46.16 Methane is burned with 20% excess air. What is the air-to-fuel ratio?

A. $14\frac{lb}{lb}$

B. $17\frac{lb}{lb}$

C. $21\frac{lb}{lb}$

D. $24\frac{lb}{lb}$

Look up the table Combustion Reactions of Common Fuel Constituents and find the combustion reaction for methane burned stoichiometrically in air. Include 3.76 nitrogen molecules for every 1 oxygen molecule since nitrogen has been omitted in the table. Nitrogen does not participate in the reaction; however, it does contribute mass to the air and thus impacts the air-to-fuel ratio.

$$CH_4 + 2O_2 + 2\,(3.76)\,N_2 \rightarrow CO_2 + 2H_2O + 2\,(3.76)\,N_2$$

Add 20% excess air. Air-to-fuel ratio applies only to the reactants, so it is not necessary to balance the reaction and write out the product side.

$$CH_4 + 1.2\,[2O_2 + 2\,(3.76)\,N_2] \rightarrow products$$

$$CH_4 + (2.4)\,O_2 + (9.02)\,N_2 \rightarrow products$$

Calculate the air-to-fuel ratio by multiplying the number of moles of each constituent times the atomic weight and dividing the air mass by the fuel mass. Use the Periodic Table to look up atomic weights as needed.

$$\frac{m_{air}}{m_{fuel}} = \frac{n_{O_2}M_{O_2} + n_{N_2}M_{N_2}}{n_{CH_4}M_{CH_4}} = \frac{(2.4)\,(32) + (9.02)\,(28)}{(1)\,(16)} = 20.6\frac{lb}{lb}$$

Alternatively, in the Combustion Reactions table, notice the heading for Stoichiometric Oxygen and Air Requirements. The amount of air required to burn methane stoichiometrically is given as $17.24\frac{lb}{lb}$. Increase this value by 20% to account for excess air.

$$(1.2)\left(17.24\frac{lb}{lb}\right) = 20.7\frac{lb}{lb}$$

Answer C

46.17 A refrigeration cycle using R-134a has a refrigeration effect of $8000\frac{Btu}{hr}$ and a coefficient of performance of 11. What is the power required to run the compressor?

A. $210W$

B. $730W$

C. $28KW$

D. $90KW$

Use the definition of Coefficient of Performance for Refrigerators and Air Conditioners. Solve for the work of the compressor. Convert units to Watts.

$$COP = \frac{Q_L}{W}$$

$$W = \frac{Q_L}{COP} = \frac{8000\frac{Btu}{hr}}{11}\left(\frac{1W}{3.412\frac{Btu}{hr}}\right) = 213W$$

Answer A

46.18 $100,000\frac{lb_m}{hr}$ of steam at $5psig$ with quality $\chi = 0.9$ flows through a pipe with an inside diameter of $20in$. What is the velocity?

A. $230\frac{ft}{s}$

B. $255\frac{ft}{s}$

C. $850\frac{ft}{s}$

D. $940\frac{ft}{s}$

Since the steam is a saturated mixture, use the quality to determine the specific volume at $5psig$. Use the steam table by searching Properties of Saturated Water and Steam by pressure. $5psig \approx 20psia$. Collect the values for specific volume of a liquid, v_f, and specific volume change during phase change, v_{fg}.

$$v_f = 0.0168\frac{ft^3}{lb}$$

$$v_{fg} = 20.09\frac{ft^3}{lb}$$

Use the equation for specific volume of a two-phase system.

$$v = v_f + \chi v_{fg} = 0.0168\frac{ft^3}{lb} + (0.9)\left(20.09\frac{ft^3}{lb}\right) = 18.1\frac{ft^3}{lb}$$

Next find the area of a pipe with an inside diameter of $20in$ in ft^2.