PAPER-2 COLOR C0DE : PINK

24th NATIONAL CERTIFICATION EXAMINATION
FOR
ENERGY MANAGERS & ENERGY AUDITORS - SEPTEMBER, 2024
PAPER - 2 : ENERGY EFFICIENCY IN THERMAL UTILITIES

Section – I : OBJECTIVE TYPE **Marks: 50 x 1 = 5**

1. Boiler Evaporation ratio means: kilogram of _____________ per kilogram of fuel consumed.
   a) Heat generated c) Flue gas generated
   b) **Steam generated** d) Ash generated

2. The supercritical steam exists when pressure and temp is above the critical point. At the critical point the pressure and temp values are:
   a) 101.2 bar and 374.15 Deg C c) 101.2 bar and 274.15 Deg C
   b) 221.2 bar and 274.15 Deg C **d) 221.2 bar and 374.15 Deg C**

3. Economic Thickness of Insulation (ETI) is that insulation thickness at which:
   a) Sum of cost of energy loss and cost of insulation is maximum
   b) Sum of cost of energy loss and cost of insulation is minimum
   c) Cost of energy loss is more than cost of insulation
   d) Cost of energy loss is less than cost of insulation

4. In which of the following equipment heat is added in a power plant?:
   a) Deaerator c) Economizer
   b) Air preheater **d) All of the above**

5. A topping cycle of cogeneration the fuel supplied is used for producing:
   a) Power primarily followed by byproduct heat output
   b) Heat primarily followed by product power output
   c) Power, heat, and refrigeration simultaneously
   d) None of the above

6. Which of the following is not a befitting choice of bottoming cycle of Cogeneration:
   a) Cement plant requiring thermal energy at 1450^{0}C
   b) Sugar mill needing thermal energy at 120^{0}C
   c) Blast furnace in Steel plant requiring heat at 1200^{0}C
   d) All the above

7. Which of the following is not a loss from Industrial Heating Furnaces:
   a) Flue gas loss c) Radiation loss from openings
   b) Wall loss **d) Blowdown loss**

8. Which of the following basic type of Fluidised Bed Combustion(FBC) boiler is also called “Bubbling bed boiler”:
   a) PFBC
   b) CFBC
   c) AFBC
   d) All the above

9. Steam Turbine cylinder Efficiency is defined as the ratio of _______________ to ________________.
   a) Actual entropy drop to isentropic entropy drop
   b) Actual enthalpy drop to isentropic enthalpy drop
   c) Actual enthalpy drop to isobaric enthalpy drop
   d) Actual entropy drop to isochoric entropy drop

10. The heat required to change water to steam at boiling point is called as ________________ heat.
    a) Super c) Specific
    b) Sensible **d) Latent**

11. The excess air level of a packaged boiler operating at 5% O2 level is:
    a) 23.8% c) 21.25%
    b) 21.25% **d) 31.25%**

12. The Chemical De-aeration or chemical oxygen scavenging is done by dosing _______________ in condensate water.
    a) Phosphate c) Alum
    b) Limestone **d) Hydrazine**

13. Difference in Gross calorific Value and Net Calorific Value is accounted to the presence of:
    a) Water vapour and/or moisture
    b) Sulphur
    c) Ash
    d) Flue gas

14. What is the % Flash steam available after the following flashing process: Sensible heat at Higher pressure condensate = 165 kCal/kg; Sensible heat at lower pressure = 120 kCal/kg; Latent heat of flash steam(at lower pressure) = 526 kCal/kg
    a) 4.6% **c) 8.6%**
    b) 6.8 % d) 4.8%

15. Proximate analysis of coal will give:
    a) % Hydrogen
    b) % Volatile Matter
    c) % Carbon
    d) None of the above

16. In Cross Flow type of Heat Exchanger as regards direction of flow of the cold fluid and hot fluid:

a) Hot fluid and cold fluid flow parallel to each other in the same direction
b) Hot fluid and cold fluid flow parallel to each other in opposite direction
c) Hot fluid and cold fluid flow at perpendicular direction with respect to each other
d) None of the above

17. Typical Boiler Specification contains:
a) Make
b) Maximum Continuous Rating
c) Fuel Fired
d) All of the above

18. An increase in the steam pressure from 3 bar to 10 bar will result in a decrease of:
a) Sensible heat
b) Enthalpy of steam
c) Specific volume
d) Saturation temperature

19. Select the wrong statement with respect to steam traps:
a) Discharges condensate as soon as it is formed
b) Does not allow steam to escape
c) Capable of discharging air and other incondensable gases
d) Does not allow condensate to escape

20. The efficiency of a reheating furnace operating at 10 tonne per hour consuming furnace oil of 230 kg/hour for reheating the material from 40°C-1100°C (consider specific heat of material is 0.13 kcal/kg°C and calorific value of furnace oil is 10000 kcal/kg) is:
a) 55 **c) 60**
b) 65 d) 70

21. Which fuel requires maximum air for stoichiometric combustion?
a) Butane
b) Propane
c) Hydrogen
d) Coal

22. The device that upgrades a low temperature heat source to a high temperature heat sink is called:
a) Heat pipe
b) Heat pump
c) Plate heat exchanger
d) Economizer

23. Flash steam can be recovered from:
a) Superheated steam
b) Saturated steam
c) High pressure condensate
d) Condensate at atmospheric pressure

24. The minimum capacity of any closed vessel which generates steam under pressure as covered under Indian Boilers Regulation Act is:
    a) 22.75 litres
    b) 25 litres
    c) 15 kilolitres
    d) 25 kilolitres

25. Major heat loss in an oil-fired boiler is accounted by:
    a) Blowdown loss
    b) Un-burnt carbon loss
    c) Surface radiation loss
    d) Stack loss

26. The equipment having the highest efficiency in case of coal-fired cogeneration plant is:
    a) Electric generator
    b) Boiler feed water pump
    c) Steam turbine
    d) Boiler

27. When pure hydrogen is burnt with stoichiometric air percentage CO2 on volume basis in flue gas on dry basis will be:
    a) 79%
    b) 21%
    c) 0%
    d) 100%

28. Oxygen percentage (by volume) measurement in flue gas can be done by using:
    a) Ultrasonic tester
    b) Potassium oxide probe
    c) Pitot tube
    d) Zirconium oxide probe

29. In a combustion process the theoretical air required for complete combustion of 1 kg of carbon is:
    a) 12.5 kg
    b) 11.6 kg
    c) 10.5 kg
    d) None of the above

30. The flue gas analysis of a combustion process indicates a high level of CO2. What does this imply about the combustion process?
    a) Efficient combustion
    b) Incomplete combustion

c) High excess air supply
d) High moisture content in fuel

31. A boiler operates at 85% efficiency. If the energy required for the process is 1000000 kJ calculate the actual energy input needed:
    a) 850000 kJ
    b) 1176471 kJ
    c) 1000000 kJ
    d) 1250000 kJ

32. In a steam boiler what is the function of the economizer?
    a) To preheat the feed water
    b) To remove impurities from the water
    c) To increase steam pressure
    d) To cool the flue gases

33. The boiler efficiency can be increased by:
    a) Increasing the blowdown rate
    b) Increasing the flue gas temperature
    c) Using an economizer
    d) Reducing the feed water temperature

34. In a boiler system the main purpose of a deaerator is to:
    a) Remove dissolved gases from feed water
    b) Preheat the combustion air
    c) Increase steam temperature
    d) Reduce water hardness

35. Which component is essential for maintaining the quality of steam in a steam distribution system?
    a) Condenser
    b) Economizer
    c) Steam trap
    d) Superheater

36. Calculate the amount of steam required to heat 2000 kg of water from 30°C to 90°C given that the latent heat of steam is 2260 kJ/kg and specific heat of water is 4.18 kJ/kg°C:
    a) 116 kg
    b) 132 kg
    c) 221.9 kg
    d) 121.9 kg

37. Furnace efficiency can be improved by:
    a) Reducing the furnace temperature
    b) Preheating combustion air
    c) Increasing the fuel flow rate

d) Reducing the air supply

38. What is the primary function of a ceramic fiber blanket in high-temperature applications?
    a) Provide thermal insulation
    b) Increase structural strength
    c) Reduce noise levels
    d) Improve aesthetic appearance

39. Which of the following is an advantage of fluidized bed combustion systems?
    a) High combustion efficiency
    b) Lower NOx emissions
    c) Fuel flexibility
    d) All of the above

40. In fluidized bed combustion the primary purpose of adding limestone to the bed material is to:
    a) Reduce SO2 emissions
    b) Increase combustion temperature
    c) Improve bed fluidization
    d) Reduce NOx emissions

41. Which of the following is a common device used for waste heat recovery in industrial furnaces?
    a) Recuperator
    b) Heat wheel
    c) Heat pump
    d) All of the above

42. What is the primary function of a baffle in a shell and tube heat exchanger?
    a) Direct the flow of fluid
    b) Increase heat transfer area
    c) Reduce pressure drop
    d) Prevent fouling

43. Calculate the log mean temperature difference (LMTD) for a counter flow heat exchanger with inlet temperatures of 150°C and 50°C for the hot and cold fluids respectively and outlet temperatures of 100°C and 70°C:
    a) 75°C
    b) 80°C
    c) 85°C
    d) 64°C

44. In a cogeneration system, the efficiency can be maximized by:
    a) Increasing the temperature of the exhaust gases
    b) Using high-pressure steam
    c) Utilizing waste heat
    d) Increasing fuel consumption

45. A power plant has a gross heat rate of 2,100 kCal/kWh and a net heat rate of 2282 kCal/kWh. if the plant operates 500 MWh of electrical energy, calculate the percentage of auxiliary power consumption.
   a) 8.6 %
   b) 8.0 %
   c) 10 %
   d) None of the above

46. Heat to Power Ratio is defined as ratio of _______________ to ______________ required by energy consuming facility.
   a) thermal energy , electricity c) electricity , thermal energy
   b) thermal enegy , mechanical energy d) chemical energy , mechanical energy

47. Which of the following characteristics of steam make it popular and useful in industries
   a) Highest specific heat and latent heat
   b) Highest heat transfer coefficient
   c) Inert
   d) All of the above

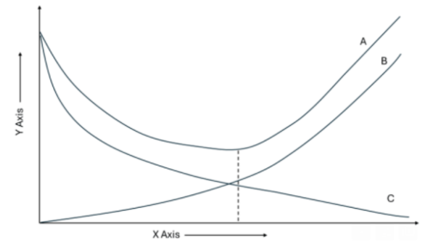
48. The average temp difference between cold fluid and hot fluid in heat exchanger is described by LMTD. What does LMTD stands for ?
   a) Log Mean Temperature difference b) Long Mean Temperature Difference
   c) Log Mean temperature Depth d) Long Mean Temperature depth

49. Water hammer in a steam line can be stopped by a continuous _____________ in flow direction and adequate number of _______________ points at regular intervals:
   a) bend , vent **c) slope , drain**
   b) reducer , drain d) expander , vent

50. What are the three modes of heat transfer ?
   a) Radiation, Conduction, Convection b) Radiation, Distillation, Convection
   c) Radiation, Conduction, Compression d) Radiation, Condensation ,Compression

Section - II: SHORT DESCRIPTIVE QUESTIONS Marks: 8 x 5 = 40

S1	Calculate the effectiveness of a parallel flow heat exchanger, where the hot fluid enters at 200°C and leaves at 140°C, and the cold fluid enters at 50°C and leaves at 120°C. The mass flow rates of the hot and cold fluids are 3000 kg/hr and 2500 kg/hr, respectively, with specific heat capacities of 2.5 kJ/kg°C and 4.18 kJ/kg°C, respectively. **Solution:** $C_{max}=m_{cold}\times Cp,_{cold}=2500kg/hr\times4.18kJ/kg^{\circ}C=10450kJ/hr^{\circ}C$ $C_{min}=m_{hot}\times Cp,_{hot}=3000kg/hr\times2.5kJ/kg^{\circ}C=7500kJ/hr^{\circ}C$ Effectiveness(ϵ)=Maximum possible heat transfer / Actual heat transfer $Q_{actual}=m_{cold}\times Cp,_{cold}\times(T_{cold,out}-T_{cold,in})$ $Q_{actual}=2500kg/hr\times4.18kJ/kg^{\circ}C\times(120-50)^{\circ}C=2500\times4.18\times70=731,500kJ/hr$ $Q_{max}=C_{min}\times(T_{hot,in}-T_{cold,in})$ $Q_{max}=7500kJ/hr^{\circ}C\times(200-50)^{\circ}C=7500\times150=1125000$ kJ/hr $\epsilon=731,500/1125000 = 0.65$
S2	An oil-fired furnace is operating at 1380 ^{0}C with ambient temperature of 30 ^{0}C and average fuel consumption of 370 litres/hr. The Calorific value of oil is 10,000 kCal/kg. Specific gravity of oil is 0.93. Weight of the billet heated is 8000 kg/hr and Specific heat of billet is 0.13 kCal/kg/0C. **Calculate the following:** a) Efficiency of furnace by direct Method. b) Heat loss in furnace in terms of Fuel loss in lit/hr? **Solution:** Heat Input = 370*0.93* 10000 = 3441000 kCal/hr Heat Output = mCpDeltaT = 8000 *0.13 * (1380-30) = 1404000kCal/ hr Efficiency = Heat Output / Heat Input = 1404000 / 3441000 = 40.8% Energy loss from furnace = 3441000 *(1-0.408) kCal/hr =2,037,072 kCal/hr Fuel Loss / hour = 2,037,072/10000 = 203.7 kg /hr = 203.7/0.93 = 219 lit/h

S3	In the chart given below for determining the economic thickness of insulation, what do the following represent: Curve A, Curve B, Curve C, X Axis and Y Axis.  **Solution:** A – Combined Costs B – Depreciation cost of insulation C – Fuel cost due to loss X Axis – Insulation thickness Y axis – Annual cost
S4	How do multiple effect evaporators save energy? Multiple effect evaporators are used to reduce energy consumption by using the vapor produced from one effect to heat the product in the subsequent lower-pressure effect. This allows for efficient use of energy by minimizing steam usage, making the evaporation process more economical. **Solution:** Page-247
S5	In a cogeneration system using a gas turbine, if the heat rate is 3050 kcal/kWh and the calorific value of the natural gas is 9500 kCal/sm³, calculate the fuel consumption for generating 3000 kW of power. **Solution:** For a gas turbine with a heat rate of 3050 kcal/kWh and the calorific value of natural gas being 9500 kcal/sm³, the fuel consumption for generating 3000 kW of power is: Fuel Consumption = $\frac{3050\frac{kCal}{kWh}\times 3000\ kW}{9500\ kCal/sm^3}$ = $\frac{9150000\ kCal}{9500\ kCal/sm^3}$ = 963.16 sm^3

S6	Match the following wrt to FBC boilers:

1.	Complete combustion of volatile matter	a) Secondary Air
2.	NOx formation	b) Tertiary Air
3.	Turbulence and burns residual volatile matter	c) Air Distributor
4.	Instant combustion as fuel enters the furnace	d) Primary Air
5.	Prevents channeling and ensures consistent reaction rates	e) Combustion temperature

Solution:

1.	instant combustion as fuel enters the furnace	Primary Air
2.	complete combustion of volatile matter	Secondary Air
3.	turbulence and burns residual volatile matter	Tertiary Air
4.	NOx formation	Combustion temperature
5.	Prevents channeling and ensures consistent reaction rates	Air Distributor

S7

For heating application, a drier requires 80 m^3/min of air at 92 ^oC, which is heated by wood fired thermic fluid heater. The density of air is 1.2 kg/m^3 and the specific heat of air is 0.24 kCal/kg ^oC. The inlet air temperature to the drier is 32 ^oC and the drier is operating for 8 hrs per day. The efficiency of the wood fired heater and its distribution piping system is 50 %. The gross calorific value and the cost of purchased wood are 2000 kCal/kg and Rs. 5000 per ton. The auxiliary power consumption for operating the thermic fluid heater is 10 kW.

The plant is planning to replace the existing drying system with a 110 kW infrared electric heater drier. The efficiency of the electric heater is 90%. The investment in the new drier is Rs. 10 Lakhs. If the cost of electricity is Rs. 7/kWh, comment on the cost economics of the proposal.

