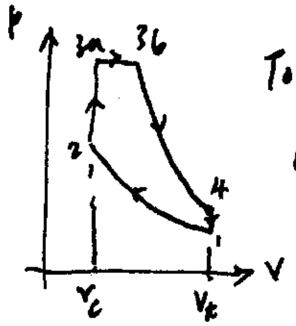
2.61S

Solution to H.W. #2

5-3



To maintain same peak pressure, less fuel must be burned with the turbo-charge operation.

The peak pressure p_3 is related to p_1 as follows:

$$\frac{p_3}{p_1} = \frac{p_3}{p_2}\frac{p_2}{p_1} = \underbrace{\left(\frac{T_{3a}}{T_2}\right)}_{\text{const. vol } 2\to 3a} \underbrace{\left(r_c^{\gamma}\right)}_{\text{isentropic } 1\to 2}$$

Process $2\to 3a$: $\quad m c_v (T_{3a} - T_2) = \frac{m_f}{2} Q_{HV}$ (The factor of ½ is because ½ of the fuel is burned in $2\to 3a$)

Therefore

$$\frac{T_{3a}}{T_2} = 1 + \left(\frac{m_f}{m}\right)\frac{Q_{HV}}{2}\frac{1}{c_v T_1}\frac{T_1}{T_2} \; ; \; \left\{ \begin{array}{l} \frac{m_f}{m} = \frac{m_f}{m_f + m_a} = \frac{1}{1 + A/F} = \frac{1}{1+[(F/A)_s \phi]^{-1}} \\ T_1/T_2 = 1/r_c^{\gamma-1} \end{array}\right.$$

Stoichiometric

$$= \left(1 + \frac{1}{1+[(F/A)_s\phi]^{-1}}\frac{1}{2}\frac{Q_{HV}}{c_v T_1}\frac{1}{r_c^{\gamma-1}}\right)$$

$$\therefore \; p_3 = p_1 \left\{ 1 + \frac{1}{1+[(F/A)_s\phi]^{-1}}\frac{1}{2}\frac{Q_{HV}}{c_v T_1}\frac{1}{r_c^{\gamma-1}} \right\} r_c^{\gamma}$$

(a) Initial configuration $\quad p_1 = 1$ bar, $\phi_{max} = 0.75$

(b) Turbo-charged configuration $\quad p_1 = 1.6$ bar $\quad \phi_{max} = ?$ if $\underbrace{p_3(b)/p_3(a) = 1}_{\text{no change in } p_3}$

$$1 = \frac{p_3^{(b)}}{p_3^{(a)}} = \frac{p_1^{(b)}\{\quad\}_b}{p_1^{(a)}\{\quad\}_a}$$

numerical value

$$\left[1 + \frac{1}{1+(0.0666\times .75)^{-1}}\frac{1}{2}\frac{42.5\times10^6}{900\times 325}\frac{1}{16^{0.35}}\right] = 2.31$$

Therefore $\quad \{\quad\}_b = \frac{p_1^{(a)}}{p_1^{(b)}}\{\quad\}_a = \left(\frac{1}{1.6}\right)\times 2.31 = 1.44$

or

$$1.44 = \left\{1 + \frac{1}{1+(0.0666\,\phi)^{-1}}\frac{1}{2}\frac{42.5\times10^6}{900\times 325}\frac{1}{16^{.35}}\right\}$$

Solving for ϕ: $\quad \phi = \underline{\underline{0.24}}$

The max indicated mep ratio would be (since m_a are the same)

$$\frac{(imep)_b}{(imep)_a} = \frac{(m_f Q_{HV})_b}{(m_f Q_{HV})_a} = \frac{\left[\left(\frac{m_f}{m_a}\right)_s \phi\, m_a\right]_b}{\left[\left(\frac{m_f}{m_a}\right)_s \phi\, m_a\right]_a} = \frac{\phi_b\, p_{1(b)}}{\phi_a\, p_{1(a)}} = \frac{0.24\times 1.6}{0.75\times 1}$$

The mep of the turbo charged engine is in fact lower! $\quad = \underline{\underline{0.51}}$

(Usually the compression ratio is reduced in normal turbo-charge design.)

