**Roll No: --------------------------**

# UNIVERSITY OF PETROLEUM AND ENERGY STUDIES

**End Semester Examination, December 2017**

| | |
|---|---|
| **Program: B tech (ET+IPR)** | **Semester – VII** |
| **Subject (Course): Waste Heat Recovery & Cogeneration** | **Max. Marks : 100** |
| **Course Code : ETEG411** | **Duration : 3 Hrs** |
| **No. of pages: 4** | |

**Section-A (All Questions are Compulsory)** **(4×5= 20)**

1. Enlist the waste heat recovery options in energy intensive industries. In that context elaborate on the four major industries which find application for the same. **[CO3]**

2. Why waste heat recovery is critical for **Oil Refineries**? Enumerate some major corporations who have gone for such installments. **[CO3]**

3. Elaborate on sources of waste heat for a **Fertilizer Industries**. **[CO1]**

4. Elaborate with examples on function of an absorbent and a refrigerant in the context of **Vapor Absorption Machines (VAM)**. **[CO4]**

**Section-B (All Questions are Compulsory)** **(4×10= 40)**

5. A backpressure steam turbine at inlet has a pressure of 44 kg/cm$^2$, T = 418 °C, Q = 69 MT/hr, H = 770 kCal/kg. The system has two extraction points, details for which are given below:

| First Extraction | Second Extraction |
|---|---|
| P = 8 kg/cm$^2$, T = 190 °C, Q = 4.7 MT/hr, H = 672.6 kCal/kg | P = 2.5 kg/cm$^2$, T = 130 °C, Q = 47.9 MT/hr, H = 650.2 kCal/kg |

The condenser operates at P = 0.1 kg/cm$^2$, T = 45 °C, Q = 16.4 MT/hr., H = 571.6 kCal/kg.

**Evaluate the following:** **[CO2]**

a. Heat load on cooling tower.
b. Process Diagram to represent the entire system.
c. Power generation in MW.

6. Explain how increasing the "**Use of tri-generation based Energy efficient cooling technologies can help reduce power shortages in India and decrease GHG emissions.**"

You may use the GIZ case study to elaborate on the aforementioned topic. **[CO4]**

7. With the help of a neat diagram show the various heat and waste heat sources in a **Cement Industry**. Also explain the implementation of Cement WHR based CPP schematic, and justify it to be economical. **[CO3]**

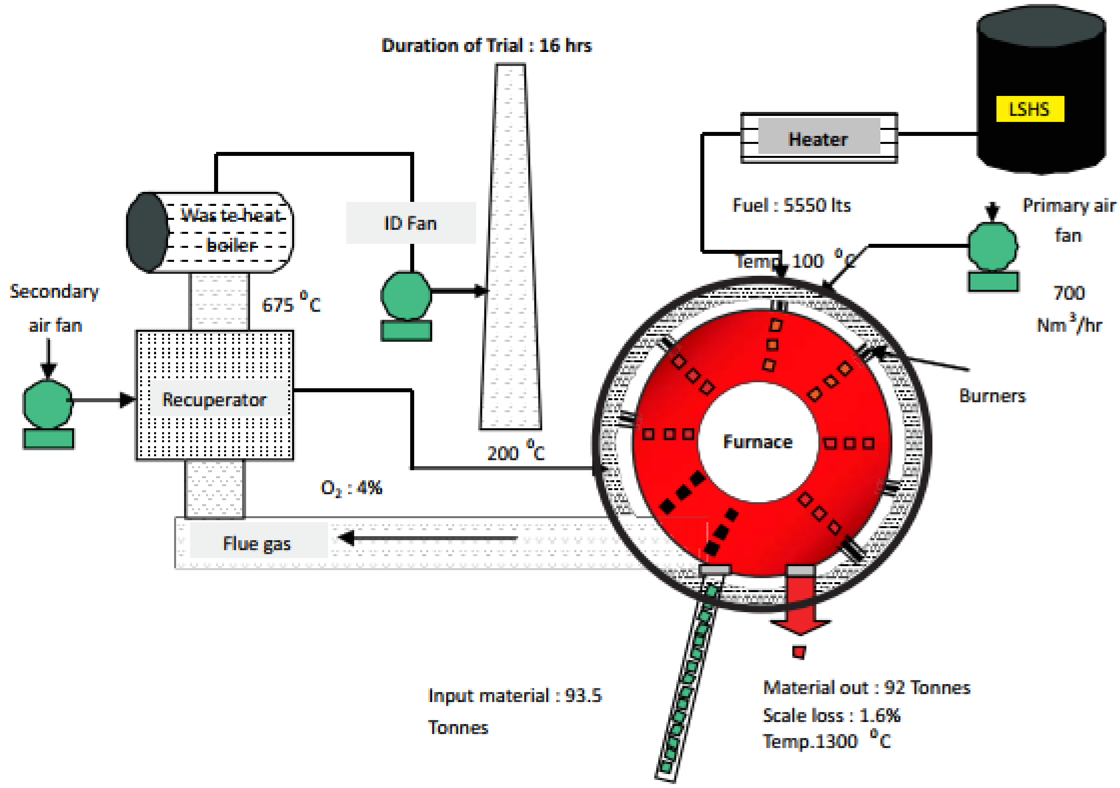
8. Elaborate on the working of **Double Effect Vapor Absorption Machines** with the help of a neat flow diagram. How are such systems more efficient than single effect VAM? Comment on the COPs of such systems. **[CO4]**