Solution:

Cost of wood fired thermic fluid heater operation:
Air flow rate (volume) = 80 m^3/min x 60 = 4800 m^3/hr
Air flow rate (mass) = 4800 x 1.2 = 5760 kg/hr
Sensible heat of air = m x Cp x T = 5760 x 0.24 x (92-32) = 82944 kcal/hr
Efficiency of wood fired heater =50%
Wood consumption = 82944/ (2000 x0.5) per hr =83 kg per hr
Cost of wood per day = 83 x Rs 5 x 8 hour = Rs 3320 per day
Cost of Auxiliary electricity = 10 kW x 8 hrs x 7 = Rs.560 per day
Total cost of operation = Rs.3880 per day

Cost of Infra-red heater operation:
Electric heater power consumption= 82944/0.9/860 =107.2 kw
Electricity consumption per day= 107.2 kW x 8 hr = 857.3 kwh per day

	Cost of operation per Day= 857.3 x Rs 7= Rs 6001.00 per day Since the per day expenses are higher in case of electric heater, it is not economical.
S8	A textile plant has an extensive steam network and the condensate is not being recovered. The plant management is planning to recover the flash steam from the high-pressure condensate and return the remaining condensate back to the boiler. The following are the parameters observed: Condensate quantity : 1000 kg/hr Condensate Pressure :10 bar Cost of steam :Rs 1100/ T Annual operating hours :6000 Low pressure process steam (flash steam) pressure 2 bar Sensible heat of condensate at 10 bar 188 kCal/kg Sensible heat of condensate at 2 bar 135 kCal/kg Latent heat of steam at 2 bar 518 kCal/kg Boiler Efficiency 80 % GCV of fuel oil 10,200 kCal/kg Specific Gravity of fuel oil 0.92 Condensate temperature when recovered 95 ^{o}C Make up water temperature 35 ^{o}C Calculate the quantity of flash steam which can be recovered, and the annual fuel oil savings on account of the flas recovery. **Solution:** Flash steam available % = S1- S2/(L2) % of Flash steam recoverable = (188 – 135)/518 = 10.2 % a) Quantity of flash steam recovered from condensate = 1000 x 0.102 = 102 kg/hr Balance Condensate available for recovery after flash steam = 1000 – 102 = 898 kg/hr Heat recovered = Latent Heat of Flash Steam + Sensible Heat of Condensate = (102*518) + (898 x (95 – 35)) = 106716 kCal/hr b) Oil saved = 106716 x 6000 / (0.80 x 10200) = 78.5 tons/yr

Section - III: LONG DESCRIPTIVE QUESTIONS **Marks: 6 x 10 = 60**

<table>
<tr><td>L1</td><td>Briefly explain the following waste heat recovery devices.

• Recuperators, Refer Guide Book, Page 219
• Regenerators, Refer Guide Book, Page 222
• Heat Wheels, Refer Guide Book, Page 222
• Heat Pipes, Refer Guide Book, Page 223
• Plate Heat Exchangers, Refer Guide Book, Page 226</td></tr>
<tr><td>L2</td><td>A textile plant utilizes steam for various processes, including dyeing and finishing. The plant operates a boiler at a pressure of 9 kg/cm²(g). For a specific batch process, the plant requires superheated steam at 250°C. The steam saturation temperature at this pressure is 180°C. Given the specific heat of superheated steam is 0.45 kcal/kg°C.

a) Calculate the total heat content of the superheated steam used in the process.
b) Explain, why superheated steam should not be used for process heating?

Solution:
• Superheat temperature: 250°C
• Saturation temperature: 180°C
• Specific heat of superheated steam (Cp): 0.45 kcal/kg°C
• Total heat content of dry saturated steam at 9 kg/cm²(g) (h): 663 kcal/kg

Calculations:
1.Total Heat Content of Superheated Steam (hsuperheat):
Hsuperheat = h + Cp x ΔT
= 663kcal/kg+0.45kcal/kg°Cx70°C
= 663kcal/kg+31.5kcal/kg
= 694.5kcal/kg

2.Why Superheated Steam Should Not Be Used for Process Heating:

• Temperature Control: Superheated steam does not condense immediately upon releasing heat, making it difficult to control temperature precisely. For processes requiring precise temperature control, this can lead to overheating or underheating.
• Heat Transfer Efficiency: The heat transfer coefficient of superheated steam is lower than that of saturated steam. This means that superheated steam is less efficient in transferring heat to the process materials, potentially leading to longer processing times and higher energy consumption.
• Equipment Wear and Tear: The higher temperature of superheated steam can lead to increased wear and tear on process equipment, reducing its lifespan and increasing maintenance costs.</td></tr>
</table>

L3	A back pressure cogeneration plant is designed to generate both power and process heat. The electrical power generated is 25 MW. The cogeneration boiler is having coal feed rate of 80 TPH and GCV of 18,800 kJ/kg. The turbine mechanical efficiency is 98%, Gear box efficiency is 97% and alternator efficiency is 98%. Assume steady operating conditions and no steam loss in entire process. The steam parameters are as follows: Main Steam Parameters: Steam Parameters at Turbine inlet: High-pressure steam at 9 MPa, 400°C and enthalpy of 3118.8 kJ/kg Exhaust Steam Parameters: Exhaust of steam of turbine being sent for process heating has an enthalpy of 2815.8 kJ/kg The return Condensate from the process is saturated liquid at 10 kPa having enthalpy of 191.81 kJ/kg. Calculate the following: a) Energy Utilization Factor , b) Heat to Power Ratio, **Solution:** **Net enthalpies drop per kg of Steam:** Work done by the turbine per kg of steam: h1−h2=3118.8 kJ/kg−2815.8 kJ/kg=303 kJ/kg **Total Mass Flow Rate of Steam:** To achieve a net power output of 25 MW Turbine input = 25/(0.98*0.97*0.98) =26.84 MW Steam Required = 26.84 * 1000 *860*4.18 /303/1000 = 318.4 TPH **Total Thermal Energy Output:** Thermal energy output to the process heater (enthalpy difference): process=h2−hf=2815.8 kJ/kg−191.81 kJ/kg=2624 kJ/kg Total thermal energy output = 318.4 TPH * 1000 * 2624 kJ/kg /4.18/860 /1000= 232.4 MW **Energy Utilization Factor (EUF):** Total fuel energy input = m fuel × GCV=80000 kg/hr × 18800 kJ/kg /4.18/860 /1000 =418 MW Total useful energy output = 25 MW + 232.4 MW= 257.4 MW Energy Utilization Factor = 257 MW / 418 MW = 61% **Heat to Power Ratio**: 232.4/25 = 9.29
L4	A steam pipeline with a diameter of 100 mm is insulated with 30 mm of mineral wool material. The pipeline carries steam at 6 ata and has a length of 150 meters. Due to increased fuel costs, the Energy Auditor has recommended increasing the insulation thickness by an additional 20 mm. Calculate the economic benefits of this recommendation, given the following details: • The plant operates for 6,500 hours per year. • The existing surface temperature of the insulation is 90°C. • The expected surface temperature after additional insulation is 50°C. • Ambient temperature is 25°C. • Boiler efficiency on NCV (Net Calorific Value) basis is 82%. • Cost of fuel oil is Rs. 50,000 per tonne. • Net Calorific Value of fuel is 9,500 kCal/kg. • The cost of insulation is Rs. 2000/meter.

Calculate the following:

1. Heat Loss for Existing Insulation ,
2. Heat Loss for Modified Insulation,
3. Fuel Savings,
4. Simple Payback Period,

Solution:

1. Calculate Heat Loss for Existing Insulation

Given Data:

- Pipe diameter: 100 mm (0.1 m)
- Existing insulation thickness: 30 mm (0.03 m)
- Surface temperature with existing insulation: 90°C
- Ambient temperature: 25°C

Heat Loss Formula:

$S=[10+20(Ts-Ta)]\times(Ts-Ta)$

$S=[10+20(90-25)]\times(90-25)$

$S=13.25\times65=861.25$ kCal/hr/m^2

2. Calculate Heat Loss for Modified Insulation

Given Data:

- New insulation thickness: 50 mm (0.05 m)
- New surface temperature: 50°C

Heat Loss Formula:

$S=[10+20(Ts-Ta)]\times(Ts-Ta)$

$S=[10+20(50-25)]\times(50-25)$

$S=11.25\times25=281.25$ kCal/hr/m^2

3. Calculate Total Heat Loss

Existing Insulation:

- Length of pipe = 150 m
- Diameter of pipe = 100 mm
- Outer diameter after existing insulation = 0.1 m + (0.03x2) m = 0.16 m

Surface area (existing) $=\pi\times 0.16 \times 150 = 75.4\ m^2$

Total Heat Loss (Existing):

Total Heat Loss existing=861.25 kCal/hr/$m^2\times$ 75.4 m^2= 64938.25 kCal/hr

Modified Insulation:

- New thickness of insulation = 50 mm (0.05 m)
- New diameter = 0.1+ (0.05*2) = 0.2m

Surface area (Amodified) = $\pi\times0.2\times150= 94.23\ m^2$

Total Heat Loss (Modified):

Total Heat Loss modified=281.25 kCal/hr/m^2×94.23 m^2= 26502.2 kCal/hr

Reduction in Heat Loss:
Reduction=Total Heat Loss existing−Total Heat Loss modified= 64938.25 −26502.2 = 38436 kCal/hr

Annual Heat Savings:
Annual Heat Savings=38436 kCal/hr×6,500 hr/year= 24,98,34,325 kCal/year

Fuel Savings:

Fuel Oil Data:
- Net Calorific Value (NCV) = 9,500 kCal/kg
- Boiler Efficiency = 82%

Convert heat savings to fuel required:
Fuel Required=NCV× Efficiency/Annual Heat Savings

Substitute the values:

Fuel Required=(249834325/9,500/0.82)/1000
= 32 tonnes

Monetary Savings:
Monetary Savings=Fuel Required×Cost per Tonne= 32 tonnes × 50,000 Rs/tonne =Rs 16 lakhs

4. Calculate Simple Payback Period

Cost of Insulation:
- Cost = Rs. 2000 x 150 = Rs. 3,00,000/-

Simple Payback Period:

Payback Period= Cost of Insulation / Monetary Savings
= 3,00,000 / 16,00,000 = 0.1875 Year or 2.25 Months

L4 A steam pipeline with a diameter of 100 mm is insulated with 30 mm of mineral wool material. The pipeline carries steam at 6 ata and has a length of 150 meters. Due to increased fuel costs, the Energy Auditor has recommended increasing the insulation thickness by an additional 20 mm. Calculate the economic benefits of this recommendation, given the following details:

- The plant operates for 6,500 hours per year.
- The existing surface temperature of the insulation is 90°C.
- The expected surface temperature after additional insulation is 50°C.
- Ambient temperature is 25°C.
- Boiler efficiency on NCV (Net Calorific Value) basis is 82%.
- Cost of fuel oil is Rs. 50,000 per tonne.
- Net Calorific Value of fuel is 9,500 kCal/kg.
- The cost of insulation is Rs. 2000/meter.

Calculate the following:

5.Heat Loss for Existing Insulation ,
6.Heat Loss for Modified Insulation,
7.Fuel Savings,
8.Simple Payback Period,

Solution:
2. Calculate Heat Loss for Existing Insulation

Given Data:
- Pipe diameter: 100 mm (0.1 m)
- Existing insulation thickness: 30 mm (0.03 m)
- Surface temperature with existing insulation: 90°C
- Ambient temperature: 25°C

Heat Loss Formula:
$S=[10+20(Ts-Ta)]\times(Ts-Ta)$
$S=[10+20(90-25)]\times(90-25)$
$S=13.25\times65=861.25$ kCal/hr/m^2

2. Calculate Heat Loss for Modified Insulation
Given Data:
- New insulation thickness: 50 mm (0.05 m)
- New surface temperature: 50°C

Heat Loss Formula:
$S=[10+20(Ts-Ta)]\times(Ts-Ta)$
$S=[10+20(50-25)]\times(50-25)$
$S=11.25\times25=281.25$ kCal/hr/m^2

3. Calculate Total Heat Loss

Existing Insulation:
- Length of pipe = 150 m
- Diameter of pipe = 100 mm
- Outer diameter after existing insulation = 0.1 m + (0.03x2) m = 0.16 m

Surface area (existing) $=\pi\times 0.16 \times 150 = 75.4$ m^2

Total Heat Loss (Existing):
Total Heat Loss existing=861.25 kCal/hr/m^2× 75.4 m^2= 64938.25 kCal/hr

Modified Insulation:
- New thickness of insulation = 50 mm (0.05 m)
- New diameter = 0.1+ (0.05*2) = 0.2m

Surface area (Amodified) = $\pi\times0.2\times150= 94.23$ m^2

Total Heat Loss (Modified):
Total Heat Loss modified=281.25 kCal/hr/m^2×94.23 m^2= 26502.2 kCal/hr

Reduction in Heat Loss:
Reduction=Total Heat Loss existing−Total Heat Loss modified= 64938.25 −26502.2 = 38436 kCal/hr

Annual Heat Savings:
Annual Heat Savings=38436 kCal/hr×6,500 hr/year= 24,98,34,325 kCal/year

Fuel Savings:

Fuel Oil Data:
- Net Calorific Value (NCV) = 9,500 kCal/kg
- Boiler Efficiency = 82%

Convert heat savings to fuel required:
Fuel Required=NCV× Efficiency/Annual Heat Savings

Substitute the values:

Fuel Required=(249834325/9,500/0.82)/1000
= 32 tonnes

Monetary Savings:
Monetary Savings=Fuel Required×Cost per Tonne= 32 tonnes × 50,000 Rs/tonne =Rs 16 lakhs

4. Calculate Simple Payback Period

Cost of Insulation:
- Cost = Rs. 2000 x 150 = Rs. 3,00,000/-

Simple Payback Period:

Payback Period=16/3
= 5.33 years

L5

a) Explain the significance of bulk density in refractory materials.
b) Explain the benefits of using monolithic refractories.
c) For combustion of 500 liters per hour of furnace oil, estimate the quantity of combustion air required per hour with 20% excess air. The specific gravity of furnace oil is 0.95. The fuel analysis is as follows: Carbon (C) - 84%, Hydrogen (H_2) - 12%, Sulphur (S) - 3%, Oxygen (O_2) - 1%.

Solution:

a) Refer Page no 156 or
Bulk density impacts a refractory material's strength and heat flow. High bulk density means fewer pores, making the material stronger and more durable but less insulating. Low bulk density means better insulation but less strength. Choosing the right bulk density helps balance strength and insulation based on application needs.
b) Refer Page no 161 or

	Monolithic refractories are seamless and joint-free, reducing weak spots. They are easy to install and repair, saving time and costs. Their design improves heat efficiency and durability, making them suitable for various industrial uses. **c)** Basis: 1kg of fuel Oxygen requirement for Carbon= (0.84*32/12) = 2.24 kg of O2 Oxygen requirement for Hydrogen= (0.12*16/2) = 0.96 kg of O2 Oxygen requirement for Sulphur= (0.03/1/1) = 0.03 kg O2 Total Oxygen required to be supplied = 2.24+0.96+0.03-0.01 = 3.22 kg of O2 Therefore, Air required to be supplied = 3.22/0.23 = 14 kg of air per kg of fuel Now, Mass of Fuel being supplied = 500*0.95 = 475 kg per hr Quantity of Air required with excess air = 475*14*1.2 = 7980 kg/hr
L6	Fill in the following blanks : 1. If the steam generation in a boiler is 24 tonnes in 3 hours and the fuel consumption in the same period is 2 tonnes, the evaporation ratio is _______. 2. A boiler generates 10 TPH of steam. If the feed water temperature is 80°C and the enthalpy of steam at 10 kg/cm² pressure is 665 kcal/kg, the total heat output per hour is _______ kcal/hr. 3. If the GCV of coal is 4000 kcal/kg, boiler efficiency is 75%, enthalpy of steam is 665 kcal/kg and enthalpy of feed water is 80 kcal/kg. The heat input required to generate 8000 kg/hr of steam is _______ kcal/hr. 4. If the boiler feed water temperature increases from 30°C to 80°C, the heat added per kg of water is _______ kcal. 5. The stochiometric air required for combustion of 30 kg of carbon is __________. 6. A boiler has a blowdown rate of 2% and produces 20 TPH of steam. The amount of blowdown water per hour is _______ kg/hr. 7. If the specific heat of flue gas is 0.24 kcal/kg°C and the flue gas temperature drops from 200°C to 150°C, the heat recovered per kg of flue gas is _______ kcal. 8. The ____________removes oxygen and carbon di-oxide from the boiler feed water on heating. 9. The process of periodically removing a portion of water from the boiler to remove accumulated impurities is called____________. 10. The heat required to convert water into steam at constant pressure and temperature is known as_______. **Solution:** 1. 12 2. 5850000 kCal/hr 3. 6240000 kCal/hr 4. 50 kcal/kg

	5. 348 kg 6. 400 kg/hr 7. 12 kCal/kg 8. De-aerator 9. Blowdown 10. latent heat of vaporization

Paper 2 Pink

23rd NATIONAL CERTIFICATION EXAMINATION
FOR
ENERGY MANAGERS & ENERGY AUDITORS - MARCH, 2023
PAPER - 2 : ENERGY EFFICIENCY IN THERMAL UTILITIES

Date : 25.03.2023 Timings : 14:00-17:00 HRS Duration : 3 HRS Max. Marks : 150

Section – I: OBJECTIVE TYPE **Marks: 50 x 1 = 50**

1.	Which one of the following is not true with respect to the role of nitrogen in the combustion of any fuel? A) produces oxides of nitrogen B) **reduces the volume of combustion by-products** C) dilutes the flue gases D) carries useful heat in flue gases
2.	Which of the following statement is true? A) LPG vapour is heavier than air B) LPG is a mixture of propane and butane C) LPG is a gas at normal atmospheric pressure D) **All of the above**
3.	One kg of wood contains 40% moisture and 5% hydrogen by weight. How much water is evaporated during complete combustion of one kg of wood? **A) 0.85 kg** B) 0.65 kg C) 0.45 kg D) 0.4 kg
4.	A boiler generates 8 TPH of steam at an efficiency of 75 %. The enthalpy added to steam in the boiler is 580 kCal/kg. The fuel flow rate with a GCV of 4000 kCal/kg is __________. A) 1457 kg/hr B) 870 kg/hr C**) 1547 kg/hr** D) 1768 kg/hr
5.	Which of the following benefits is not true of condensate recovery? **A) Reduces boiler output** B) Reduces water treatment costs C) Reduces energy input costs D) Increases feed water temperature
6.	Surface heat losses from a boiler depends on ____________. A) Wind velocity B) Emissivity C) Surface temperature D) **All of the above**
7.	Electrical conductivity of water is used for determining the ______ in boiler water. A) alkalinity of water B) PH **C) TDS** D) Hardness
8.	Steam at 6 bar has a sensible heat of 159.33 kCal/ kg and latent heat of 498.59 kCal/ kg. If the steam is dry saturated than the total enthalpy is _________. A) 159.33 kCal/ kg B) **657.92 kCal/ kg** C) 498.59 kCal/ kg D) 339 kCal/ kg
9.	In a PRV, which of the following does not change at the outlet?

