# Prince of Songkla University
# Faculty of Engineering

**Midterm Examination** **Semester 2/2552**

**27 December 2011** **Time 09:00-12:00**

**215-665 ENERGY FROM BIOMASS AND CONVERSION** **Room:**

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**Directions**

- Closed book examination
- All types of calculator are permitted.
- Attempt all 5 questions.
- The exam paper has 11 pages.

**Juntakan Taweekun**
**Instructor**

| Problem | Marks | Your Marks |
|---|---|---|
| 1 | 12 | |
| 2 | 20 | |
| 3 | 20 | |
| 4 | 15 | |
| 5 | 20 | |
| Total | 87 | |

Name _____

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Name _____ ID _____

**Question 1 (12 points)**

Explain the meaning of the following words

1.1 Fixed Carbon

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1.2 Volatile Matter

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1.3 Biogas

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1.4 Ultimate Analysis

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1.5 Bulk Density

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1.6 Gasification

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.....

Name _____ ID _____

**Question 2 (20 points)**

The capacity of Boiler is 30 Tons/h. Calculate the energy in and energy out for this boiler (in unit of MJ/h). Also calculate the efficiency of boiler, draw the energy balance and sankey diagram. The followings are the parameters using for calculation.

Fuel

- Fiber fed to boiler is 6,000 kg/h.
- Low Heating Value of fiber (Fuel) 11,000 kJ/kg

Air

- The ambient temperature is 30 °C.
- Specific capacity of air 1.1 kJ/kg.°C
- Air flow rate for combustion 13,000 $m^3$/h
- Air density 1.2 kg/$m^3$

Reference Air Temperature

- Reference air temperature is 25 °C.

Water to Boiler

- Temperature of raw water 29 °C.
- Temperature of feed water is 100 °C.
- Feed water to boiler is 19.2 $m^3$/h.

Steam

- Temperature and pressure of steam are 260 °C and 20 bar.
- Enthalpy of steam 2799.50 kJ/kg.
- surface temperature of boiler is 50 °C

Blow Down

The blow down temperature is 90 °C from field measurement and blow down 2 times per hour for 60 seconds per time. Table 1 shows the amount of blow down.

Table 1 Amount of Blow down

| Item | Blow down ($m^3$) | Time (s) |
|---|---|---|
| Manual Blow down | | |
| 1 | 0.3 | 60 |

Remark: 2 times per hour

Name _____ ID _____

Flue Gas

Use G = 7.44 $Nm^3/kg$

Table 2 Flue Gas Measurement

| Item | Measurement Data | Unit | Value |
|---|---|---|---|
| 1 | Flue gas Temp | °C | 280.1 |
| 2 | Excess air | % | 145.3 |
| 3 | $O_2$ – Content | % | 12 |
| 4 | $CO_2$ – Content | % | 8.3 |
| 5 | CO – Content | Ppm | 156 |
| 6 | Eff.Gross | % | 85.1 |
| 7 | Eff.Net | % | 90.6 |
| 8 | Amb.Air.Temp | °C | 36.5 |
| 9 | Flue.Draught | Mbar | -0.78 |

Table 3 Amount of Ash

| Item | Ash (kg/time) | Time (h/time) | Ash (kg/h) | Remarks |
|---|---|---|---|---|
| Fly Ash | | | | |
| 1 | 300 | 4 | 75 | |
| Bottom Ash | | | | |
| 1 | 300 | 6 | 50 | Above grate |
| 2 | 450 | 240 | 2 | Under grate |
| Total Ash | | | 127 | |

Name _____ ID _____

Name _____ ID _____

**Question 3 (20 points)**

The followings are details for floating drum design:

| Item | Details | Values |
|---|---|---|
| 1 | Amount of manure | 2,900 kg/day |
| 2 | Ratio of amount of manure and digester volume | 5.7 kg/0.075 $m^3$ |
| 3 | Retention period | 60 day |
| 4 | Cylindrical Shaped digester<br>- Thick<br>- Ratio of diameter and height | <br>0.15 m<br>1:1.25 |
| 5 | Amount of required biogas | 105 $m^3$/day |
| 6 | Coldest ambient temperature | 17 °C |
| 7 | Surrounding temperature of digester | 22 °C |
| 8 | Inside temperature of digester | 35 °C |
| 9 | Thermal conductivity of material for gas holder | 3 kJ/(hr.$m^2$.°C) |
| 10 | Thermal conductivity of material for digester (floor, area between digester and gas holder) | 2.5 kJ/(hr.$m^2$.°C) |

