0.85
H_2	7	0.07	0.07
O_2	5	0.05	0.05
S	3	0.03	0.03
Total	100.0	1.00	1.00

Gas Mixtures –Combustion

Converting volumetric to gravimetric

Mixture by volume is: 85% C; 7% H_2; 5% O_2; 3% S. Let the mixture volume be 1 kilomole.

Constituent	Molar mass M_i, kg/kmol	Mass, kg $m_i = N_i*M_i$	Mass fraction $mf_i = m_i/m_{mix}$	% By weight
C	12	10.20	0.7907	79.1
H_2	2	0.14	0.0109	1.09
O_2	32	1.60	0.1240	12.40
S	32	0.96	0.0744	7.44
Total	-	12.90	1.0000	100.00