	A) Temperature B) Pressure C) Volume D) **<u>Mass of Steam</u>**
10.	Which of the following does not contribute to steam savings? A) insulation of steam pipelines **<u>B) superheated steam for indirect process heating</u>** C) providing dry steam for process D) none of the above
11.	If a vapor-liquid combination of 1 kg at 150 ºC is supplied with 25 kCal of heat without change in state and at constant pressure conditions; its temperature will be __________. A) 100 ºC B**) 150 ºC** C) 125 ºC D) 175 ºC
12.	1M^3 of water is to be heated from 25 to 65 ^{0}C. the heat gained by the water will be ________. A) 70,000 kcal B**) 40,000 kCal** C) 40,000 kJ D) 100,000 kcal
13.	In a batch type furnace, which of the following would have adverse impact on energy efficiency? A) Maximizing the loading of furnace **B) <u>Increases the excess air</u>** C) Pre-heating the combustion air D) Reducing excess air.
14.	In which of the following equipment, a low mass ceramic fiber insulation most suitable to reduce specific fuel consumption. **A) <u>Batch type furnace</u>** B) Continuous Hoffmann tunnel kiln C) Rotary high temperature furnace D) Drying oven
15.	Quality of waste heat in flue gas refers to ____________. A) dust concentration in flue gas B**<u>) Temperature of flue gas</u>** C) moisture in flue gas D) corrosive gases in flue gas
16.	Estimate the efficiency of a re-heating furnace, operating at 10 tonnes per hour and consuming furnace oil of 450 kg/hour for reheating the material from 30ºC to 900ºC. Consider specific heat of material as 0.12 kCal/kgºC. GCV of the fuel is 10000 kCal/kg. **<u>A) 23.2%</u>** B) 25.2% C) 30.2% D) 21.2%
17.	In determining the optimal economic insulation thickness for a steam pipeline, which of the following factors need not be considered? A) surface temperature B) calorific value C) Boiler efficiency **<u>D) None of the above</u>**
18.	Which is not a property of Ceramic fiber insulation? A) low thermal conductivity B) light weight **C) <u>high heat storage</u>** D) thermal shock resistance
19.	The equipment having the lowest efficiency among the following in case of cogeneration plant is ____________. A) Boiler **B) ID Fan** C) Electric generator D) transformer

20.	In a boiler flue gas path, economizer is installed _______________. A) **before the air preheater** B) before superheater C) after the air preheater D) after ESP	
21.	Which type of the following co-generation system has high heat-to-power ratio? A) combined cycle **B) back pressure turbine** C) extraction condensing turbine D) reciprocating engine	
22.	The heat recovery device in which high conductivity bricks are used for storing heat is ____________. A) heat pipe B) heat pump C) thermo compressor **D) regenerator**	
23.	Which of the following is a unit of Measurement of Viscosity? A) Saybolt B) Redwood C) Centistokes **D)All of the above**	
24.	In which of the following Heat Exchanger type Temperature Cross cannot be achieved? A) Counter Flow B) Counter Current **C) Parallel Flow** D) Cross Flow	
25.	Water flow at rate of 30 m^3/hr at 15 ^oC in a 150 mm bore pipe horizontally. What is velocity of water flow in pipe? A) **0.47 m/s** B) 0.94 m/s C) 1.88 m/s D) 3.7 m/s	
26.	To drain condensate from tracer steam line the most common trap used is _______. A) **Bimetallic** B) inverted bucket C) float trap D) Both B and C	
27.	For any fuel, which of the following expression is true? A) GCV=NCV B) GCV< NCV **C) GCV> NCV** D) GCV= 1/ NCV	
28.	Liquid fuels such as Furnace oil is stored at elevated temperature for _____________. A) Quick Ignition **B) Ease of pumping** C) Driving out Moisture D) None of the above	
29.	The component of Coal which facilitate easy ignition is ____________. A) Moisture B) Ash C) Fixed Carbon D) **Volatile matter**	
30.	Which among the following doesn't leads to efficiency loss ______________. **A) Low H_2 content in fuel** B) High excess air C) Formation of CO D) High Flue gas temperature	
31.	The component requiring least amount of oxygen per kg of substance for complete combustion is ______________. A) Hydrogen B) Carbon	

	C) Sulphur	D) Both a and b
32.	Which of the following cause permanent hardness in Boilers? A) Calcium bicarbonate C) Sodium Chloride	 **B) Calcium Sulphate** D) Magnesium Bicarbonate
33.	For same inlet conditions of the steam which of the following will generate the maximum power ____________. **A) Condensing Turbine** C) extraction-cum-condensing turbine	 B) back pressure turbine D) extraction-cum-back pressure turbine
34.	Which among the following fuels when used in a Boiler has higher tendency in causing Cold End Corrosion of Air Preheater Baskets? **A) Heavy Furnace Oil** C) Naphtha	 B) Diesel Oil D) Kerosene
35.	The difference in temperature between steam and condensate is the principle of operation of ____________. A) thermodynamic trap C) orifice type trap	 **B) thermostatic trap** D) float trap
36.	The purpose of using de-mineralised water in boiler is for ________________. **A) Preventing scale formation** C) Preventing erosion	 B) Improving evaporation rate D) Deaeration
37.	A recuperator in a furnace is used to extract heat from flue gases for preheating ________. A) Stock C) Furnace oil	 B**) Air** D) All of the above
38.	The emissivity of conventional refractories used in a furnace _______________. A) increases with increase in temperature **B) decreases with increase in temperature** C) remains constant D) decreases with increase in furnace pressure	
39.	Identify the component not common to subcritical and super critical boilers ___________. **A) Steam drum** C) Economiser	 B) Super heaters D) Reheater
40.	Flash steam quantity per kg of condensate depends upon ____________. A) condensate pressure only B) condensate pressure and flow C) **condensate pressure and flash steam pressure** D) none of the above	
41.	A paper industry uses a back pressure turbine cogeneration system. This is called ______. A) bottoming cycle C) Open cycle	 B) combined cycle **D) topping cycle**

42.	The device used to upgrade a lower pressure steam to a higher pressure steam is ______. A) heat pump B) heat pipe C) heat wheel **D) none of the above**
43.	In an efficiency test of a coal fired boiler, O_2 percentage in flue gas at furnace and Air preheater outlet were observed to be 3% and 5.5 % respectively. Which out of the following could be the probable reason for higher O_2 % at air preheater outlet? A) High excess air B) Low furnace draft C) Fouling of Air preheater baskets **D) Air preheater seal leakage**
44.	Select the correct statement with respect to steam _____________. A) latent heat at critical point is zero B) evaporation is a constant temperature process C) higher the pressure lower the latent heat **D) All of the above**
45.	Two identical pipelines carry hot brine over a distance of 200 m. Pipes are having insulation made up of different materials having thermal conductivity K1 and K2 (K1>K2), but having same thickness. Which will supply brine at a higher temperature at the delivery side compared to other pipe? **A) The pipe insulated with K2** B) The pipe insulated with K1 C) Both will deliver at same temperature D) Data insufficient
46.	Which type of boiler has maximum Specific Energy consumption for coal sizing? A) AFBC boiler B) CFBC boiler C**) Pulvorised boiler** D) stoker fired boiler
47.	Which of the following is an expression of Turbine heat rate? A) Kcal/KWh B) KJ/ KWh C) MJ/ MWh D) **All of the above**
48.	The waste heat recovery equipment that doesn't require any work input for performing its function is _______________. A) Heat Pump B**) Heat Pipe** C) Heat wheel D) All of the above
49.	The effectiveness of a counter flow heat exchanger, é=1 when __________. A) Inlet temperature of cold fluid equals Inlet temperature of hot fluid B) **Outlet temperature of cold fluid equals Inlet temperature of hot fluid** C) Inlet temperature of cold fluid equals outlet temperature of hot fluid D) Outlet temperature of cold fluid equals outlet temperature of hot fluid
50.	What is the primary mode of heat transfer in an oil fired melting furnaces a) convection **b) radiation** c) conduction d) pulsation

.... End of Section – I ....

Section - II: SHORT DESCRIPTIVE QUESTIONS **Marks: 8 x 5 = 40**

<table>
<tr><td>S-1</td><td>For combustion of 300 kg/hr of natural gas containing 100% methane,
i) Write the stoichiometric equation.
ii) Calculate the percentage of CO_2 in the dry flue gas while 10 % excess air is supplied for gas firing system.
iii) Calculate air to fuel ratio by volume basis with excess air.</td></tr>
<tr><td>Ans</td><td>i)Stoichiometric equation
$$\mathbf{CH_4 + 2\,O_2 \rightarrow CO_2 + 2\,H_2O}$$ $$\mathbf{16 + 64 \rightarrow 44 + 36}$$
16 Kg of Methane requires 64 Kg of Oxygen. (64/16=4)
16 Kg of Methane produces 44 Kg of CO2. (44/16=2.75)
300 Kg/hr of Methane requires 1200 Kg/hr of Oxygen.
300 Kg/hr of Methane produce 825 Kg/hr of CO2.
ii) Theoretical air required for combustion = 1200 / 0.23 = 5217.4 Kg/hr
Considering 10% excess air,
Actual air supplied for combustion = 5217.4 x 1.10 = 5739.14 Kg/hr of air
Flue gas generation with 10%excessair = 300 +5739.14 = 6039.14 Kg/hr
% CO_2 generation in the dry flue gas = (825/44) / {(0.77*5739.14/28) + (825/44) + (5217.4*0.1*0.23/32)} *100= 10.39 %
iii)Actual Air to fuel ratio on volume basis = (5739.14/28.28)/(300/16)=10.8%</td></tr>
<tr><td>2</td><td>A) A 5 TPH capacity boiler is generating saturated steam at 8 kg/ cm^{2}g. The following operating parameters were observed during the survey.
Furnace oil consumption - 200 kg/hr.
GCV of furnace oil - 10,500 kCal/kg
Quantity of steam generation - 3000 kg/hr
Feed water temperature - 60 ^oC
Enthalpy of dry saturated steam - 660 kCal/kg
Dryness fraction - 0.9
Saturation temperature of steam - 170 ^oC
Calculate the boiler efficiency by direct method.
B) In a paper industry, 40,000 kg/hr of soda liquor with specific heat of 0.38 kCal/kg°C is heated using saturated steam at 8 bar in a heat exchanger from 70°C to 120°C. Calculate the amount of steam required in Tons per hour for heating using the following data:
<table><tr><td rowspan="2">Steam Pressure (bar)</td><td rowspan="2">Steam Temperature °C</td><td colspan="3">Enthalpy kCal/kg</td></tr><tr><td>Water</td><td>Evaporation</td><td>Steam</td></tr><tr><td>8.0</td><td>170</td><td>170</td><td>490</td><td>660</td></tr></table></td></tr>
</table>

Ans	A) Sensible Heat output = (3000 x 0.1) x (170-60) = 33000 kCal Latent Heat output = (3000 x 0.9) x (660-60) = 1620000 kCals Boiler Efficiency = (1620000 + 33000)/(200 kg x 10500 kcal/kg) x 100 = 78.71% B) Heat gain by soda liquor = 40000 x 0.38 x (120-70) = 7,60,000 kCal/hr Heat lost by saturated steam = 7,60,000 Kcal/hr Steam required for heating = 7,60,000/490 = 1551 kg/hr Amount of steam required for heating = 1.51 Ton/hr
S3	In a chlor-alkali process industry, 150 TPD caustic solution at 33% concentration is dried to 50% concentration by using a steam from oil fired boiler. The existing single effect evaporator, where steam input to moisture removal ratio is 1.0 kg/kg is replaced by a triple effect evaporator where the ratio of steam input to moisture removal is 0.5 kg/kg for energy saving measure. Determine the steam consumption reduction per day and also fuel oil saving per day if the evaporation ratio of oil-fired boiler is 13.
Ans	Dry caustic in the solution of 0.33 concentration= 150 TPD x 0.33 = 50 TPD Inlet moisture / day = (150 – 50) = 100 TPD Dry caustic in the outlet solution of 0.50% concentration = 50% Outlet quantity / day = 50 / 0.5 = 100 TPD (50%DRY AND 50% MOISTURE) Outlet moisture / day = 100 TPD - 50 TPD= 50 TPD Moisture removed/ day (INLET- OUTLET) = 100 – 50 = 50 TPD Initial steam consumption IN **single effect evaporator** @ 1 kg/kg = 50 TPD Steam consumption with triple effect evaporator @ 0.5 kg/kg = 50 x 0.5 = 25 TPD Steam savings per day = 50 – 25 = 25 TPD FO savings / day at evaporation ratio of 13 = 25/13= 1.92 TPD
S4	Match the following: a) Heat pump — 1) Feed Water b) Regenerator — 2) Condensate discharge c) Thermocompressor — 3) Gas to Air Heat recovery d) Steam Trap — 4) Low to Medium Pressure Steam e) Economizer — 5) Refrigerant

Ans	a) Heat pump — 5) Refrigerant b) Regenerator — 3) Gas to Air Heat recovery c) Thermocompressor — 4) LP to MP Steam d) Steam Trap — 2) Condensate discharge e) Economizer — 1) Feed Water
S5	Briefly explain the operation of a thermic fluid heater used in a Textile Industry and its advantages over steam heating system using steam boiler.
Ans	Refer guidebook 2, page no 56-57
S6	An industrial boiler rated at 120 T/h produces saturated steam for heating application at 4 MPa pressure. Due to constraints in water quality, the operator was recommended for keeping a boiler blowdown rate of 1% of feed water on a continuous basis to maintain feed water TDS. Calculate the annual revenue loss in Rs. Lakhs on account of boiler blowdown using the following data. Type of fuel fired - Heavy furnace oil GCV of oil - 9000 kCal/l Cost of fuel - Rs.65000/ kl Boiler efficiency - 80% Enthalpy of boiler water at 4 MPa - 1087 kJ/kg Enthalpy of Feed water inlet - 420 kJ/kg
Ans	Steaming rate of boiler = 120 T/hr Recommended blowdown = 1% = 120 x 1/100 = 1.2 T/hr Enthalpy loss of feedwater due to blowdown = $1.2 \times 10^3 \times (1087 - 420) / 4.18$ = 191483.25 kCal /hr Fuel wasted in blowdown = 191483.25 / (0.8 x 9000 kCal /l) = 26.59 litres / hr Annual revenue loss = 26.59 lit/hr x 65000/ 1000 x 24 x 365 = Rs.151 Lakhs
S7	Give Brief answer:

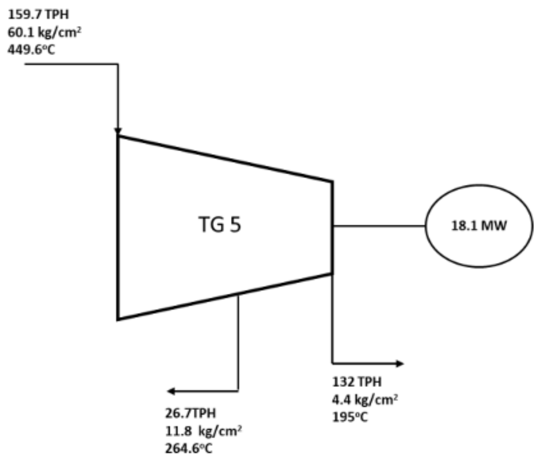
A	Among the constituents of furnace oil, percentage of ______ influences the exhaust flue gas leaving temperature.
B	Sox formation in FBC boiler is controlled by adding _____ in bed material.
C	For a super critical boiler operating at 246 bar and 565 ^{0}C the latent heat addition to feed water is _____ kCal?
D	The type of steam trap used for main steam distribution line is _____ .

E	__________ is predominantly used as a waste heat recovery device in glass melting furnaces.

Ans

A) Sulphur
B) Dolomite
C) Zero
D) Thermodynamic
E) Regenerator

S8 In a co-generation system, when the power generation was 18.10 MW, the following systems were assessed.



Enthalpy of main steam to the turbine : 788 kcal/kg.
Enthalpy of MP steam : 708 kcal/kg
Enthalpy of LP steam : 679 kcal/kg

Calculate the following:

i) Heat to Power ratio
ii) The Energy Utilisation Factor (EUF) for the co-generation plant with 35 T/hr of coal consumption having a calorific value of 4500 kCal/kg.

Ans

Heat input to the turbine = 788 kCal/kg x 1,59,700
= 1,25,843 MCal/hr.
Heat output in MP steam = 708 kcal/kg x 26,700 kg/hr
= 18,903 MCal/hr.
Heat output in LP steam = 679 kCal/kg x 1,32,000 kg/hr
= 89,628 MCal/hr.
Power output converted to heat units = 18100 kW x 860 kcal/hr
= 15,566 MCal/hr.
i)Heat to Power Ratio = (18903+89628)/15566) = 6.97

ii)Heat Input to the Co-generation plant = 35 x 1000 x 4500 = 157500 MCal/hr.
Energy Utilisation Factor = (18,903+89628+15566)/ 157500
= 78.8%

………….. **End of Section – II** ……………

Section - III: LONG DESCRIPTIVE QUESTIONS **Marks: 6 x 10 = 60**

L-1 In an automobile industry, electrical heated furnace of efficiency 80%, is used for heat treatment of the components. The heat treatment cycle and corresponding energy consumption is given below:

S.No	Heat treatment cycle	Temperature ^{0}C	Time hrs	Power drawn in kW
1	Heating cycle	30 – 900	4	100
2	Holding cycle	900	5	200
3	Cooling cycle	900 – 70	6	50

The electrical energy drawn in each sub-cycle is uniform and plant operates 40 batches per month. The cost of electricity is Rs. 10/kWh.