2.615

Solution to H.W. # 2

3.1) $\underbrace{C_8H_{18}}_{114\,gm} + \underbrace{12.5\,(O_2 + 3.773N_2)}_{12.5\times 4.773\times 28.96\ gm\ =\ 1727.83\ gm} \rightarrow 8CO_2 + 9H_2O + 12.5\times 3.773N_2$

Air flow rate: $2\times\frac{1727.83}{114} = \underline{30.31\ g/s}$; Power out $= 2\times10^{-3}\times 44\times10^{6}\times 0.3 = \underline{\underline{26.4\ kW}}$ ← typical cruise power

Assume 4 stroke engine, 1 firing cycle per cylinder per two Revolutions, 4 cylinders

$m_f = \left[\frac{2}{4}\ \frac{1}{\frac{1500}{2}\times\frac{1}{60}}\right] = \underline{\underline{4\times10^{-2}\,g}}$ (A very small amount!)

$m_a = 4\times10^{-2}\times\left(\frac{30.31}{2}\right) = \underline{\underline{0.61\,g}}$

$\eta_v = \frac{m_a}{\rho_{ao}V_D}$; $\rho_{ao} = 1.18\times10^{-3}\ g/cc\ @\ 25°c \Rightarrow \eta_v = \frac{0.61}{1.18\times10^{-3}\times\frac{2400}{4}} = \underline{\underline{0.86}}$

3.3) Propane fueled engine: $\phi(C_3H_8) + 5(O_2 + 3.773N_2)$

$\longrightarrow 3\phi\,CO_2 + 4\phi H_2O + (5 - 3\phi - 2\phi)O_2 + 5\times3.773N_2$

$\frac{N_{CO_2}}{N_{O_2}} = \frac{10.8}{4.5} = \frac{3\phi}{5(1-\phi)} \Rightarrow \phi = \underline{\underline{0.80}}$

3.13) Fuel Lean: no CO or H_2 $\quad \phi C_8H_{18} + 12.5(O_2 + 3.773N_2) \rightarrow 9\phi H_2O + 8\phi CO_2$
$+ 12.5(1-\phi)O_2 + 12.5\times3.773N_2$

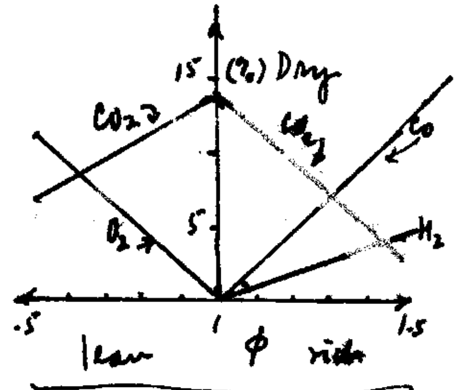
Fuel Rich: $CO : H_2 = 3:1$; let $N_{H_2} = a$, then

$\phi C_8H_{18} + 12.5\,(O_2 + 3.773N_2) \rightarrow (9\phi - a)H_2O + (8\phi - 3a)CO_2 + 3a\,CO + aH_2 + (12.5\times3.773)N_2$

oxygen balance → $a = N_{H_2}$ such that $(9\phi - a) + 2\times(8\phi - 3a) + 3a = 25$

Thus $a = -\frac{25}{4}(1-\phi)$

	ϕ	0.5	0.7	1	1.08	1.3	1.5
(mole per 59.66 mole of air)	N_{H_2}	0	0	0	0.50	1.88	3.13
	N_{CO}	0	0	0	1.50	5.63	9.38
	N_{CO_2}	4	5.6	8	7.14	4.775	2.625
	N_{O_2}	6.25	3.75	0	0	0	0
	N_{N_2}	←			47.16		→
dry	N_{total}	57.51	56.51	55.16	56.30	59.44	62.29
dry mole fraction	X_{H_2} (%)	0	0	0	0.89	3.15	5.02
	X_{CO} (%)	0	0	0	2.66	9.46	15.05
	X_{CO_2} (%)	6.97	9.91	14.5	12.68	8.03	4.21
	X_{O_2} (%)	10.9	6.64	0	0	0	0



14:1 air Fuel $\Rightarrow \phi = \frac{1/14}{1/(1727.83/114)} = 1.08$

$N_{H_2} = .5,\ N_{CO} = 1.5,\ N_{CO_2} = 7.14,\ N_{N_2} = 47.16$

Wet $\quad N_{H_2O} = (9\phi - a) = 9.22$; $N_{total} = 65.52$

$X_{H_2} = \underline{\underline{0.76\%}}$; $X_{CO} = \underline{\underline{2.3\%}}$; $X_{CO_2} = \underline{\underline{10.9\%}}$

$X_{N_2} = \underline{\underline{72\%}}$ $\quad X_{H_2O} = \underline{\underline{14.1\%}}$