## Section-C (All Questions are Compulsory) (1×40= 40)

9. Construct **a Heat Balance** for the following rotary hearth furnace in a steel plant.

In a rolling mill of a steel plant, slabs are reheated in a rotary hearth furnace (as shown in figure below) for downstream rolling. The trial data for the same is given. **[CO5]**

Rotary Hearth Furnace




Duration of Trial = 16 hours of rolling.

Water content = 0.5%

Specific gravity of LSHS = 0.95

Hydrogen in fuel = 12%

Calorific value of LSHS = 10200 kCal/kg

Specific heat of fuel = 0.5 kCal/kg°C

Fuel consumption = 5550 liters

Temperature of fuel before firing = 100 °C

Temperature of Furnace = 1300 °C

Theoretical air required for combustion = 14 kg of air/kg of fuel

| | |
|---|---|
| **Input Material** | 93.5 T |
| **Production** | 92 T |
| **Scale loss** | 1.6% |
| **Specific heat of steel at 30 °C** | 0.11 kCal/kg °C |
| **Specific heat of steel at 1300 °C** | 0.158 kCal/kg°C |
| **Specific heat of scale at 1300 °C** | 0.215 kCal/kg°C |
| **Heat of formation of scale** | 1335 kCal/kg of Fe |

| | |
|---|---|
| **Ambient Temperature** | 30 °C |
| **Humidity of air** | 0.034 kg/kg of dry air |
| **Atomising air flow rate** | 896 kg/hr |
| **Secondary air temperature** | 200 °C |
| **Specific heat at 200 °C** | 0.24 kCal/kg°C |

| | |
|---|---|
| **Oxygen in flue gas** | 4% |
| **Flue gas temperature after Air Preheater** | 675 °C |
| **Specific heat of flue gas** | 0.26 kCal/kg°C |
| **Specific heat of water vapor** | 0.48 kCal/kg°C |

Take cooling water flow rate as 28 $m^3$/hr and temperature difference as 10 °C.

| | |
|---|---|
| **Number of doors** | 2 |
| **Factor for radiation, Ψ** | 0.7 for rectangular door |
| **Area of opening, A** | 1 m × 1 m = 1 $m^2$ |
| **Diameter of furnace** | 10 m |
| **Height of furnace** | 2.5 m |
| **Wall surface area** | 3.14 × 10 × 2.5 = 78. 5 $m^2$ |
| **Roof surface area** | 3.14 × $5^2$ = 78. 5 $m^2$ |

Average wall temperature = 65 °C

Average roof temperature = 100 °C.

In reference to heat input, calculate the following:

a. **Product rate.**
b. **Fuel rate.**

c. **Specific fuel consumption.**
d. **Specific atomizing air.**
e. **Specific secondary air.**
f. **Specific Flue gas Quantity.**
g. **Specific Water Vapor (Given by: 9 × %$H_2$ + %water content/100).**
h. **Specific scale formation.**
i. **Specific cooling water requirement.**
j. **Total Heat Input.**

In reference to heat output, calculate the following:

a. **Sensible heat of steel.**
b. **Sensible heat of scale.**
c. **Sensible heat of dry flue gas.**
d. **Heat loss due to formation of water vapor from fuel (ΔH = 584 kCal/kg).**
e. **Heat loss due to formation of water vapor from air.**
f. **Heat taken away by cooling water.**
g. **Radiation heat losses**
    1. **Radiation heat loss through furnace openings.**
    2. **Radiation heat loss through walls.**
    3. **Radiation heat losses through roof.**
    4. **Total radiation loss from furnace.**
h. **Total Heat Output.**

Construct the **Heat Balance Table** for the input and output materials.

For radiation loss calculation use the following empirical relationships:

i) Radiation heat loss through furnace opening - $hours \times A \times \varphi \times 4.88\ [(T_f/100)^4 - (T_0/100)^4]/T$ *of billet*

ii) Surface radiation losses

$$Q = a \times (t_1 - t_2)^{1.25} + 4.88 \times E \times \{((t_1 + 273)/100)^4 - ((t_2 + 273)/100)^4\}$$

Where $\mathbf{T_f}$ and $\mathbf{T_0}$ are in absolute scale, and a = 2.2 and E = 0.8.