The management has decided to replace the electric furnace with Furnace Oil fired furnace with efficiency of 50%. The cost of F.O is Rs. 40/kg. Calculate cost savings and payback period of converting from electric to oil fired furnace. Investment for FO fired furnace is Rs. 25 lakhs. The GCV of F.O is 10,000 kCal/kg.

Ans Energy consumption per treatment batch:

Heat up time = 100 x 4 = 400 kWh;
Holding time = 200 x 5 = 1000 kWh
Cooling time = 50 x 6 = 300 kWh
Total energy consumption per batch= 1700 kWh
Monthly energy consumption by electric heat treatment furnace:
= 1700 x 40
= 68,000 kWh / month
Actual consumption by the components at electrical furnace efficiency of 80%
= (68000 x 0.8)
= 54,400 kWh / month
Equivalent FO required to be supplied to the oil
fired furnace at an efficiency of 50% = 54,400 x 860 / (10000 x 0.5)
= 9356.8 kg / mth
Annual Cost saving = [(68000 x 10) – (9356.8 x 40)] x 12
= Rs.36,68,736 / yr
Payback period = 2500000 / 3668736
= 8.2 months

L-2
a) Explain the Mechanical De-aeration and Chemical De-aeration.
b) Explain the following properties of Refractories.
1. Cold Crushing Strength 3 Creep
2. Refractories Under Load 4 Reversible thermal Expansion.

Ans
a)Refer guidebook 2, page no 48
b) Refer guidebook 2, page no 156-158

L-3	A heat exchanger is to be designed to condense the hydrocarbon vapour mixture from a distillation column at the rate of 11.0 kg/sec which is available at its saturation temperature of 120 ^oC. The latent heat of condensation of the hydrocarbon vapour mixture is 450 kJ/kg. The cooling water at 32 ^oC is used in counter current direction at the of 58 kg/sec to condense the vapour mixture. The specific heat of cooling water is 4.18 kJ/kg ^oC. Determine the LMTD and area of the heat exchanger surface if the overall heat transfer coefficient is 550 J/m^2 ^oC.
Ans	Heat loss in Hydrocarbon vapour mixture = Heat gain in cooling water 11 x 450 = 58 x 4.18 x (T -32) 4950= 242.44 x(T-32) T = 52.4 ^oC Water leaves the exchanger at 52.4^oC LMTD = (120-32) – (120-52.4) / Ln [(120-32)/(120-52.4)] = (88-67.6)/ Ln(88/67.6) = 77.4 ^oC LMTD of counter flow pattern = 77.4 ^oC Q = mxCp x ΔT = U x A x LMTD 58 x 4.18 x (52.4 – 32) x 1000 = 550 x A x 77.4 A = 116.3 m^2 Area of the heat exchanger surface is 116.3 m^2
L4	As a part of energy conservation measure Air preheater (APH) is installed in fired heater. The APH is designed to preheat 240 m^3/min of combustion air to 250 ^oC. Flue gas enters the APH at 375 ^oC. Calculate the flue gas leaving the stack and also determine the improvement in furnace efficiency after the installation of APH with the following data. Density of Air = 1.15 kg/m^3 Specific Heat of Air = 0.23 kCal/kg ^oC Specific heat of flue gas = 0.26 kCal/kg ^oC Calorific value of fuel = 9850 kCal/kg Air to fuel ratio = 18 Efficiency of furnace = 73% Ambient Temperature = 30 ^oC
Ans	Amount of Air Flow = 240 x 60 x 1.15 = 16560 kg/hr Amount of Fuel = 16560 /18 = 920 kg/hr Amount of Flue gas = 16560 + 920 = 17480 kg/hr Heat absorbed by combustion air

	= 16560 x 0.23 x (250-30) = 837936 kcal/hr Temperature difference in flue gas = 837936 / (17480 * 0.26) = 184 ^{o}C Flue gas leaves the stack at temp = 375 -184 = 191 ^{o}C % of heat recovered in APH = Heat absorbed by air / Heat input x 100 = 837936 x 100 / (920 x 9850) = 9.2 % Overall efficiency after APH = 73 % + 9.2 % = 82.2 %
L 5	A process industry decides to reduce the heat loss from steam pipe network in view of the increase in fuel charges. A proposal was prepared by Energy management team for providing extra insulation over the existing one. The details are given below. Total length of steam Pipe : 200 m Thickness of existing insulation : 25 mm Thickness of new insulation : 25 mm External Diameter of the bare pipe :150 mm Surface temp of old insulation : 90 deg Surface temp expected with new insulation : 50 deg Ambient temperature : 30 deg GCV of fuel : 4200 Kcal/Kg New fuel cost : Rs.5000 /Ton Boiler efficiency : 80% Total cost for providing additional insulation : Rs.5 lakhs Calculate the simple payback period in year for the above modification.
Ans	Heat loss with previous insulation/ m^2 S1 = [10 + (Ts – Ta)/20] x (Ts – Ta) = [10 + (90 – 30)/20] x (90-30)

	$= 780$ kCal/hr-m^2 S2 = [10 + (Ts – Ta)/20] x (Ts – Ta) = [10 + (50 – 30)/20] x (50-30) $= 220$ kCal/hr-m^2 Area of original pipe for heat transfer - $2\pi R_1 L$ $A_1 = 2\pi$ x (75+25/1000) x 200 = 125.66 m^2 $A_2 = 2\pi$ x (75+50/1000) x 200 = 156.1 m^2 Savings in heat energy = (780 x 125.66) – (220 x 156.1) = 63,672.8 kCal/hr Reduction in fuel consumption = 63,672.8 / (0.8 x 4200) = 18.95 kg/hr Annual savings = 18.95 x 24 x 365 x (5000/1000) = Rs.8,30,010/- Payback period = 5,00,000/ 8,30,010 = 0.6 years
L6	A combined Heat and Power unit running on Natural gas utilises steam produced from its waste heat recovery unit for process application apart from producing electric power through a gas turbine unit. Due to price escalation and restricted availability of gas, the management decides to operate the unit for 6 hours a day for meeting its entire demand during peak hours when the market cost of electricity is Rs.12/kWh. During non-peak hours, it draws the power from the grid when average market price is Rs. 3.2/kWh. The steam requirement for remaining part of the day is met from an auxiliary boiler running on coal. A) Calculate the amount of fuel consumed for running the Gas turbine unit and Auxiliary boiler on daily basis. B) How much is the monetary gain in running the gas turbine during peak hours on daily basis. Assume heat and power demand of the industry is constant throughout the day. Following operational data may be used: Electrical output of Gas turbine unit- 5000 kW Gas Turbine exhaust gas temperature- 550 ^oC Stack flue gas temperature- 125 ^oC Sp heat of Flue gas – 0.25 kCal/kg ^oC Exhaust gas flow rate- 50 T/h Calorific value of Natural Gas- 9500 kCal/sm^3

	Cost of Natural gas – Rs. 10 /sm^3 Calorific value of Coal- 3500 kCal/kg Landed Cost of coal – Rs.4500/Ton Gas turbine Efficiency – 35% Efficiency of Aux.Boiler- 70%
Ans	A) i) Fuel for running gas turbine unit Heat input required for gas turbine = 5000 kW / 0.35 = 14285.7 kJ/s = (14285.7 /4.18)*3600 = 1,23,03,474 kCal/hr Amount of Natural gas burnt = Heat input required for gas turbine / Calorific value of Natural Gas = 1,23,03,474 / 9500 = 1295.1 Sm^3/ hr As Gas turbine is operated for 6 hours a day during peak hours, Natural gas consumption per day = 1295.1 x 6 = 7770.6 Sm^3 ii) Enthalpy of steam produced in WHRB = Heat lost by Flue gas from gas turbine = mc_px (Ti-To) = 50 x 10^3x 0.25 (550-125) = 5,312,500 kCal/hr Coal requirement in Aux. boiler for producing same amount of steam as produced by WHRB = Enthalpy of Steam / Aux. Boiler efficiency x GCV of Coal = 5,312,500 / (0.70 x 3500) = 2168 kg / hr Coal requirement per day (for 18 hr operation) = 18 x 2168 = 39024 kg/d B) Monetary gain in running gas turbine during peak hours i) Fuel cost for peak hour gas turbine operation = 6 x 1295.1 x 10 = Rs. 77706/- Electricity cost for 18 hr = 5000 x 18 x 3.2 = Rs. 2,88,000/- Coal cost for Aux. Boiler = 39.03 x 4500 = 1,75,635

	Total cost with 6 hours mode operation = 77706 + 2,88,000+ 1,75,635 = 5,41,341 ii) Cost for 24 hour grid drawal & Auxillary boiler Electricity charge for 6 hrs = 12 Rs.kWh x 5000 kW x 6 hr = 3,60,000/- Electricity cost for 18 hrs = 5000 x 18 x 3.2 = Rs. 2,88,000/- Coal charges (Aux Boiler) = 2.168 T/hr x 24 hrs x 4500 Rs./T = 2,34,144/- Total cost for 24 hr grid drawal = 3,60,000 + 2,88,000+ 2,34,144 = 8,82,144 Therefore savings = 8,82,144 – 5,41,341 = Rs.3,40,803/-

………….. End of Section – III ……………

Paper 2 Pink

22nd NATIONAL CERTIFICATION EXAMINATION
FOR
ENERGY MANAGERS & ENERGY AUDITORS - JULY, 2022
PAPER - 2 : ENERGY EFFICIENCY IN THERMAL UTILITIES

Date : 30.07.2022 Timings : 14:00-17:00 HRS Duration : 3 HRS Max. Marks : 150

Section – I: OBJECTIVE TYPE Marks: 50 x 1 = 50

1.	Which of the following is correct for 'Viscosity'. a) Increases with temperature b) Increase with pressure and temperature **c) Decreases with temperature** d) None of the above
2.	'Specific Heat' is measured with which unit. a) Kcal/Kg b) kcal/^oC c) Kg/cubic meter **d) None of the above**
3.	How much Energy is released from burning of 1 kg Hydrogen. **a) 28922 Kcal/Kg** b) 36200 Kcal/kg c) 8084 Kcal/Kg d) 2225 Kcal/Kg
4.	How much air is required for burning of 3 kg of Carbon in fuel. a) 8.0 Kg **b) 34.7 Kg** c) 3.6 Kg d) 47.8 Kg
5.	Which of the following refers to External Water Treatment Methods. a) Ion Exchange Process b) De-aeration c) Reverse Osmosis d) **All of the above**
6.	Which of the following is correct related to critical point of water? a) 221.2 bar absolute pressure and 374.18 Deg C b) Latent heat is zero. c) Super critical boilers operate above critical conditions d) **All of the above**
7.	With increase in steam pressure, which of the following is correct for 'Latent Heat' of water. **a) Latent heat decreases** b) Sensible heat decreases c) Boiling point decreases d) Total enthalpy decreases
8.	If h_f is 159 kcal/Kg, h_{fg} is 498 kcal/Kg , what will be total heat of steam with 5% Moisture. a) 649 Kcal/Kg **b) 632 Kcal/Kg** c) 657 Kcal/kg d) 624 Kcal/Kg

9.	Which of the following is function of steam trap : a) To discharge condensate as soon as it is formed. b) Not to allow steam to escape c) To discharge air and other non-condensable gases **d) All of the above.**
10.	Which of the following trap is suited for steam tracing applications. a) Inverted Bucket trap b) Ball Float trap **c) Thermostatic trap.** **d) Thermodynamic trap.**
11.	Recuperators are used for . **a) Preheating of combustion air** b) Preheating of Fuel c) Preheating of water. d) Preheating the stock.
12.	The wall losses of furnace depends on : a) Emissivity of wall b) Thermal conductivity of refractories c) wall thickness **d) All of the above**
13.	Determination of economic thickness of insulation depends on a) Cost and heat content of fuel b) Estimated cost of insulation and hours of operation c) Boiler efficiency **d) All of the above**
14.	The unit of surface heat loss is a) kcal/hr m **b) kcal/hr m^2** c) kcal/hr Deg C d) None of the above
15.	Electrostatic Precipitators can remove ash upto: a) 60-85 % of fly ash b) 70-95 % of fly ash **c) 95-99% of fly ash** d) 50-80% of fly ash
16.	Which of the following boiler will have lowest size for 500 MW generation. a) CFBC Boiler b) AFBC Boiler **c) PFBC Boiler** d) None of the above
17.	A co-generation system configuration in which heat is utilized and power is produced in next stage a) Combined cycle **b) Bottoming Cycle** c) Topping Cycle d) None of the above
18.	Simultaneous generation of steam, power and refrigeration refers to: a) Triple point **b) Trigeneration** c) Combined cycle generation d) Bottoming cycle cogeneration

19.	For every 15° C rise in feed water temperature of boiler will result into overall thermal efficiency improvement by ________ a) 6% b) 1% **c) 3%** d) 5%
20.	Which of the following is direct contact heat exchanger___________ a) Reboiler/Kettle b) Heat Pipe **c) Deaerator** d) Heat Pump
21.	A pinch analysis can result in a) Reduction in cooling water b) Increase in cooling water c) reduction in steam d) **both a & c**
22.	Regenerators utilizing waste heat are widely used in __________ a. Cement industries **b. Steel** **c. Glass melting furnace** d. Aluminium
23.	A pulp and paper needs steam at 3 bar and 10 bar in addition to the electric power. The most suitable cogeneration choice among the following will be a. Condensing turbine b. Back pressure turbine **c. Extraction cum back pressure turbine** d. Bottoming cycle
24.	Low combustion temperature in FBC boiler results in reduction of _______ a. Sox **b. NOx** c. CO_2 d. O_2
25.	An increase in bulk density of refractory increases its a. Volume stability b. Heat capacity c. Resistance to slag penetration **d. All of the above**
26.	The efficiency of a reheating furnace, operating at 10 tonnes per hour consuming furnace oil of 230 kg/hour for reheating the material from 40 °C-1100 °C (consider specific heat of material is 0.13 kcal/kg °C and calorific value of furnace oil is 10000 kcal/kg) is______ . a. 55 **b. 60** c. 65 d. 70
27.	The devise that upgrades a low temperature heat source to a high temperature sink is called a. Heat pipe **b. Heat pump** c. Plate heat exchanger d. economiser
28.	The difference between mean solid and mean gas velocity in FBC boilers is called a. Fluidization factor **b. Slip velocity** c. Settling velocity d. None of the above
29.	Which of the following is not a property of ceramic fibre insulation? a. Low thermal conductivity b. Light weight **c. High heat capacity** d. Thermal shock resistant
30.	Furnace wall heat loss does not depend on a. Temperature of external wall surfaces b. Velocity of air around the furnace **c. Temperature of combustion air** d. None of the above

31.	Which among the following is most viscous fluid? a. LDO b. Kerosene c. HSD **d. Furnace oil**
32.	Hot condensate at 4 bar g pressure has heat content of about 600 kJ/kg, when it released to atmospheric pressure (0 bar g), each kilogram of water can only retain about 419 kJ of heat, The latent heat of flash steam is 2134 kJ/kg, then percentage (%) flash steam available will be a. 11.48 % b. 12.48 % **c. 8.48 %** d. 14.48 %
33.	Correction factor for LMTD is applicable for a. Counter current b. Parallel flow **c. Cross flow** d. Both a & b
34.	Which one is the preferred waste heat recovery system in large gas turbine? a. Economiser b. Air pre heater **c. HRSG** d. Heat wheel
35.	An axial compressor is used in conjunction with which of the following a. Back pressure steam turbine **b. Gas turbine** c. Condensing turbine d. Extraction cum condensing turbine
36.	Pick up the wrong statement: The thermal efficiency of the furnace increases by a. Increasing the furnace loading **b. Increasing the excess air flow rate** c. Reducing the surface heat loss d. Minimizing the CO loss and unburnt losses
37.	Major heat loss in an oil-fired boiler is accounted by a. Blowdown loss b. Un-burnt carbon loss c. Surface radiation loss **d. Stack loss**
38.	For complete combustion of every kg of FO firing, the approximate theoretical quantity of air required is: a. 12 kg **b. 14 kg** c. 16 kg d. 18 kg
39.	Select the odd one among the following a. Condenser b. distillation column c. evaporator **d. cooling tower**
40.	The equipment having the highest efficiency in case of cogeneration plant is **a. Electric generator** b. Boiler ID fan c. Steam or gas turbine d. Boiler
41.	Oxygen percentage (by volume) can be measured in flue gas by using___________. a. Ultrasonic tester b. Potassium oxide probe c. Copper tubes **d. Zirconium oxide probe**
42.	1000 kg of water is to be heated from 30 to 70 °C. the heat gained by water will be a. 40000 kcal/hr **b. 40000 kcal** c. 40000 kJ d. 40000 kJ/hr

43.	Heat wheels are mostly used in situation of___________ a. high temperature exhaust gases **b. heat exchange between large masses of air having small temperature differences** c. heat transfer between a liquid and gas d. corrosive gases
44.	In a CFBC boiler the capture and recycling of bed materials is accomplished by a. Bag filter b. Settling chamber **c. Cyclone** d. Scrubber system
45.	The best quality of steam for industrial process heating is a. High pressure steam b. Wet steam c. Superheated Steam **d. Dry saturated steam**
46.	Which of the following is related with heat pipe_____________ **a) Can transfer upto 100 times more thermal energy than copper** b) Uses a pump for moving the working fluid c) Consists of several plates in series d) All the above
47.	Condensate recovery in steam system ______ a) Improves boiler feed water quality b) Maximizes boiler output c) Reduces water consumption **d) All the above**
48.	Across the pressure reducing valve of a steam system ____________. a) Output enthalpy decreases b) Steam becomes wet c) Steam temperature increases **d) Enthalpy remains the same**
49.	The flash point of a fuel is the ________temperature at which fuel can be heated so that the vapour gives off flashes momentarily when an open flame is passed over it. a) highest **b) lowest** c) medium d) None of the above
50.	Unit of heat to power ratio is ____________ a) kwh/kcal **b) kcal/kWh** c) kwh/btu d) All the above

.... End of Section – I ....