Calculate

3.1 Digester volume, diameter and height of digester.

3.2 Gas holder volume, diameter and height of gas holder.

3.3 Heat loss from digester and gas holder (in unit of kJ/day)

Name _____ ID _____

Name _____ ID _____

**Question 4 (15 points)**

There are different types of gasifiers. How many types of gasifier? Explain and draw each type in details. Also explain various zones in each type of gasifier.

Name _____ ID _____

**Question 5 (20 points)**

5.1 Explain the meaning of the following words

1. Low Heating Value (LHV)
2. High Heating Value (HHV)
3. Dry Heating Value

Which heating value is appropriate for the use in industrial sector? Why?

5.2 Explain the meaning of the following words. Also give the 4 examples and application of each item

1. Fossil fuels
2. Renewable energy

# TABLE A.1 Thermodynamic Properties of Steam

## TABLE A.1.1 Saturated Steam: Temperature Table

| Temp. Sat. °C | Press. Sat. kPa | Specific Volume $m^3/kg$ | | Internal Energy $kJ/kg$ | | | Enthalpy $kJ/kg$ | | | Entropy $kJ/kg\,K$ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Sat. Liquid $v_f$ | Sat. Vapor $v_g$ | Sat. Liquid $u_f$ | Evap. $u_{fg}$ | Sat. Vapor $u_g$ | Sat. Liquid $h_f$ | Evap. $h_{fg}$ | Sat. Vapor $h_g$ | Sat. Liquid $s_f$ | Evap. $s_{fg}$ | Sat. Vapor $s_g$ |
| 0.01 | 0.6113 | 0.001000 | 206.14 | .00 | 2375.3 | 2375.3 | .01 | 2501.3 | 2501.4 | .0000 | 9.1562 | 9.1562 |
| 5 | 0.8721 | 0.001000 | 147.12 | 20.97 | 2361.3 | 2382.3 | 20.98 | 2489.6 | 2510.6 | .0761 | 8.9496 | 9.0257 |
| 10 | 1.2276 | 0.001000 | 106.38 | 42.00 | 2347.2 | 2389.2 | 42.01 | 2477.7 | 2519.8 | .1510 | 8.7498 | 8.9008 |
| 15 | 1.7051 | 0.001001 | 77.93 | 62.99 | 2333.1 | 2396.1 | 62.99 | 2465.9 | 2528.9 | .2245 | 8.5569 | 8.7814 |
| 20 | 2.339 | 0.001002 | 57.79 | 83.95 | 2319.0 | 2402.9 | 83.96 | 2454.1 | 2538.1 | .2966 | 8.3706 | 8.6672 |
| 25 | 3.169 | 0.001003 | 43.36 | 104.88 | 2304.9 | 2409.8 | 104.89 | 2442.3 | 2547.2 | .3674 | 8.1905 | 8.5580 |
| 30 | 4.246 | 0.001004 | 32.89 | 125.78 | 2290.8 | 2416.6 | 125.79 | 2430.5 | 2556.3 | .4369 | 8.0164 | 8.4533 |
| 35 | 5.628 | 0.001006 | 25.22 | 146.67 | 2276.7 | 2423.4 | 146.68 | 2418.6 | 2565.3 | .5053 | 7.8478 | 8.3531 |
