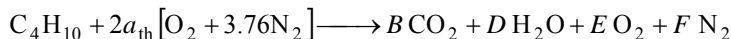


15-27 Butane C_4H_{10} is burned with 200 percent theoretical air. The kmol of water that needs to be sprayed into the combustion chamber per kmol of fuel is to be determined.

Assumptions 1 Combustion is complete. 2 The combustion products contain CO_2 , H_2O , O_2 , and N_2 only.

Properties The molar masses of C, H_2 , O_2 and air are 12 kg/kmol, 2 kg/kmol, 32 kg/kmol, and 29 kg/kmol, respectively (Table A-1).

Analysis The reaction equation for 200% theoretical air without the additional water is



where a_{th} is the stoichiometric coefficient for air. We have automatically accounted for the 100% excess air by using the factor $2a_{th}$ instead of a_{th} for air. The coefficient a_{th} and other coefficients are to be determined from the mass balances

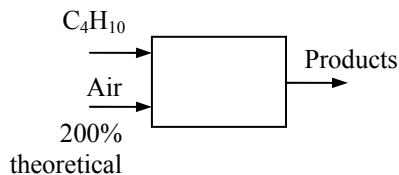
Carbon balance: $B = 4$

Hydrogen balance: $2D = 10 \longrightarrow D = 5$

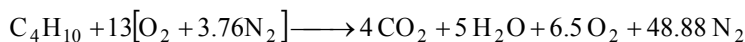
Oxygen balance: $2 \times 2a_{th} = 2B + D + 2E$

$$a_{th} = E$$

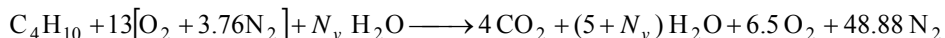
Nitrogen balance: $2a_{th} \times 3.76 = F$



Solving the above equations, we find the coefficients ($E = 6.5$, $F = 48.88$, and $a_{th} = 6.5$) and write the balanced reaction equation as



With the additional water sprayed into the combustion chamber, the balanced reaction equation is



The partial pressure of water in the saturated product mixture at the dew point is

$$P_{v,prod} = P_{sat@60^\circ C} = 19.95 \text{ kPa}$$

The vapor mole fraction is

$$y_v = \frac{P_{v,prod}}{P_{prod}} = \frac{19.95 \text{ kPa}}{100 \text{ kPa}} = 0.1995$$

The amount of water that needs to be sprayed into the combustion chamber can be determined from

$$y_v = \frac{N_{water}}{N_{total,product}} \longrightarrow 0.1995 = \frac{5 + N_v}{4 + 5 + N_v + 6.5 + 48.88} \longrightarrow N_v = \mathbf{9.796 \text{ kmol}}$$