Section - II: SHORT DESCRIPTIVE QUESTIONS **Marks: 8 x 5 = 40**

S-1	The ultimate analysis of Indonesian coal is as given below: Carbon : 59%, Hydrogen: 4%, Sulphur : 0.56%, Mineral Matter: 14% Oxygen : 12%, Moisture: 9.43%, Nitrogen: 1.01% a. Find out actual mass of air supplied for combustion of 2000 kg/hr of coal with 60% excess air **3 Marks** b. Find out NCV of the fuel if GCV of the coal is 5500 kcal/kg **2 Marks**
Soln	a) Theoretical air required for complete combustion = [(11.6 x C) + {34.8 x (H_2 -O_2 /8)} + (4.35 x S)]/100 kg/kg of fuel = [(11.6 x59) + {34.8 x (4 -12/8)} + (4.35 x0.56)]/100 kg/kg of fuel = 7.73 kg of air/kg of fuel Excess air supplied = 60% Actual mass of air supplied = {1 + EA/100} x theoretical air = {1+60/100} X 7.73 = 12.37 kg of air/kg of fuel Air supplied for combustion of 2000 kg/hr of coal = (12.37 x 2000)/1000 = 24.74 TPH……………………………………3 marks b) NCV of the fuel GCV = NCV + 584 x (9H+M) 5500 = NCV + 584 x (9x0.04+0.094) NCV = 5234 kcal/kg …………………………………………………………………………………………..2 marks
S2	Name any five parameters required for determination of furnace oil fired reheating furnace efficiency by direct method.
Soln	Weight of input material t/Hr Furnace oil consumption litre/hr Specific gravity of oil Final material temperature Deg C Initial material temperature Deg C Outlet flue gas temperature Deg C Specific heat of the material Kcal/Kg Deg C GCV of Oil Kcal/Kg
S3	Milk is evaporated in a steam jacketed kettle of 700 kg capacity as a batch process. Milk is heated from 35 ^{O}C to 100 ^{O}C, where 35 % of its mass is driven off as vapour. The other data's are given below: Specific heat of milk is 0.9 kcal/kg ^{O}C Latent heat of steam at 1 kg/cm^{2}g is 525 kcal/kg. Ignoring the heat required for heating the kettle, calculate the quantity of steam required per batch.
S3 Sol	Quantity of Water evaporated from milk = 700 x 0.35 = 245 kg/batch Heat required to raise temperature of milk = 700x0.9x(100-35) = 40950 kcal/batch Amount of heat required to evaporate 245 kg of water = 245x540

	=132300 Kcal/Batch Total Heat required = 40950+132300 = 173250 Kcal/batch Total steam required =173250/525 =330 kg/batch.
S4	Calculate the heat loss from an uninsulated pipeline of 50 mm diameter of 500 mtr length carrying process liquid. The surface temperature of the pipe is 150 ^{O}C. After process modification the liquid temperature was brought down resulting in a surface temperature of 50^{O} C. Calculate the reduction in heat loss if the ambient temperature is 32^{o}C in both the cases.
S4 Sol	Existing Heat loss (S) = {10+(150-32)/20}x(150-32) = 1876.2 kcal/hr-m^2 ………………………………… 2 marks Modified Heat Loss (S1) = {10+(50-32)/20}x(50-32) = 196.2 kcal/hr-m^2…………………………………… 2 marks Reduction in heat loss = πxDxL x(2035-196.2) = 3.14x0.05x 500x(1876.2-196.2) = 131946.89 kcal/hr…………………………………………. 1 mark
S5	Write short notes on : Each 2.5 Marks a) Heat wheel b) Heat pump
S5 Sol	Heat wheel – Refer Guidebook -2, Page 222 Heat pump – Refer Guidebook -2, Page 228
S6	A counter flow heat exchanger using hot process liquid is used to heat water. The flow rate of water is 10 m^3/hr. The process liquid enters the heat exchanger at 95 Deg C and leaves at 55 Deg C. The inlet and exit temperatures of water are 30 Deg C and 42 Deg C respectively. The specific heat of water is 4.18 KJ/Kg Deg C. Calculate the heat transfer area, if the overall heat transfer coefficient is 762 W/m^{2} ^{O}C.
S6 Sol	Water flow rate = 10 x 1000 = 10,000 kg/hr Heat content in water = 10000 x 4.18 x (42-30) = 10000 x 4.18 x12 = 5,01,600 kJ/hr = 501600/3600 = 139.33 kW Now $LMTD_{CF} = \dfrac{\Delta T_1 - \Delta T_2}{\ln\left(\dfrac{\Delta T_1}{\Delta T_2}\right)}$ ΔT_1 = 95-42 = 53 ΔT_2 = 55-30 = 25 $= \dfrac{53-25}{\ln\left(\dfrac{53}{25}\right)}$

	$= \dfrac{28}{\ln\left(2.12\right)}$ $= 37.33\ ^0C$ Area of Heat Exchanger = 139.33x1000/ (762x37.33) = 139330 /28445.46 = 4.89 m^2
S7	A coal fired boiler is generating 40TPH steam and operates for 8000 hrs/year. The TDS in boiler feed water is 500 ppm. The maximum permissible limit is 3000 ppm and make up water is 8%. The temperature of blow down water is 170 ^0C and feed water temperature is 75 ^0C. The GCV of fuel is 5000 kCal/kg and efficiency of boiler is 72%. Calculate the fuel saving achieved by reduction in blow-down, if the TDS of feed water is reduced to 300 ppm.
S7 Sol	$Blow\ Down\ (\%) = \dfrac{[Feed\ Water\ TDS\ in\ ppm\ x\ \dfrac{Makeup\ Water(\%)}{100}\ x\ 100}{(Maximum\ Permissible\ TDS - Feed\ Water\ TDS}$ Initial blow down = (500 x 8/100 x 100)/(3000-500) = 1.6 % Improved blow down with TDS of 300 ppm = (300 x 8/100 x 100)/(3000 – 300) = 0.88% Reduction in Blow down = 1.6 – 0.88 = 0.72% Reduction in blow down quantity = 0.72 x 40 x 1000/ 100 = 288 kg/hr Heat Energy Saving = M x Cp x dT = 288x 1 x (170 – 75) = 27360 kcal/hr Fuel Oil Saving = 27360 / (5000 x 0.72) = 7.6 kg/hr **Annual Fuel Saving = 7.6 x 8000 = 60800 kg/annum = 60.8 MT/annum**
S8	Explain the difference between bottoming and topping cycle with an example.
S8 Sol	Refer Guidebook -2, Page no: 194 & 195

…………. End of Section – II ……………

Section - III: LONG DESCRIPTIVE QUESTIONS **Marks: 6 x 10 = 60**

L-1	i) Explain how a FBC boiler works. How is it different from CFBC boiler? 5 Marks ii) List any five properties of refractories. 5 Marks
S	i) Refer Guidebook -2, Pg 173, 178 & 179 ii) Refer Guidebook -2, Pg 156 & 157
L-2	Each 2 Marks 1) Explain the working of a direct contact heat exchanger. 2) Explain any two methods of testing of steam traps. 3) What are the benefits and applications of pinch technology in process industry? 4) List any two advantages of ceramic fibre. 5) Why slight positive pressure is to be maintained in a reheating furnace?

S	1) Refer Guidebook -2, Pg 230 2) Refer Guidebook -2, Pg 94 to 96 3) Refer Guidebook -2, Pg 252 4) Refer Guidebook -2, Pg 165 5) Refer Guidebook -2, Pg 132
L-3	An oil refinery has a captive power plant with petcoke fired boiler. The following are the data collected to assess the boiler performance.

Ultimate analysis of Petcoke (%)	
Carbon	88.8
Hydrogen	3.6
Nitrogen	1.2
Oxygen	1.4
Sulphur	3.6
Moisture	1.4

GCV of Petcoke : 8430 kcal/kg
O_2 in flue gas : 6 %
Flue gas temperature : 250 °C
Heat loss due to radiation & convection : 1 %
Loss due to unburnt in fly ash & bottom ash : 0.5%
Specific heat of flue gas : 0.29 kcal/kg °C
Specific heat of water vapour : 0.45 kcal/kg °C
Ambient Temperature : 30 °C
Humidity in ambient air : 0.0204 kg/kg dry air
Steam generation at 110 barg & 520 °C
Steam enthalpy at generation pressure and temp : 816 kcal/kg
Feed water temperature : 200 °C
Steam drum pressure : 115 bar g
Saturated liquid enthalpy at steam drum pressure: 352 kcal/kg

Calculate the following:

a) Boiler efficiency using indirect method **8 Marks**

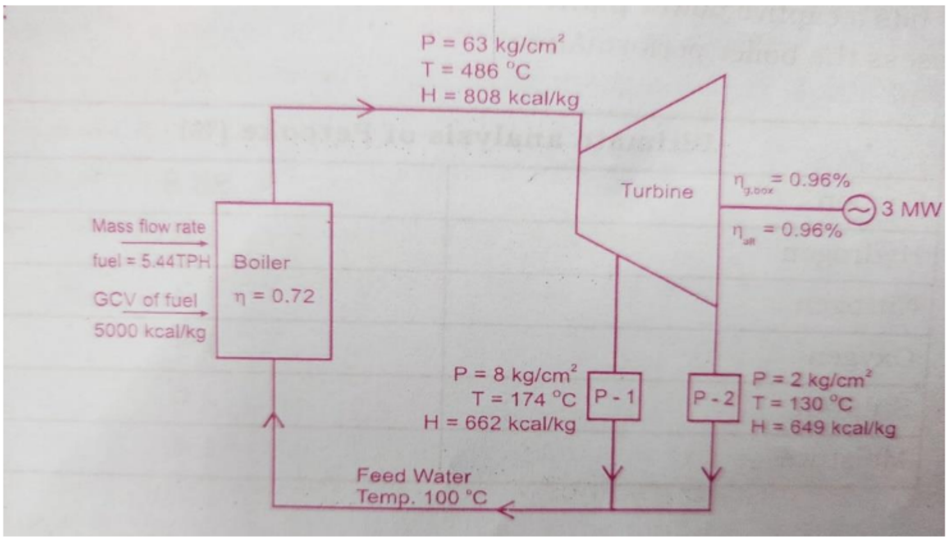
b) Specific boiler steam generation MT/MT of petcoke (Evaporation Ratio) **2 Marks**

L 3 Sol	a)	Theoretical Air required	= {(11.6x0.888)+[34.8x(0.036-.014/8)]+4.35x0.036} = 11.64	kg air / kg of petcoke
		% Excess Air supplied	= (6/(21-6)x100 = 40.0	%
		Actual Air supplied	= (1+40/100)x11.65 = 16.31	kg air / kg of petcoke
		Mass of dry flue gas	={(0.888x44/12)+0.012+(16.31x0.77) +(16.31 -11.65)x0.23+(0.036x 64/32)} = 16.97	kg air / kg of petcoke
		Stack losses, L1	= 16.97x0.29x(250-30)/8430x100 = 12.84	%
		Loss due to formation of water vapor from H2 in fuel, L2	= 9x0.036x{584+0.45*(250-30)}/8430x100 = 2.63	%
		Loss due to moisture in fuel, L3	= 0.014x{584+0.45x(250-30)}/8430x100 = 0.11	%
		Loss due to moisture in Air, L4	=16.31x0.0204x0.45x(250-30)/8430x100 = 0.39	%
		Loss due to radiation and convection	= 1.0	%
		Loss due to unburnt in ash	= 0.5	%
		Efficiency of boiler using indirect method	= (100-12.84-2.63-0.11-0.39-1.0-0.5) **= 82.53**	**%**
	b)	Heat added per unit of steam generation	= (816-200) = 616.0	kcal/kg of Steam
		Heat supplied by fuel for steam generation	= (82.5/100)x 8430 = 6957	kcal/kg of petcoke
		Specific boiler steam generation (Evaporation Ratio)	= 6957/616 = 11.29	

L4

In a paper industry a coal fired boiler of 72% efficiency is proposed to be replaced with paddy husk fired boiler of 65% efficiency. The boiler and steam requirement details are given below.

GCV of coal	= 3900 kcal/kg
Cost of coal	= Rs.12,000/MT
GCV of paddy husk	= 3500 kcal/kg
Cost of paddy husk	= Rs 9,000/MT
Quantity of steam requirement	= 20 TPH
Enthalpy of steam	= 760 kcal/kg

	Enthalpy of feed water =120 kcal/kg Annual operating hours of boiler = 8000 hours Calculate the annual fuel cost savings by changing over to paddy husk boiler?
L4 Sol	<u>For Coal Fired Boiler :</u> Heat content in the output steam = 20000x (760-120) = 12800000 kcal/hr Coal requirement = (12800000)/(3900x0.72) = 4558.4 kg/hr Annual operating hours = 8000 Annual coal consumption = 4558.4 x 8000 = 36467.2 MT Annual cost of coal = 36467.2 x Rs 12000 = 4376 lakhs <u>For Paddy Husk Fired Boiler:</u> Paddy husk requirement = (12800000)/(3500*0.65) = 5626.4 kg/hr. Annual operating hours = 8000 Annual paddy husk consumption = 5626.4 x 8000 = 45011.2 MT Annual cost of paddy husk = 45011.2 x Rs 9000 =Rs 4050.98 lakh. Annual fuel Cost saving = 4376– 4050.98 = Rs 325.02 lakhs
L 5	The co-generation configuration of a process plant along with relevant data are given in the figure below.  If the extraction steam from the turbine is 8 TPH, calculate the following a) Energy Utilization Factor **6 Marks**

	b) Heat to power ratio, kW thermal to kW electrical **4 Marks**
L5 Sol	a) Energy Utilization Factor Total steam flow into co-generation system: 0.72 = X x (808-100) / (5000 x 5.44 x 1000) 19584000 = X x (808-100) X = 27661.0 kgs or 27.66 TPH Extraction steam flow = 8TPH Back pressure steam flow = 27.66 - 8 = 19.66TPH EUF = (Electrical o/p (Qe) + Thermal o/p (Qt)) / Fuel Input x GCV (Qf) Qf = (5.44 x 1000 x 5000) = 27.2 Mkcals Qe = 3 x 1000 x 860 = 2.58 Mkcals Qt = [8 x 1000 x(662-100)] + [19.66x1000x(649-100)] = 4.49 + 10.79 = 15.28 Mkcals EUF = ((2.58 + 15.28) x 100)/ 27.2 = 0.656 x 100 = 65.66 b) Heat to power ratio, kW thermal to kW electrical Q_{th} = 15.28 / 860 = 17.77 MW Q_e = 2.58 /860 = 3 MW Heat to power ratio = 17.77 / 3 = 5.92
L6	a) Two boilers A & B are delivering steam in equal amount to a common header, both at pressure of 15 bar. Boiler A has super heater and Boiler B is without super heater. The temperature of steam supplied by boiler A is 300 ^{0}C. The temperature of resulting mixture of steam in the common header is 235 ^{0}C. Find out the dryness fraction of steam supplied by the boiler B. Take specific heat of superheated steam, C_p = 2.09 kJ/kg Properties of Steam at 15 bar: • Saturation temperature, t_{sat} = 198.3 ^{o}C • Sensible heat of Steam, h_f = 844.6 kJ/ kg • Latent heat of steam, h_{fg} = 1945.3 kJ/ kg • Total heat of steam, h_g = 2789.9 kJ/kg **5 Marks**

	b) An oil-fired boiler is rated for 10 TPH of saturated steam and pressure of 10 kg/cm^2 at F&A condition. The Boiler is operating at rated pressure with a feed water temperature of 60^{o}C. Estimate the maximum possible steam generation at the operating pressure. The following data is provided Latent heat of steam at 100^{o}C is 540 kcal/kg Enthalpy of steam at 10 kg/cm^2 is 662 kcal/kg **5 Marks**
L6 Sol	Ans: a) Let us assume each boiler delivers 1 kg of steam. Then the mass of the mixture of steam in header = 1 + 1 = 2 kg. Using Heat and Mass Balance: Enthalpy from Boiler A + Enthalpy from Boiler B = Enthalpy in common header $\{2789.9 + 2.09 \times (300-198.3)\} + \{844.6 + X \times 1945.3\} = 2 \times \{2789.9 + 2.09 \times (235 - 198.3)\}$ $X = 0.97$ b) Ans: Maximum possible steam generation = 10 x 1000 x 540 / (662-60) = 8970 kg/hr or 8.97 TPH