| 40 | 7.384 | 0.001008 | 19.52 | 167.56 | 2262.6 | 2430.1 | 167.57 | 2406.7 | 2574.3 | .5725 | 7.6845 | 8.2570 |
| 45 | 9.593 | 0.001010 | 15.26 | 188.44 | 2248.4 | 2436.8 | 188.45 | 2394.8 | 2583.2 | .6387 | 7.5261 | 8.1648 |
| 50 | 12.349 | 0.001012 | 12.03 | 209.32 | 2234.2 | 2443.5 | 209.33 | 2382.7 | 2592.1 | .7038 | 7.3725 | 8.0763 |
| 55 | 15.758 | 0.001015 | 9.568 | 230.21 | 2219.9 | 2450.1 | 230.23 | 2370.7 | 2600.9 | .7679 | 7.2234 | 7.9913 |
| 60 | 19.940 | 0.001017 | 7.671 | 251.11 | 2205.5 | 2456.6 | 251.13 | 2358.5 | 2609.6 | .8312 | 7.0784 | 7.9096 |
| 65 | 25.03 | 0.001020 | 6.197 | 272.02 | 2191.1 | 2463.1 | 272.06 | 2346.2 | 2618.3 | .8935 | 6.9375 | 7.8310 |
| 70 | 31.19 | 0.001023 | 5.042 | 292.95 | 2176.6 | 2469.6 | 292.98 | 2333.8 | 2626.8 | .9549 | 6.8004 | 7.7553 |
| 75 | 38.58 | 0.001026 | 4.131 | 313.90 | 2162.0 | 2475.9 | 313.93 | 2321.4 | 2635.3 | 1.0155 | 6.6669 | 7.6824 |
| 80 | 47.39 | 0.001029 | 3.407 | 334.86 | 2147.4 | 2482.2 | 334.91 | 2308.8 | 2643.7 | 1.0753 | 6.5369 | 7.6122 |
| 85 | 57.83 | 0.001033 | 2.828 | 355.84 | 2132.6 | 2488.4 | 355.90 | 2296.0 | 2651.9 | 1.1343 | 6.4102 | 7.5445 |
| 90 | 70.14 | 0.001036 | 2.361 | 376.85 | 2117.7 | 2494.5 | 376.92 | 2283.2 | 2660.1 | 1.1925 | 6.2866 | 7.4791 |
| 95 | 84.55 | 0.001040 | 1.982 | 397.88 | 2102.7 | 2500.6 | 397.96 | 2270.2 | 2668.1 | 1.2500 | 6.1659 | 7.4159 |
| 100 | 101.35 | 0.001044 | 1.6729 | 418.94 | 2087.6 | 2506.5 | 419.04 | 2257.0 | 2676.1 | 1.3069 | 6.0480 | 7.3549 |
| 105 | 120.82 | 0.001048 | 1.4194 | 440.02 | 2072.3 | 2512.4 | 440.15 | 2243.7 | 2683.8 | 1.3630 | 5.9328 | 7.2958 |
| 110 | 143.27 | 0.001052 | 1.2102 | 461.14 | 2057.0 | 2518.1 | 461.30 | 2230.2 | 2691.5 | 1.4185 | 5.8202 | 7.2387 |
| 115 | 169.06 | 0.001056 | 1.0366 | 482.30 | 2041.4 | 2523.7 | 482.48 | 2216.5 | 2699.0 | 1.4734 | 5.7100 | 7.1833 |
| 120 | 198.53 | 0.001060 | 0.8919 | 503.50 | 2025.8 | 2529.3 | 503.71 | 2202.6 | 2706.3 | 1.5276 | 5.6020 | 7.1296 |
| 125 | 232.1 | 0.001065 | 0.7706 | 524.74 | 2009.9 | 2534.6 | 524.99 | 2188.5 | 2713.5 | 1.5813 | 5.4962 | 7.0775 |
| 130 | 270.1 | 0.001070 | 0.6685 | 546.02 | 1993.9 | 2539.9 | 546.31 | 2174.2 | 2720.5 | 1.6344 | 5.3925 | 7.0269 |
| 135 | 313.0 | 0.001075 | 0.5822 | 567.35 | 1977.7 | 2545.0 | 567.69 | 2159.6 | 2727.3 | 1.6870 | 5.2907 | 6.9777 |