2.37.1 Example: Suppose that the first stage of a binary cycle power plant has an efficiency of 35%. What is the maximum possible overall efficiency if the second stage operates at a temperature of 227°C = 500K and expels heat to the environment at 27°C = 300K ?

Solution

$$e_{cc} = \frac{Work}{Heat_{in}} = \frac{e_1 Q + e_2(1-e_1) Q}{Q} = e_1 + e_2 - e_1 . e_2$$

The maximum efficiency for the second stage is found from the Carnot efficiency, which gives

$$e_2 = 1 - \left(\frac{300}{500}\right) = 0.4$$

Thus, using equation for the overall efficiency, we find:

$$e_{cc} = e_1 + e_2 - e_1 . e_2 = 0.35 + 0.40 - (0.35).(0.4)$$

$$= 0.61$$

$$= \%61$$

lowest value, and average value of the energy content of anthracite assuming that no elements besides C, H, O and S are present.

Solution

✓

Based on the values of constants in equation, the maximum energy density requires H to be as high as possible and O is as low as possible, and the minimum energy requires the opposite.

$$E_{max} = 337(95.25) + 1442(3.75 - 0/8) + 93(1) = 36700k\,J/kg$$

$$= 15,800\ Btu/lb,$$

$$E_{min} = 337(96.5) + 1442(0 - 2.5/8) + 93(1) = 32,200\ kJ/kg$$

$$= 13,800\ Btu/lb$$

2.2.5.1 Example: Given that coal ignites at around 450°C, how does the % 33 efficiency of coal-fired power plant compare with the highest possible efficiency dictated by the Carnot limit?

$$e_c = 1 - \frac{T_a}{T_c}$$

Solution

$T_c = 450°C = 723K$ and $T_a \approx 300\ K$, we find ;

$$e_c = 1 - \left(\frac{300}{723}\right) = 0.59$$

almost twice as great as the average coal plant efficiency.

10.)

Calculate the overall efficiency of a three stage combined cycle gas-fired power plant, with respect to efficiencies of each stage.

Solution

$Q_0 \longrightarrow$ [e_1] $\longrightarrow W_1 = e_1 . Q_0$

$\downarrow$

$Q_1 = Q_0 . (1 - e_1)$

$\downarrow$

[e_2] $\longrightarrow W_2 = Q_1 . e_2$

$\downarrow$

$Q_2 = (1 - e_2) . Q_0 . (1 - e_1)$

$\downarrow$

[e_3] $\longrightarrow W_3 = (1 - e_2) Q_0 (1 - e_1) . e_3$

$\downarrow$

Q_3

$$e_{system} = \frac{W_1 + W_2 + W_3}{Q_0}$$

$$e_{system} = \frac{e_1 . \cancel{Q_0} + \cancel{Q_0} . (1 - e_1) . e_2 + (1 - e_2) . \cancel{Q_0} . (1 - e_1) . e_3}{\cancel{Q_0}}$$

$$e_{system} = e_1 + (1 - e_1) . e_2 + (1 - e_2)(1 - e_1) . e_3$$

$$= e_1 + e_2 + e_3 - e_1 . e_2 - e_1 . e_3 - e_2 . e_3 + e_1 . e_2 . e_3$$

6. In section 2.2.8, It is noted that since the industrial revolution, the average oceanic pH has decreased from 8.25 to 8.14. Show that this corresponds to an increase in oceanic acidity of nearly % 30. Note that based on its definition, the pH is 7.0 for neutral distilled water and that the percentage increases in acidity are relative to this neutral point.

Solution

$pH = -\log_{10} H^+$ $\qquad H^+ = 10^{-pH}$

$pH = 8.25 \rightarrow 10^{-8.25} = 5.62 \times 10^{-9}$

(Hydrogen ion concentration)

$pH = 8.14 \rightarrow 10^{-8.14} = 7.24 \times 10^{-9}$

$pH = 8.25 \rightarrow H^+ = 5.62 \times 10^{-9}$

$pH = 8.14 \rightarrow H^+ = 7.24 \times 10^{-9}$

$$\frac{7.24 \times 10^{-9}}{5.62 \times 10^{-9}} = 1.28 \rightarrow \% 30$$

- Show that the green effect caused by combusitron of methane is indeed 115×10^4 pounds of CO_2 for every BTU of burned fuel.

(Methane = $2{,}4 \times 10^4$ BTU/lb)

Solutron

There is one carbon atom in one molecule of methane. When methane burns, one carbon dioxide molecule is produced for every carbon atom in methane.

$$\frac{1 \text{ atom C}}{1 \text{ molecule } CH_4} = \frac{1 \text{ mol C}}{1 \text{ mol } CH_4} = \frac{12 \text{ lb C}}{16 \text{ lb } CH_4}$$

$$= \left(\frac{12 \text{ lb C}}{16 \text{ lb } CH_4}\right) \cdot \left(\frac{44 \text{ lb } CO_2}{12 \text{ lb C}}\right) \left(\frac{1 \text{ lb } CH_4}{2{,}4 \times 10^4 \text{ BTU}}\right)$$

$$= 115 \cdot \frac{\text{lb } CO_2}{10^6 \text{ BTU}}$$

2.2.2 Example: An emprically determined formula for the energy content of coal based on the elemental abudances of carbon, hydrogen, oxygen and sulfur is

$$E = 337C + 1442(H - O/8) + 93S,$$

where E is units of kilojoules per kilogram, and the symbols stand for the mass percentage of elements C, H, O and S. Use equation and the information provided earlier about anthracite.
$H = 0-3{,}75\%$, $O = 0, 2.5\%$ and S 1%, to estimate the highest value,