………….. **End of Section – III** ……………

21st NATIONAL CERTIFICATION EXAMINATION
FOR
ENERGY MANAGERS & ENERGY AUDITORS

PAPER - 2 : ENERGY EFFICIENCY IN THERMAL UTILITIES

Date : 27.03.2021 Timings : 14:00-17:00 HRS Duration : 3 HRS Max. Marks : 150

General Instructions :

- *Please check that this question paper contains **8** printed pages*
- *Please check that this question paper contains **64** questions*
- *The question paper is divided into three sections*
- *All questions in all three sections are compulsory*
- *All parts of a question should be answered at one place*

Section - I: OBJECTIVE TYPE **Marks: 50 x 1 = 50**

1.	The ratio of the weight of a given volume of oil to the weight of the same volume of water at a given temperature is a) Density **b) Specific gravity** c) Viscosity d) Specific volume	**B**
2.	Which of the following Agro residues has the highest GCV ? a) Deoiled bran b) Paddy husk **c) Saw dust** d) Coconut shell	**C**
3.	For each kg of CO formed in combustion reaction, the heat released in kcal is a) 8084 kcal b) 2430 kcal **c) 5654 kcal** d) 2224 kcal	**C**
4.	The typical evaporation ratio of Coal Fired Boilers with a calorific value of 4500 kcal/kg will be in the range of a) 2.0-3.0 **b) 4.0-5.5** c) 13.5-14.5 d) 11.0-13.0	**B**
5.	Which of the following fuels require the lowest excess air %? a) Pulverized Coal b) Fuel Oil **c) Natural Gas** d) Wood	**C**
6.	Which of the following boiler water treatment ensures complete removal of salts? **a) Demineralization** b) Softening c) De-Aeration d) none of the above	**A**
7.	The velocity of steam in steam pipe is directly proportional to a) Number of bends in pipe b) 5^{th} power of the diameter of pipe **c) Specific volume of steam** d) Length of pipe	**C**
8.	Which of the following traps work under the principle of buoyancy? **a) Inverted bucket type** b) Thermodynamic c) Thermostatic d) all of the above	**A**
9.	The working medium in a Thermo-Compressor is a) Electricity b) Compressed air c) Atmospheric air **d) Steam**	**D**
10.	Which of the following is not true of "Critical Point" of steam/water mixture? a) The temperature at critical point is 374.15 Deg	**D**

	b) The pressure at critical point is 221.2 bar c) Saturated liquid and saturated vapour lines meet at critical point **d) Enthalpy of evaporation is maximum at critical point**	
11.	The temperature at which a refractory will deform under its own weight is indicated by **a) Pyrometric cone equivalent** b) Cold crushing strength c) Refractoriness under load d) none of the above	**A**
12.	Which of the following is a property of ceramic fibre? a) Low thermal conductivity b) Light weight c) Thermal shock resistant **d) all of the above**	**D**
13.	In a FBC Boiler, the bottom ash constitutes roughly _____ % of the total ash. a) 20-30% **b) 30-40%** c) 40-50% d) 50-60%	**B**
14.	A temperature cross cannot be achieved in a) Cross flow heat exchanger **b) Parallel flow heat exchanger** c) Counter flow heat exchanger d) all of the above	**B**
15.	In a counter flow heat exchanger, cold fluid enters at 40°C and leaves at 60°C, whereas the hot fluid enters at 160°C and leaves at 140°C. The LMTD is **a) 100°C** b) 300°C c) 0°C d) none of the above	**A**
16.	The effectiveness of a heat exchanger does not depends on **a) Specific heat of hot fluid** **b) Specific heat of cold fluid** **c) Inlet temperature of hot fluid** **d) all of the above**	**A,B C,D**
17.	In determining the economic cost of insulation thickness for a steam pipe, which of the following factors need to be considered? a) Calorific value of the fuel b) Annual hours of operation c) Cost of fuel **d) all of the above**	**D**
18.	Temporary hardness is caused by **a) bicarbonates** b) chlorides c) sulphates d) silica	**A**
19.	Radiation and convection heat losses in a boiler can be improved by a) economizer b) air preheating **c) proper insulation** d) increasing steam pressure	**C**
20	Mechanical de-aeration is accomplished with the help of a) turbine b) sodium sulphite **c) steam** d) reverse osmosis	**C**
21.	Which property of the ceramic coating influences the efficiency increase in the furnace? a) conductivity b) convection c) coating thickness **d) emissivity**	**D**
22.	Heat loss from the wall in a furnace depends on a) Emissivity of the wall b) wall thickness c) insulation thickness **d) all of the above**	**D**
23.	Which one of the following is an organic insulation material? a) mineral wool **b) thermocol** c) calcium silicate d) mica	**B**
24.	Refractories with higher thermal conductivity is preferred in	**D**

	a) boilers b) furnaces c) kiln **d) regenerator**	
25.	In FBC boiler the combustion is carried out at a temperature a) above the ash fusion temperature of the fuel used b) close to the steam temperature **c) below the ash fusion temperature of the fuel** d) close to the critical temperature	**C**
26.	The extraction condensing turbines when compared to the back pressure turbines has **a) higher power to heat ratios** b) lower power to heat ratios c) same power to heat ratios d) higher thermal efficiency	**A**
27.	When a pressure reducing valve is replaced by a steam turbine? a) inlet and outlet enthalpies are same b) outlet temperature is more than inlet temperature **c) Inlet enthalpy is more than outlet enthalpy** d) Outlet enthalpy is more than inlet enthalpy	**C**
28.	Power is generated from the waste gases of a gas turbine. This type of co-generation is called **a) topping cycle** b) bottoming cycle c) Rankine cycle d) Brayton cycle	**A**
29.	Pinch analysis generally depicts the plot of a) temperature Vs entropy **b) Temperature Vs enthalpy** c) Temperature Vs specific heat d) Temperature Vs heat transfer coefficient	**B**
30.	Tuyeres is part of the equipment associated with a) re-heating furnace b) induction furnace c) electric arc furnace **d) none of the above**	**D**
31.	If 10% air is entrained in a steam system at 5 kg/cm^2g then the saturation temperature of steam will be **a) less than the saturation temperature at 5 kg/cm^2g** b) more than the saturation temperature at 5 kg/cm^2g c) equal to the saturation temperature at 5 kg/cm^2g d) equal to the saturation temperature at 5.5 kg/cm^2g	**A**
32.	Steam at 6 bar has a sensible heat of 159.33 kcal/kg and latent heat of 498.59 kcal/kg. If the steam is 95% dry then the total enthalpy is a) 625 kcal/kg b) 649.95 kcal/kg **c) 633 kcal/kg** d) none of the above	**C**
33.	Insulation used for temperatures more than 350°C is a) polyurethane b) polystyrene **c) calcium silicate** d) wood	**C**
34.	A power plant which uses a gas turbine first followed by steam turbine for power generation is called a) rankine cycle **b) combined cycle** c) brayton cycle d) bottoming cycle	**B**

35.	Sulphur percentage in furnace oil **a) sets lower flue gas temperature limit** b) improves viscosity c) does not add to heat value d) forms soot	**A**
36.	A paper plant needs steam at 3 bar and 10 bar in addition to electric power. The most suitable cogeneration choice among the following will be a) condensing turbine b) back pressure turbine **c) extraction cum back pressure turbine** d) bottoming cycle	**C**
37.	The maximum possible evaporation ratio of a boiler (From & At 100°C basis with an enthalpy of 540 kcal/kg steam) fired with coal having a calorific value of 4050 kcal/kg and operating at 80% efficiency will be a) 5 **b) 6** c) 7.5 d) 9.4	**B**
38.	In a turbine, the thermodynamic process taking place is a) contraction **b) expansion** c) condensation d) both (a) & (b)	**B**
39.	Specific Heat of oil is a function of a) viscosity b) flash Point c) pour point **d) specific gravity**	**D**
40.	NCV of a fuel is 8200 kcal/kg, moisture content is 9% and hydrogen is 12%. The GCV of fuel is **a) 8883** b) 7380 c) 9400 d) 8322	**A**
41.	Sulphur percentage is the highest in a) kerosene b) diesel **c) furnace oil** d) LSHS	**C**
42.	For optimum combustion of fuel oil, the O_2 in the flue gases should be around **a) 4%** b) 14% c) 800ppm d) 21%	**A**
43.	Which of the following metal requires the highest latent heat for melting? a) gold b) copper c) steel **d) aluminium**	**D**
44.	Stored Heat loss in furnace is high due to a) numbers of cold starts b) mass of refractory c) high thermal conductivity of refractory **d) all the above**	**D**
45.	If the actual O_2 measured in flue gas is 3.5%, what is the % excess air supplied? a) 21% **b) 20%** c) 30% d) 3.5%	**B**
46.	The amount of O_2 required for complete combustion of 18 kg of sulphur is ________. **a) 18** b) 36 c) 27 d) 9	**A**
47.	Fuel utilization factor will be high with a) gas turbine cogeneration b) diesel engine cogeneration c) gas engine cogeneration **d) gas engine trigeneration**	**D**

48.	Deaerator is a _____type heat exchanger a) shell and tube heat exchanger b) double pipe heat exchanger **c) direct contact heat exchanger** d) single stage evaporator	C
49.	Expansion loops in steam distribution lines are useful a) to reduce steam velocity b) to reduce friction in pipe **c) to manage cold start requirements** d) to reduce steam loss in large lines	C
50.	The optimum steam pressure required for direct injection of steam for making hot water is ______________. a) 5 Kg/cm² b) 7 kg/cm² c) 3 Kg/cm² **d) 1 kg/cm²**	D

Section - II: SHORT DESCRIPTIVE QUESTIONS **Marks: 8 x 5 = 40**

(i) Answer all **Eight** questions

(ii) Each question carries **Five** marks

S-1 a)	**Explain the function of a steam trap?** **2 Marks**
	• To discharge condensate as soon as it is formed. • Not to allow live steam to escape Refer Guidebook-2, Page 82 & 83
S-1 b)	**Name the suitable trap for each of the following applications**: **3 Marks**

Sl.No	Application	Type of Trap to be installed
1	Heat Exchangers	Bucket, Inverted bucket, Float trap
2	Tracer Lines	Thermostatic trap/ Bimetallic traps
3	Steam mains	Thermodynamic trap

S-2 **A small foundry is producing cast iron products through Cupola. Monthly liquid metal production is 150 Tons. The existing Coke to Iron ratio is 1: 7. After modifying the hot air system, the coke to iron ratio has improved to 1:9. Calculate the annual coke savings and annual monetary savings, if the cost of coke is Rs. 8400/ton.**

5 Marks

Present coke consumption = (1/7) x 1000 = 142.86 kg/ton
Coke consumption with Hot air system = (1/9) x 1000 =111.11 kg/ton
Savings in Coke = 142.86-111.11 = 31.75 kg/ton
Annual Coke Savings = 31.75 x 150 x12 = 57.163tonne.
Annual monetary savings = Rs 8400 x 57.163 = Rs.4,80,160/-

(or)

Present coke consumption = (1/7) x 150x 1000 = 21428.57 kgs coke
Coke consumption with Hot air system =(1/9)x150x1000 =16665 kgs coke
Savings in Coke = 21428.57 -16665= 4763.6 kg/month
Annual Coke Savings = 4763.6 x12 = 57162.84 kgs/yr = 57.163 TPY
Annual monetary savings = Rs 8400 x 57.163 = Rs.4,80,160/-

S-3 **A steam pipe with OD of 100 mm is carrying steam from a boiler to an offsite location at a distance of 1 km from the boiler plant. The steam line already had 20 mm of outer insulation. The management has decided to increase the insulation thickness by 20 mm, to further reduce heat loss. Calculate the reduction in annual heat loss in Million kcals, with this additional 20 mm insulation.**

Given Data :

i)	Outside surface temperature with 20 mm insulation	90°C

ii)	Outside surface temperature after adding 20 mm additional insulation thickness	40°C
iii)	Ambient Temperature	25°C
iv)	Annual operating hours	8000 hrs

5 Marks

Heat loss with 20mm insulation:

Heat Loss in Case S1 = [10 +(90-25)/20] x (90-25)
= 861.25 Kcal/hr-m^2

Surface Area A1 = 3.14 x (100+20+20/1000) x1000
= 439.6 m^2

Total Heat Loss with 20mm insulation thickness

L1 = S1 x A1
= (861.25x439.6)
= 378605.5 kcal/hr

Heat lost with (20+20= 40 mm) insulation

Heat Loss in Case 2 S2 = [10+ (40-25)/20] x (40-25)
= 161.25 Kcal/hr-m^2

Surface Area A2 = 3.14x(100+40+40/1000) x1000
= 565.2 m^2

Total Heat Loss L2 = 161.25 x 565.2
= 91184.727 kcal/hr

Additional hourly heat savings = (378605.5-91184.727)
=287612.8 kcal/hr

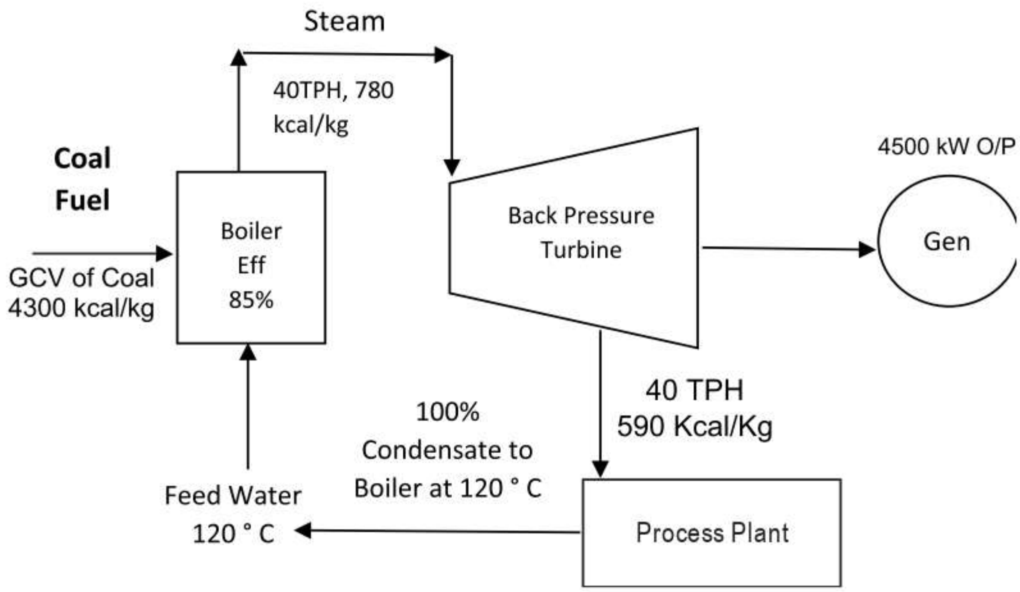
Annual heat savings = (288738.7 x 8000 /10^6)
=2300.90 Million kcals/yr

S-4	**List five advantages of Thermo-compressors.**	**5 Marks**

Refer Guidebook-2, Page 80

- No condensation loss takes place
- Thermal efficiency of system is extremely high
- Entrainment of low-pressure steam results in substantial savings
- No moving parts and hence maintenance need is minimum
- No major operational changes
- Low space requirements
- Insensitive to fouling
- High operating reliability

S-5 i)	**Explain any three advantage of FBC Boilers.**	**3 Marks**
	Refer Guidebook-2, page 182-183	
S-5 ii)	**Explain how SOx and NOx are controlled in FBC Boilers**	**2 Marks**
	Refer Guidebook-2, Page No 183, Point 6	
S-6	**The schematic of a backpressure steam turbine cogeneration system of a process plant operating round the clock is depicted below. Find the Heat to Power ratio and the Energy Utilization Factor.**	**5 Marks**



Heat output to process Q_{th}= 40000 * (590-120)
= 1,88,00,000 kcal/hr
Power O/P, Q_e= 4500 KW
= 4500*860 kcal/hr
= 38,70,000 kcal/hr

Heat to Power Ratio = 18800000 /3870000
= 4.85

Fuel input Calculation:

Boiler Efficiency = Steam Flow * (Steam Enthalpy-FW Enthalpy)/(GCV * Fuel Flow)

Fuel input to boiler = 40000*(780-120)/(4300*.85)
= 7222.982 Kg
Fuel input heat (Q_f)= Fuel input to boiler * GCV
= 7222.982*4300
= 31058823 kcal/hr

EUF = $(Q_{th}+Q_e)/Q_f$
= (18800000+3870000)/ 31058823
EUF = 0.729 (72.9%)

S-7 a) **List five factors for reducing energy use in hot air dryers using steam.** **3 Marks**

Refer Guidebook-2, Page no 81

S-7 b) **In a process plant, 12,000 kg/hr of hot condensate is discharged at 8 bar(g) having a sensible heat of 186 kcal/kg. The plant also requires steam at 2 bar(g) for some other heating application. Find out the quantity of flash steam generation possible in kg/hr if the condensate at 2 bar(g) has a sensible heat of 135 kcal/kg and a latent heat of 550 kcal/kg.**

2 Marks

Flash steam generation % = (S1 – S2) x 100 / L2

S1 – sensible heat of high-pressure condensate
S2 – sensible heat of low-pressure steam
L2 – latent heat of low-pressure steam

Flash steam % = $\frac{186-135}{550} \times 100$
= 9.273 %

Flash steam generated = flash steam % x Volume of hot condensate
= 0.0927 x 12000 = 1112.73 kgs/hr

S-8	**In a double pipe heat exchanger, flow rates of hot and cold-water streams are 50 and 60 kg/min. Hot and cold streams inlet temperatures are 100°C and 35°C. The exit temperature of the cold stream is 55°C. The specific heat of water is 4.18 kJ/kg K. The overall heat transfer coefficient is 800 W/m²K. Calculate the heat transfer area required for parallel flow.** **5 Marks**

