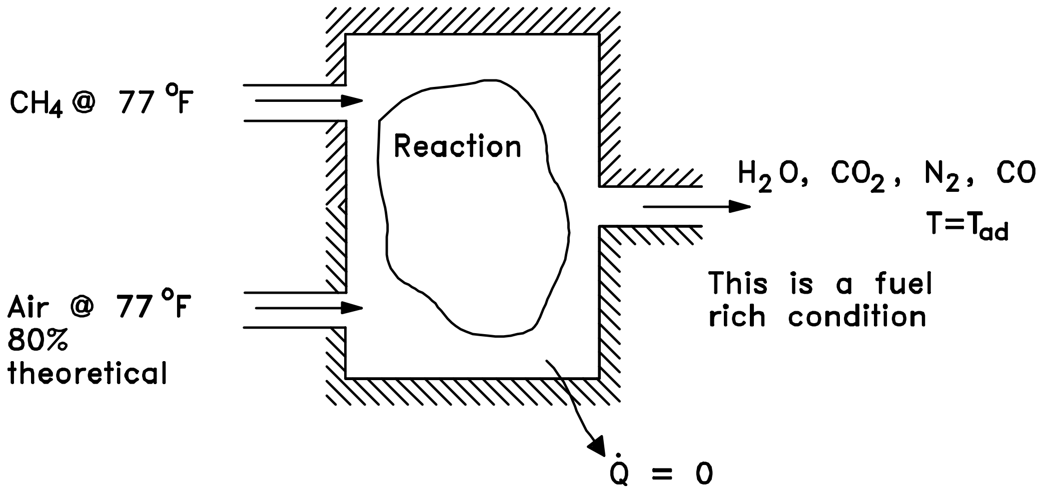
Problem: 11-35

Given: Methane (CH_4) at 77 $^\circ F$ reacts with 80% theoretical air at 77 $^\circ F$.

Find: Adiabatic flame temperature (T_{ad})



The assumption is made that the products are H_2O, CO_2, N_2 and CO.
First we must calculate the theoretical air in order to give meaning to the term 80% theoretical air.
Consider the global reaction:

$$CH_4 + 4.77Z \underbrace{\left[\frac{O_2 + 3.77N_2}{4.77}\right]}_{\text{represents 1 mole of air}} \to aCO_2 + bH_2O + cN_2$$

Solving for a, b, c, Z

$$\begin{aligned} C &: \; 1 = a \\ H &: \; 4 = 2b \to b = 2 \\ O &: \; 2Z = 2a + b \to z = 2 \\ N &: \; \cancel{2}(3.77Z) = \cancel{2} \to c = 7.54 \end{aligned}$$

Therefore for every 1 mole of CH_4 $(4.77)\times$ 2 moles of air are required for complete combustion.
If only 80% theoretical air is available this means that only $(.8)(4.77)\times$ 2 moles of air are available per mole of CH_4 present.

The equation now becomes:

$$CH_4 + (4.77)(2)(.8)\left[\frac{O_2 + 3.77N_2}{4.77}\right] \rightarrow aCO_2 + bH_2O + cN_2 + dCO$$

The presence of CO in the reactants indicates that not enough air is available for complete conversion to CO_2.
Solving for a, b, c, d

$$\begin{aligned}
C &: 1 = a + d \rightarrow a = .2 \\
H &: 4 = 2b \rightarrow b = 2 \\
O &: (2 \times .8) = a + \frac{1}{2}b + \frac{1}{2}d \rightarrow d = .8 \\
N &: (2 \times .8 \times 3.77) = c \rightarrow c = 6.032
\end{aligned}$$

Therefore the equation is:

$$CH_4 + 7.632\left[\frac{O_2 + 3.77N_2}{4.77}\right] \rightarrow 0.2CO_2 + 2H_2O + 6.032N_2 + 0.8CO$$

Calculating the enthalpy of the reactants ($T = 77\ {}^\circ F \approx 537\ R$).

$$\begin{aligned}
\sum_{reactants} n_i\tilde{h}_i &= n_{CH_4}\tilde{h}_{CH_4} + n_{O_2}\cancel{\tilde{h}_{O_2}}^{\,0} + n_{N_2}\cancel{\tilde{h}_{N_2}}^{\,0} \text{ (enthalpies found in Table B)} \\
&= (1)(-32179) = -32179\ Btu
\end{aligned}$$

Choosing T_{ad} the enthalpy of the products is calculated until

$$\sum_{products} n_i\tilde{h}_i = -32179\ Btu$$

Choosing $T_{ad} = 3500\ R$

$$\begin{aligned}
\sum_{products} n_i\tilde{h}_i &= (.2)(-1317.3) + (2)(-73912.8) + (6.032)(23286.4) + (.8)(-23984.7) \\
&= -52799\ Btu \rightarrow \text{not equal to} - 32179\ Btu
\end{aligned}$$

Choosing $T_{ad} = 3700\ R$

$$\begin{aligned}
\sum_{products} n_i\tilde{h}_i &= (.2)(-128351.9) + (2)(-71470.9) + (6.032)(25005.6) + (.8)(-22253.0) \\
&= -35579\ Btu
\end{aligned}$$

Extrapolating from the results for 3500 R and 3700 R gives

$$T_{ad} = \boxed{3739\ R}$$