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| **Program** | : | **B Tech (ET+IPR** | | | | | |
| **Semester** | : | **VII** | | | | | |
| **Name of the Subject (Course)** | : | **Waste Heat Recovery & Cogeneration** | | | | | |
| **Course Code** | : | **ETEG411** | | | | | |
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| **Note: NOT APPLICABLE** | | | | | | | |

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**Note: - Pl. start your question paper from next page**

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**Section-A (All Questions are Compulsory)** **(4×5= 20)**

**1.** What are the benefits of waste heat utilization for Industries? How low can the cost of power go in such cases? **[CO3]**

**2.** Elaborate on sources of waste heat and gas for **Steel Industries**. **[CO1]**

**3.** Enlist the applications of Vapor Absorption Machines to **Sugar Industries** and the tax benefits from it. **[CO4]**

**4.** Compare the various advantages and limitations of absorption machines. **[CO4]**

**Section-B (All Questions are Compulsory)** **(4×10= 40)**

**5.** What do you mean by **Tri-generation**? Enumerate the various site selection criteria for it. Using block diagram representation, explain how tri-generation works and where it finds applicability. **[CO5]**

**6.** Comment on the working of **Triple effect Vapor absorption Machines** with the help of a neat flow diagram. How hybrid systems can be integrated into this? Enlist the limitations of such systems. **[CO4]**

**7.** A backpressure steam turbine at the inlet has: P = 42 kg/cm$^2$, T = 410 °C, Q = 13 MT/hr, H = 760 kCal/kg. And at the extraction point it has the following parameters: P = 4 kg/cm$^2$, T = 165 °C, Q = 13 MT/hr, H = 650.2 kCal/kg. Overall power produced by the generator is 0.7 MW. Evaluate the following: **[CO2]**

**a. Thermal Efficiency.**
**b. Electrical Efficiency**
**c. Cogeneration Efficiency.**
**d. Process Diagram to represent the system.**

**8.** Give a brief account of the integration of Vapor absorption machines with gas turbine power plant, or a gas turbine cogeneration plant. Provide suitable process diagram for it.

What are the advantages with such installations? **[CO4]**

## Section-C (All Questions are Compulsory) (1×40= 40)

**9.** Construct a heat balance to determine the hot gases required for drying of materials in an operating mill. The hot gases are required for drying of feed moisture in the raw material while grinding in a close circuit ball mill, the data for which is given below: **[CO5]**

| | | | |
|---|---|---|---|
| Ght | Hot gases temperature | 280 | $^0$C |
| Ghs | Specific heat of hot gases | 0.34 | kCal/ Nm$^3$ $^0$C |
| Rt | Base temperature | 20 | deg. C |
| Amb | Ambient air temperature | 35 | deg. C |
| Ambs | Specific heat of ambient air | 0.30 | kCal/Nm$^3$ $^0$C |
| Alt | Altitude ( From mean sea level ) | 950 | M |
| Fq | Fresh feed quantity | 100 | TPH |
| Mf | Total fresh feed moisture(surface) | 8 | % |
| Mp | Total product moisture (surface) | 2 | % |
| Fs | Specific heat of raw material | 0.21 | kCal/kg $^0$C |
| Fa | False air percentage | 10 | % |
| P | Power drawn by mill motor | 3095 | kW |
| Eg | Amount of dedusting gases | 150000 | m$^3$/hr |
| Egt | Dedusting gases temperature | 105 | $^0$C |
| Egs | Specific heat of dedusting gases | 0.31 | kCal/Nm$^3$ $^0$C |
| Ra | Surface area for Radiation Losses | 185 | m$^2$ |
| Rf | Radiation Loss | 50 | kCal/m$^2$ $^0$C difference |

**Assume** raw material temperature to be less than **5°C** than the exit gas temperature.

With respect to the aforementioned data, calculate the following:

| For Output Heat | For Input Heat |
|---|---|
| a. Heat to raw material.<br>b. Heat to de-dusting gases.<br>c. Heat loss due to radiation.<br>d. Heat loss due to evaporative moisture (Take latent heat of evaporation of waster as **540 Kcal/kg**).<br>e. Heat loss due to false air.<br>f. Total heat loss at output. | a. Heat from fresh feed.<br>b. Heat from grinding power. (Take gear box efficiency as 98%, motor efficiency as 94%).<br>c. Heat from false air.<br>d. Total heat input. |

Once heat input and output is calculated, check for the consistency of the heat balance. If it is not being balanced suggest how it has to be balanced? Quantify the **parameter** which is essential to complete the heat balance and calculate how much unit of the same (in terms of **mass flow rate**) will be needed for a satisfactory heat balance.

Draw a figure showing the result of Heat Balance in terms of:

a. **Heat Inputs.**
b. **Process.**
c. **Heat Outputs.**