Rate of heat transfer of cold stream Q (Watts) = mx Cpx(t2-t1)

= (60/60) x (4.18 x 1000) x (55-35) J/s

= 83,600 W

Hot stream temperature difference = Q/ (mxCpx 1000)

= 83600/ ((50/60)x 4.18 x 1000)

t1- t2 = 24 °C

t2 = 100 – 24

= 76 °C

For parallel flow Δ T1 = 100 °C – 35°C = 65 °C

ΔT2 = 76 °C – 55°C= 21 °C

LMTD = (65 – 21) /ln(65/21)

= 38.97

Overall heat transfer co-efficient U = 800 W/m² k

Heat transfer area required = A = Q/(U x LMTD) = 83600/(800 x 38.97)

= 2.68 m²

………….. **End of Section – II** ……………

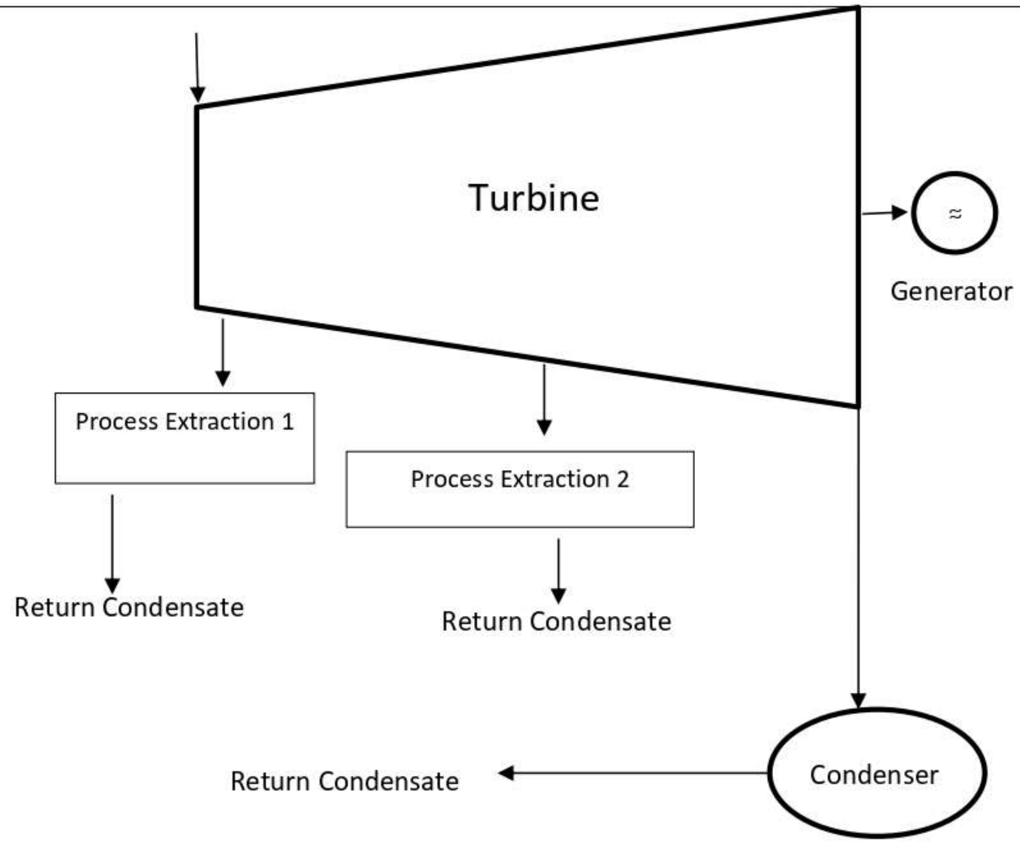
Section - III: LONG DESCRIPTIVE QUESTIONS **Marks: 6 x 10 = 60**

(i) Answer all **<u>Six</u>** questions

(ii) Each question carries **<u>Ten</u>** marks

L-1	**A medium size textile processing unit has installed a Thermic fluid heater, which is giving an output of 2,50,000 kcal/hr. The operating details of thermopack are given below:**		
	Details:		
	Fuel used	:	Coconut shell
	Fuel consumption	:	80 kg/hr
	GCV of fuel	:	4,500 kcal/kg
	Forward oil temperature	:	255°C
	Return oil temperature	:	245°C
	Flue gas Temperature (T_g)	:	295°C
	Ambient temperature (T_a)	:	30°C
	Specific heat of flue gas	:	0.25 kcal/kg.°C
	O_2% in flue Gas	:	10 %
	Stoichiometric Air Requirement	:	6 kg/kg of fuel
	Moisture in fuel	:	13 %
	Hydrogen in Fuel	:	5 %
	Calculate:		
1.	**Efficiency of thermopack** **2 Marks**		
	Capacity of thermopack	:	2,50,000 Kcal/hr
	Fuel consumption	:	80 kg/hr

	Heat input : 80 X 4500 = 360000 kcal/hr Heat output : 250000 kcal/hr Efficiency : 250000/360000= 69.444%
2.	**Flue gas Loss (*Ignore ash content in the coconut shell for calculations*).** **3 Marks**
	Excess air = (O_2/ 21- O_2) x 100 = 10/21-10 x 100 = 90.9 % Actual Air Supplied = 6 X 1.909 = 11.454 Kg/kg of fuel Flue gas quantity = 11.454 + 1 = 12.454 kg/kg Flue gas loss = ((12.454*0.25*(295-30))/4500) *100 = 18.34 % (**or** 66024 Kcal/hr)
3.	**Loss due to Moisture and Hydrogen.** **3 Marks**
	Loss due to moisture in fuel =((M x ((584 + Cp (Tg- Ta)))/GCV)) X 100 =((0.13*((584+0.45*(295-30)))/4500))*100 = 2.03 % (**or** 7308 Kcal/hr) Loss due to Hydrogen in fuel = (9 H_2 x 584 + Cp (Tg- Ta)/GCV) X 100 = ((9*0.05)*((584+0.45*(295-30)))/4500)*100 = 7.03 % (**or** 25308 Kcal/hr)
4.	**Find out radiation and other unaccounted losses.** **2 Marks**
	Radiation Loss and Unaccounted loss (by difference) = 100- 69.444 – (18.34+2.03+7.03) = 100-69.44-27.4= 3.156 % (**or** 11361.6 Kcal/hr)
L-2 1.	**List seven fuel economy measures in Furnaces.** **7 Marks**
	Refer Guidebook-2, Page No 129
L-2 2.	**Discuss briefly the effect of positive and negative pressure on furnace performance.**
	Refer Guidebook-2, Page No 132 **3 Marks**
L-3	**Explain**
i)	**LMTD with an example of counter flow heat exchanger** **4 Marks**
	Refer Guidebook-2, Page 237-238
ii)	**Temperature Correction Factor** **3 Marks**
	Refer Guidebook-2, Page 239
iii)	**Heat Exchanger Effectiveness** **3 Marks**
	Refer Guidebook-2, Page 243-244
L-4	**Explain the following:**
i)	**Turbine Cylinder Efficiency** **3 Marks**
	Refer Guidebook-2, Page 205
ii)	**Double extraction condensing turbine with a schematic diagram** **3 Marks**



iii)	**Operation and application of heat pump with a schematic diagram** **4 Marks**
	Refer Guidebook-2, Page 228-230

L-5 **A process liquid of 7 lakh litres per day is heated in a Plate heat exchanger as per process requirements using 4 kg/cm²(g) steam.**
The operating details are given below :

Evaporation ratio of the boiler is	13.5
Process Liquid Inlet temperature	30°C
Process Liquid Outlet temperature	120°C
Specific heat of the process liquid	0.94 kcals/kg.°C
Density of process liquid	1.035 kg/Lit
Fuel cost	Rs. 35/ kg
Configuration	Counter flow
Annual operation	350 days
Daily Operating hours	16 hours/day

Steam Parameters:

Pressure Kg/cm²(g)	Temperature °C	Enthalpy in kcal/kg		
		Water	Evaporation	Steam
3	133	133.42	517.15	639.15
4	143	143.70	509.96	653.66

If the existing 4 kg/cm²(g) steam is replaced by 3 kg/cm²(g) steam, estimate the annual monetary savings. **10 Marks**

Process flow = 700 000/16 = 43750 LPH = 43750 x 1.035 =45,281.25 kg/hr
Heat load = 45281.25 x 0.94 x (120-30) = 38,30,793.75 Kcal/hour

Steam required at 4 Kg/cm^2 =3830794/509.96 = 7511.95 kg
Steam required at 3 kg/cm^2 =3830794/517.15 = 7407.51 Kg/hr
Fuel required for 4 Kg/cm^2 Steam = 7511.95/13.5 = 556.44 kg/hr
Fuel required for 3 Kg/cm^2 Steam = 7407.51/13.5 = 548.70 kg/hr
Annual fuel savings =(556.44-548.70)*16*350= 43344 Kg
Annual Monitory savings =43344*35 = Rs 15,17,040/-

L-6

In a process plant, fuel oil is being pre-heated. This fuel oil is pumped from pump house located 500 m away from the boiler. Steam is supplied for pre-heating the fuel oil to raise its temperature from 25°C to 130°C in a counter flow Shell & Tube Heat Exchanger.
Calculate the Inner Diameter (ID) in "mm" of the pipe carrying the steam for pre-heating the fuel oil. The maximum permissible velocity in the pipeline is 25 m/sec.

Fuel Oil Parameters:

Flow	: 60 m^3/hr
Specific Heat	: 0.7 kcal/kg°C
Density	: 830 kg/m^3

Steam Parameters:

Pressure	: 8 kg/cm^2
Temperature	: 170°C
Specific Volume	**: 0.22 m^3/kg**
Enthalpy of water	: 170 kcal/kg
Enthalpy of evaporation	: 490 kcal/kg
Enthalpy of Steam	: 660 kcal/kg

10 Marks

Heat gained by Fuel Oil = m x Cp x (ΔT)
= 60x830x.7x(130-25)
= 3660300 Kcal/hr

Heat gained by Fuel Oil = Heat lost by Steam

Heat lost by Steam = m * H

3660300 = m x 490

Mass flow of Steam = 7470 kg/hr

Volumetric Flow of Steam = Mass Flow * Specific Volume

= 7470 x 0.22
= 1643.4 m^3/hr
= 1643.4/3600 m^3/s
= 0.4565 m^3/s

Velocity = 25m/s

Area = Volume/Velocity
= 0.4565/25
= 0.01826 m^2

Area = $\pi D^2/4$

D = $\sqrt{(Area*4)/3.14}$
= $\sqrt{(.1826*4)/3.14}$
= 0.1525 m
=15.25 cm
= 152.5 mm

Note: There was a typo error in the question paper instead of "Specific Volume 0.22 m^3/kg " it was printed "Specific Volume 22 m^3/kg" though the announcement was made in the classroom any candidate who had solved using the "Specific Volume 22 m^3/kg", it was considered for awarding marks though it is technically wrong.

.... **End of Section – III** ....

20th NATIONAL CERTIFICATION EXAMINATION
FOR
ENERGY MANAGERS& ENERGY AUDITORS- September, 2019

PAPER –2: Energy Efficiency in Thermal Utilities

General instructions:

- *Please check that this question paper contains 8 printed pages*
- *Please check that this question paper contains **64** questions*
- *The question paper is divided into three sections*
- *All questions in all three sections are compulsory*
- *All parts of a question should be answered at one place*

Section – I:OBJECTIVE TYPE **Marks: 50 x 1 = 50**

(i) Answer all **50** questions
(ii) Each question carries **one** mark
(iii) Please hatch the appropriate oval in the OMR answer sheet with Black Pen or HB pencil, as per instructions

1.	Arrange the following fuels in decreasing order of their GCV's - (p) Bagasse, (q) Furnace Oil, (r) Coal, (s) Hydrogen **a) s-q-r-p** b) p-q-r-s c) r-s-q-p d) q-r-s-p
2.	Which of the following contributes to spluttering of flame at burner tip during combustion of fuel oil? a) ash content **b) water content** c) Sulphur content d) ambient air humidity and temperature
3.	Which trap is preferred in condensate removal from steam main lines? a) Float trap **b) Thermodynamic trap** c) Thermostatic trap d) All of the above
4.	In an FBC boiler, with low ash fusion coal, if the bed temperature exceeds 950°C, the result is: a) Boiler explosion **b) clinker formation** c) Melting of lime stone d) Ash carry over
5.	Water logging of 3 m lift of condensate, at trap discharge, will result in back pressure of _________ a) 0.03 kg/cm^2 **b) 0.3 kg/cm^2** c) 3 kg/cm^2 d) 30 kg/cm^2
6.	When pure hydrogen is burnt with stoichiometric air, percentage CO_2 on volume basis, in dry flue gas, will be _____ a) 79% b) 21% **c) 0%** d) 100%
7.	Heat transfer rate for drying application will be low if we heat with _________ a) Saturated steam b) Dry steam **c) Superheated steam** d) None of the above

8.	The viscosity of furnace oil will be maximum at which of the following temperatures? **a) 40 °C** b) 60 °C c) 90 °C d) 105 °C
9.	Carpet loss in the context of coal consumers is related to : a) Short receipt b) Accounting mistakes c) Ash handling **d) coal storage**
10.	Thermo-compressor is commonly used for : a) compressing hot air **b) upgrading low pressure steam** c) converting saturated steam to super-heated steam d) reverse compression of CO_2
11.	Latent heat of any vapour at its critical point will be : a) highest b) above zero **c) zero** d) less than zero
12.	The temperature at which, refractory will deform under its own weight, is it's softening temperature, indicated by : a) melting point **b) Pyrometric Cone Equivalent** c) reform temperature d) critical point
13.	Which type of the following co-generation system has high heat-to-power ratio? a) gas turbine **b) back pressure turbine** c) extraction condensing turbine d) reciprocating engine
14.	Drain pockets are provided in a steam line for : **a) effective removal of line condensate** b) effective removal of steam c) removal of dirt d) checking of steam line
15.	Capillary wick is a part of: a) heat pump b) heat wheel **c) heat pipe** d) regenerator
16.	Scale losses in reheating furnaces will: a) increase with CO in combustion gases **b) increase with excess air** c) decrease with excess air d) have no relation with excess air
17.	Tuyeres is a terminology associated with: a) induction furnace b) pusher type furnace c) arc furnace **d) cupola**
18.	The low combustion temperature in FBC boilers results in minimal formation of : a) CO b) SOx **c) NO_x** d) CO_2
19.	Turn down ratio of a burner is the ratio of **a) maximum to minimum fuel input without affecting optimum excess air levels** b) minimum to maximum fuel input without affecting optimum excess air levels c) maximum to average fuel input d) average to minimum fuel input
20.	Dolomite is a _________ type of refractory: a) acidic **b) basic** c) neutral d) none of the above
21.	Which of the following is not true of condensate recovery? a) reduces water charges b) reduces fuel costs c) increases boiler output **d) increases boiler blow down**
22.	Calcium and magnesium bicarbonates present in feedwater fed to a boiler would form : a) acidic solution **b) alkaline solution** c) neutral solution d) none of the above

23.	In steam systems, the purpose of venting air is because, air is _________. a) a good conductor b) an inert substance c) an oxidizing agent **d) an insulator**
24.	A bottoming cycle is one in which fuel is used for producing : a) power primarily followed by byproduct heat output **b) heat primarily followed by byproduct power output** c) power, heat and refrigeration simultaneously d) none of the above
25.	A supercritical boiler has parameters beyond critical point, which refers to : **a) 221.2 bar (a) pressure and 374.15 ^{0}C temperature** b) 246.1 bar (a) pressure and 538.44 ^{0}C temperature c) 306.5 bar (a) pressure and 538.82 ^{0}C temperature d) 170.0 bar (a) pressure and 374.18 ^{0}C temperature
26.	Of the total volume of natural gas, the main constituent is : **a) methane** b) iso-octane c) propane d) hexane
27.	For optimum combustion of fuel oil, O_2 percentage in flue gases should be maintained at : **a) 2-3 %** b) 14-15 % c) 23 % d) 21%
28.	The draft caused solely by the difference in weight between the column of hot gas inside the chimney and column of outside air is known as : a) balanced draft b) induced draft c) forced draft **d) natural draft**
29.	The cogeneration system which has high overall system efficiency is : **a) back pressure steam turbine** b) combined cycle c) extraction condensing steam turbine d) reciprocating engine
30.	When 10 kg of fuel, with 60% carbon, is burnt with theoretical air, the mass of CO_2 released will be : a) 32 kg b) 440 kg c) 450 kg **d) 22 kg**
31.	F & A (from and at) rating of the boiler is the amount of steam generated from : a) water at 0 °C to saturated steam at 100 °C b) water at feed water temperature to saturated steam at 100 °C **c) water at 100 °C to saturated steam at 100 °C** d) water at ambient temperature to saturated steam at 100 °C
32.	Steam generated in a boiler is 36 tonnes in 3 hours. Fuel consumption in the same period is 1 tonne per hour. Continuous blow down is 8% of feed water input. The boiler evaporation ratio is ? **a) 12** b) 11.7 c) 36 d) 24
33.	Which of the following statement is false? **a) LPG vapour is twice as light as air** b) LPG is a mixture of propane and butane c) LPG is a gas at normal atmospheric pressure d) LPG is required to be odorized
34.	The inverted bucket operates on the principle of _______ difference between water and steam: a) pressure **b) density** c) temperature d) velocity
35.	Which of the following is not measured in proximate analysis ? a) volatile matter b) fixed carbon **c) sulphur** d) ash
36.	Reduction of steam pressure, in a process heating application will : a) reduce the steam temperature b) reduce the sensible heat c) increase the enthalpy of evaporation **d) all of the above**

