**ENE-47.132 Combustion and gasification technology** **Exam**
**Poltto- ja kaasutustekniikka** **Tentti**
**Förbränings- och förgasningsteknik** **Tent**

**21.12.2006**

**Please write on every page you hand in :**
* ENE-47.132 Exam 12.12.2006
* Your name, department, student number

The time for this exam is 3 hours. Only books with tabelised data may be consulted.

The total amount of points to be scored is 50. The result will then be : 21.....26.5 points = 1 27.....32.5 points = 2 33.....38.5 points = 3 39.....44.5 points = 4 45.....50 points = 5.

6 questions. Points: 15 + 5 +10 + 6 + 9 + 5 = 50p.

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1. a. What is the difference between the pyrolysis and the gasification of a solid fuel? (3 p.)

   b. What is the difference between the lower heating value (LHV) and the higher heating value (HHV) of a fuel? (3p).

   c. What is a low - NOx burner, how does it work? (3 p.)

   d. Define the burning velocity? and what are the factors that effect on it? (3 p.)

   e. What is flame flash back and how can be avoided? (3 p)

2. A cokes is burned in an atmospheric fluidized bed combustor. The cokes is fed at a rate of 12000 kg/h and the combustion time for a cokes particle is 180 seconds on average. The square cross section of the bed is 15 m x 15 m = 225 $m^2$, the bed material is sand with a particle density of 2200 $kg/m^3$, the voidage (porosity) of the bed is 0.5, and the height of the bed is 0.9 m. Gas density is 0.5 $kg/m^3$, and the fluidization velocity is 1.3 m/s.

   a. Give the pressure drop across the bed, in Pa (1 p.)

   b. What is the approximate amount of cokes in the bed, in %-wt ? (4 p.)

3. A gas mixture contains 70% $CH_4$ and 30% $H_2$. It is burned in a furnace at stoichiometry $\lambda$=1.5 with dry air.

   a. Calculate the composition of the flue gas (%-vol) and the air input (kg air/kg fuel) (1p.+3p.)

Measurement shows also 600 ppm-vol NO in the flue gas.

b. Calculate how many % of the $N_2$ from the air has been converted to NO (2 p).

c. Calculate the amount of $CO_2$ emitted per energy input (kg $CO_2$/MJ, based on LHV) and compare it with the case when $CH_4$ is burnt, at $\lambda$=1.5 with dry air (2+2 p.)

4. A wood stove, which has a heat output of 21000 kJ/hr and an efficiency of 85%, is found to emit 9 g/hr of particulates. How does this emission rate (g/hr) compare with furnace running on (a) natural gas, which has an emission factor 80 kg/$10^6$ $m^3$ (the HHV for natural gas is 39080 kJ/$m^3$ (b) fuel oil, which has an emission factor 1 kg/$m^3$ (Fuel oil HHV is $3.9\times10^7$ kJ/ $m^3$ ? (6 p)

5. A coal is fired with air in pulverized coal furnace, which has the following composition:

| | |
|---|---|
| Volatile matter | 40%-wt |
| Ash | 8%-wt |
| Moisture | 3%-wt |
| Fixed carbon | 49%-wt (by difference) |

The devolatilization of this coal is described by the 2 – parallel – reactions mechanism suggested by Kobayashi *et al.* (1977) for dry, ash-free coal:

*Coal* $\xrightarrow{k1}$ *0.3 Volatiles + 0.7 Char, kg*
*Coal* $\xrightarrow{k2}$ *1.0 Volatiles, kg*

with the rates k1 and k2 as a function of temperature (K) given by

$k1 = 2.0\times10^5 exp(-105000/RT),\ s^{-1}$
$k2 = 1.3\times10^7 exp(-167000/RT),\ s^{-1}$

The coal particle size is 200 μm. Pressure is 1 bar.

a. Give the composition of the coal as 1) dry and 2) dry, ash free? (3 p)

b. What will be the weight loss of 1) the dry, ash free coal particles and 2) total coal particles (in %) due to devolatilization at 1300°C, after 0.05 s? (6 p)

6. a. What are the two tasks of a black liquor recovery boiler (3 p.)

b. What is being recovered in a black liquor recovery boiler? (2 p.)

**DATA for all questions** :

ideal gas law: $pV = nRT$ p=pressure (Pa), V=volume ($m^3$), n=amount (mol), R=8.314 (J / (mol K)), T= temperature (K)

molar masses: $H_2$ : 2 g $N_2$ : 28 g $O_2$ : 32 g
C : 12 g

air: 21 %-vol $O_2$ + 79 %-vol $N_2$

STP: 1 bar, 273.15 K

equilibrium constants and Gibbs' energy of reaction : $-\Delta G = RT \ln K_p$

Heating values (LHV) $CH_4$: 802 kJ/mol
$H_2$: 242 kJ/mol

heat of vaporisation of water: 44 kJ/mol

pressure drop, $\Delta p$, across a fluidised bed : $\Delta p = (1-\varepsilon)\, \rho_p\, g\, H$

where g = gravity = 9.81 ($m/s^2$)
H = bed height (m)
$\rho_p$ = particle density ($kg/m^3$)
$\varepsilon$ = bed porosity, voidage (-)

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**Have a nice Christmas and a Happy New Year (2007).**
**Don't forget to return the course book as soon as possible, and in any case <u>before</u> April 2007 !!!**