37.	The TDS level in boiler water, in the context of boiler blow down, can be determined by measuring : a) alkalinity of water b) thermal conductivity of water **c) electrical conductivity of water** d) turbidity of water
38.	De-aeration of boiler feed water helps in combating : **a) corrosion** b) TDS c) silica d) hardness
39.	In stoichiometric combustion of furnace oil, which of the following will be absent in flue gas ? a) nitrogen b) carbon dioxide **c) oxygen** d) Sulphur dioxide
40.	Furnace wall heat loss does not depend on : a) temperatures of external wall surfaces b) velocity of air around the furnace c) thermal conductivity of wall brick **d) material of stock to be heated**
41.	In determining the optimal economic insulation thickness for a steam pipeline, which of the following factors need not be considered ? a) annual hours of operation b) calorific value **c) pipe material** d) cost of fuel
42.	Which is not a property of Ceramic fiber insulation? a) low thermal conductivity b) light weight **c) high heat storage** d) thermal shock resistant
43.	Which property is the most important, for an insulating brick ? a) Mechanical strength b) Chemical resistance c) Compact strength **d) Porosity**
44.	Quality of waste heat in flue gas refers to : a) dust concentration in flue gas b) **Temperature of flue gas** c) moisture in flue gas d) corrosive gases in flue gas
45.	In a low temperature waste heat recovery system, which of the following, is the most suitable ? a) Economizer **b) Heat Pipe** c) regenerator d) ceramic recuperator
46.	Which of the following heat recovery equipment, requires a compressor for its operation? a) thermo-compressor b) heat wheel **c) Heat pump** d) heat pipe
47.	Pinch analysis of process streams, depicts the plot of : a) temperature vs entropy b) temperature vs. area c) temperature vs specific heat **d) temperature vs enthalpy**
48.	Which of the following is true for a process heating requiring direct injection of steam? a) Thermodynamic trap is required b) Thermostatic trap is required c) Inverted bucket trap is required d) **None of the above**
49.	If a vapor-liquid combination of 1 kg at 120 ºC is supplied with 50 kcal of heat without change in state and at constant pressure conditions; its temperature will be? a) 220 ºC b) 190 ºC c) 170 ºC **d) 120 ºC**
50.	Which of the following constituent in flue gas is used for determining excess air? a) % nitrogen b) % Sulphur Dioxide **c) % Carbon dioxide** d) %

	Moisture

………….. End of Section – I …………..

Section - II: SHORT DESCRIPTIVE QUESTIONS Marks: 8 x 5 = 40

(i) Answer all **Eight** questions
(ii) Each question carries **Five** marks

S1	In an industry, an electrical oven consuming 1100 kWh/batch, is proposed for replacement, by a FO fuel fired oven. Calculate the simple payback period, given the following data: Number of batches / years = 4000 Efficiency of electric oven = 82% Efficiency of FO fired oven = 55% Cost of FO = Rs.35,000/Tonne GCV of FO = 10,200 kcal/kg Electricity cost = Rs.6.0/kWh Investment for FO fired oven = Rs. 125 Lakhs **Ans :** Useful heat, required per batch = (1100 x 860 x 0.82) **= 7,75,720 kcal/batch** FO input per batch = (7,75,720 /(0.55 x 10,200)) **= 138.27 kg FO/batch** FO cost per batch = (138.27 kg FO/batch x Rs.35/kg FO) **= Rs.4,839.45** Electricity cost per batch = (1,100 kWh/batch x Rs.6.0/kWh) = Rs.6,600 Cost savings per batch on account of replacement = (Rs.6,600 – Rs.4,839.45) = Rs.1,760.55 Annual cost savings at 4000 batches per year = (1,760.55 x 4000) **= Rs.70,42,200** **(Or) = Rs.70.422 lakhs** Investment **= Rs.125 lakhs** **Simple payback period** = (125/70.422) = **1.78 years**
S2	In a process plant, 30 TPH of steam, after pressure reduction to 20 kg/cm^2(g), through a pressure reducing valve, gets superheated. The temperature of superheated steam is 350 ^{o}C. The management desires to install a de-super heater to convert the superheated steam into useful saturated steam at 20 kg/cm^2(g) for process use. The saturated steam temperature is 210^{o}C. Calculate the quantity of water required to be injected at 30 ^{o}C, in the de-super heater, in order to obtain the desired saturated steam, using the following data: • Specific heat of superheated steam = 0.45 kcal/kg^{o}C • Latent heat of steam at 20 kg/cm^2(g) = 450 kcal/kg

	Ans : ▪ Quantity of heat available above saturation = (30,000 x 0.45 x (350-210)) **= 18,90,000 kcal/hr** By Heat & Mass balance: Q x{1 x (210-30) + 450} **= 18,90,000** ▪ **Quantity of water (Q) required to be added in de-super heater** = 18,90,000/{1 x (210-30) + 450} = 18,90,000/630 = **3000 kg/hr**
S3	In an industry the process equipment needs 5000 kg/hr of saturated steam at 10 kg/ cm^2(g). For a steam velocity of 25 m/sec, what will be the diameter of the steam pipe in 'mm', given that the specific volume of steam at 10 kg/ cm^2(g) is 0.1802 m^3/kg. **Ans :** Specific volume of steam at 10 kg/cm^2(g) = 0.1802 m^3/kg Flow rate = 25m/sec Mass flow rate = 5000 kg/hr = 1.389 kg/sec Volume flow rate = 1.389 x 0.1802 **= 0.25 m^3/sec** Volume flow rate is also = (π/4 x D^2) x25 Therefore, (π/4 x D^2) x 25 = 0.25 Hence, diameter of steam pipe line 'D' = $[(0.25/((\pi/4) \times 25)]^{0.5}$ = 0.1128m **or 112.8 mm**
S4	An economizer was installed in an oil fired boiler. The following data was obtained after commissioning the economizer. ▪ Air to fuel ratio = 18 ▪ Evaporation ratio of the boiler = 12.5 ▪ Specific heat of flue gas = 0.25 kcal/kg°C. ▪ Condensate recovery in the plant = Nil. Calculate the rise in temperature of feed water across the economizer, corresponding to a drop in flue gas temperature from 280 °C to 190 °C. **Ans :** Steam generated per kg of fuel, (*from evaporation ratio*) = 12.5 kg Required combustion air per kg of fuel, (*from air to fuel ratio*) = 18 kg combustion air/kg fuel oil Flue gas generated per kg of fuel = (18 +1) **= 19 kg flue gas/kg fuel oil** Heat balance across the Economizer : Heat given by flue gas = Heat received by water ((19 x 0.25 x (280-190)) = (12.5 kg x 1kcal/kg°C x ΔT) **Rise in temperature of water ΔT = 34.2 °C**
S5	Compute the heat loss in percentage, due to unburnt in fly ash and bottom ash, for an AFBC Boiler, using Indian coal, with: ▪ GCV = 4200 kcal/kg. ▪ % Ash in coal = 38.8 ▪ Ratio of bottom ash to fly ash = 15: 85 ▪ GCV of fly ash = 452.5 kcal/kg ▪ GCV of bottom ash = 800 kcal/kg

	Ans: **<u>Unburnt in fly ash</u>** Amount of fly ash in 1 kg of coal = (0.85 x0.388) = 0.3298 kg fly ash/kg coal GCV of fly ash = 452.5 kcal/kg fly ash Heat loss in fly ash = (0.3298 x 452.5 kcal per kg fly ash) = 149.23 kcal/kg coal **% Heat loss in fly ash** = (149.23 x 100 /4200) = **3.55 %** **<u>Unburnt in bottom ash</u>** Amount of bottom ash in 1 kg of coal = 0.15 x 0.388 = 0.0582 kg bottom ash/kg coal GCV of bottom ash = 800 Kcal/kg bottom ash Heat loss in bottom ash = (0.0582 x 800 kcal per kg bottom ash) = 46.56 kcal/kg coal **% Heat loss in bottom ash** = (46.56 x 100 /4200) = **1.11 %**
S6	List five main parameters considered for the selection of refractories**?** **(Each 1 Mark)** **Ans :** **(Page No:166, Sec 5.11)**
S7	What is the significance of volatile matter, in case of solid fuels? **Ans :** **(Page No: 9)**
S8	(i) List three functions of a steam trap. **(3 Marks)** (ii) Explain the working principle of thermodynamic trap. **(2 Marks)** **Ans :** (i) List three functions of a steam trap. **(Page 82)** (ii) Explain the working principle of thermodynamic trap. **(Page 86-87)**

.... End of Section – II ....

Section – III: LONG DESCRIPTIVE QUESTIONS Marks: 6 x 10 = 60

(i) Answer all **<u>six</u>** questions
(ii) Each question carries **<u>ten</u>** marks

L-1	A process industry consuming 10 TPH of saturated steam at 10 kg/sq.cm(g) pressure has been using coal as fuel in boiler. Typical ultimate analysis of the coal: **Carbon : 41.11%** **Hydrogen : 2.76 %**

Nitrogen : 1.22 %
Oxygen : 9.89 %
Sulphur : 0.41%
Ash : 38.63
Water : 5.89

Flue gas temperature = 200°C
Ambient temperature = 30°C
Enthalpy of steam = 668 kcal/kg
Feed water temperature = 80°C
Specific heat of flue gases = 0.23 kcal/kg°C
Boiler efficiency with Indian coal =72 %
GCV of coal = 4,000 kCal/kg
Oxygen content in dry flue gases = 10%
Annual Hours of operation = 8000 hrs.

Determine:
(i) Quantity of annual coal requirement in tonnes/year **(5 Marks)**
(ii) Calculate % dry flue gas losses **(5 Marks)**

Solution:
a)
Coal requirement Q = Steam (q) x (hg – hf)**/(** Efficiency x GCV)
= 10 x (668-80) / (0.72 x 4000)
= 2.042 T/Hr
= 2.042 x 8000 hrs
= 16336 Tonnes/year

Theoretical air requirement for coal

$$= \frac{[(11.6 \times C\%) + \{34.8 \times (H_2\% - O_2\%/8)\} + (4.35 \times S\%)]}{100} \text{ kg / kg of coal}$$

$$= \frac{[(11.6 \times 41.11) + \{34.8 \times (2.76 - 9.89/8)\} + (4.35 \times 0.41)]}{100}$$

= 5.31 kg / kg of coal

(Or)
===
=

$C + O_2 = CO_2$	12+32= 44	(C%*32)/12
$2H_2 + O_2 = 2H_2O$	4+32=36	(H%*32)/4
$S + O_2 = SO_2$	32+32=64	(S%*32)/32

Total oxygen required = (41.11* 32/12) + (2.76*32/4) + (0.41*32/32)
= (109.63) + (22.08) + (0.41)
= 132.1 kg/ 100 kg fuel

	Oxygen already present in 100 kg fuel = 9.89 kg/ 100 kg fuel Additional oxygen required = 132.1 – 9.89 kg/ 100 kg fuel = 122.21 kg/ 100 kg fuel Quantity of dry air required (Air contains 23% O_2 by weight) = 122.1/ 0.23 = 531.35 kg/ 100 kg fuel Theoretical air required = 531.35/100 = 5.31 kg air/ kg fuel == Excess air = O_2x100/(21-O_2) Excess air = 10 x 100/ (21 – 10) = 90.9% Actual air= 5.31 * (100+90.9)/100 =10.137 kg air/kg coal Heat loss in dry flue gas = m x C_P (T_f – T_a) x 100 /GCV $= \frac{(10.137+1) \times 0.23 \times (200-30) \times 100}{4000}$ = 10.89 %
L-2	a) In a double pipe heat exchanger, flow rates of the hot and the cold-water streams flowing through a heat exchanger are 10 and 25 kg/min, respectively. Hot and cold-water stream inlet temperatures are 70 °C and 27 °C, respectively. The exit temperature of the hot stream is required to be 50°C. The specific heat of water is 4.179 kJ/ kg K. The overall heat transfer coefficient is 900 W/m^2 K. Neglecting the effect of fouling, calculate the heat transfer area for a) Parallel-flow b) Counter-flow. ……….7 marks b) Write a brief note on the operation and application of plate heat exchangers in process industries. ……….3 marks **Ans:** **a)**

Rate of heat transfer, Q (watts)	Q= m x Cp x 1000 x (T2-T1) =(10/60)× 4.179 x 1000 ×(70 – 50) = 13930 W
Cold water exit temperature, T_2	T_2 = [Q/(mx Cp x 1000)]+ T1 = (13930/((25/60)* (4.179*1000)))+27 = 35°
Terminal temperature differences for parallel flow heat exchangers	= (70-27) & (50 – 35); i.e., 43°C and 15°C respectively.
LMTD	(43 – 15)/ln(43/15) = 26.59°C
Overall heat transfer coefficient U	900 W/m^2 °K
Heat transfer area required for parallel flow	A = Q/ (U*LMTD)
	= [13930/ (900 × 26.59)]
	= 0.582 m^2

Terminal temperature differences for counter flow heat exchangers	(70–35) and (50–27) ^{0}C i.e., 35 °C and 23 °C respectively.
LMTD	(35–23)/ln(35/23) = 28.58
Overall heat transfer coefficient U	900 W/m^2 °K
Heat transfer area required for counter flow	A = Q/ (U*LMTD)
	=[13930/ (900 × 28.58)]
	= 0.542 m^2

B)

Plate heat exchangers consist of a stack of parallel thin plates that lie between heavy end plates. Each fluid stream passes alternately between adjoining plates in the stack, exchanging heat through the plates. The plates are corrugated for strength and to enhance heat transfer by directing the flow and increasing turbulence. These exchangers have high heat-transfer coefficients and area, the pressure drop is also typically low, and they often provide very high effectiveness.

However, they have relatively low-pressure capability.

The biggest advantage of the plate and frame heat exchanger, and a situation where it is most often used, is when the heat transfer application calls for the cold side fluid to exit the exchanger at a temperature significantly higher than the hot side fluid exit temperature i.e. "temperature cross". This would require several shell and tube exchangers in series due to the lack of purely counter-current flow.

The overall heat transfer coefficient of plate heat exchangers under favorable circumstances can be as high as 8,000 W/m^2°C. With traditional shell and tube heat exchangers, the U-value will be below 2,500 W/m^2°C.

L-3

a) In a fruit processing plant, 105 TPD of syrup at 33% concentration is dried to 50% concentration. The existing single effect evaporator, where steam input for water removal ratio is 1.0 kg/kg is proposed to be replaced by a triple effect evaporator where the ratio of steam input for water removal is 0.4 kg/kg. Calculate the annual fuel cost savings for 300 days of operation at an evaporation ratio of 13.5 in the oil-fired boiler and at a furnace oil cost of Rs. 35,000/tonne.

………..7 marks

b) Why steam is recommended to be used at the lowest practicable pressure for indirect process heating?

………..3 marks

Ans.:

a)

Bone Dry material	= (105 TPD x 0.33)
	= 34.65 TPD
Product at 50 % concentrate	= (34.65 / 0.5)
	= 69.3
Water removed/ day	= (105 – 69.3)
	= 35.7 TPD
Initial steam consumption with single effect evaporator at 1 kg/kg	= (35.7 TPD x 1.0 kg/kg)
	= 35.7 TPD
Steam consumption with triple effect evaporator at 0.4 kg/kg	= (35.7 TPD x 0.4 kg/kg)
	= 14.28 TPD
Steam savings per day	= (35.7 TPD – 14.28 TPD)
	= 21.42 TPD

	FO savings per day at evaporation ratio of 13.5 = (21.42 TPD / 13.5 Tonne steam per Tonne FO) = 1.5867 TPD Rupee savings per day at Rs. 35,000/MT = (1.5867 TPD FO X Rs. 35,000/MT FO) = Rs. 55,535 Annual monetary savings at 300 working days per year = (Rs. 55,535 X 300 Days) = Rs.166.6 Lakhs b) The latent heat in steam reduces as the steam pressure increases. It is only the latent heat of steam, which takes part in the heating process when applied to an indirect heating system. Thus, it is important that its value be kept as high as possible. This can only be achieved if we go in for lower steam pressures. However, lower the steam pressure, the lower will be its temperature. Since temperature is the driving force for the transfer of heat at lower steam pressures, the rate of heat transfer will be slower and the processing time greater. In equipment where fixed losses are high (e.g. big drying cylinders), there may even be an increase in steam consumption at lower pressures due to increased processing time. There are however, several equipment's in certain industries where one can profitably go in for lower pressures and realize economy in steam consumption, without materially affecting production time. Therefore, there is a limit to the reduction of steam pressure. Depending on the equipment design, the lowest possible steam pressure with which the equipment can work should be selected without sacrificing either on production time or on steam consumption.
L-4	a) An oil fired reheating furnace has an operating temperature of around 1000 °C. Average furnace oil consumption is 330 litres/hour. Flue gas exit temperature after the air preheater is 820 °C. Combustion air is preheated from ambient temperature of 35 °C to 215°C through the air preheater. The other data are as given below. Specific gravity of oil = 0.92 Calorific value of oil = 10,200 kcal/kg Average O_2 percentage in flue gas = 13.5 % Theoretical air required = 14 kg of air per kg of oil Specific heat of air = 0.23 kcal/kg°C Specific heat of flue gas = 0.25 kcal/kg°C **Find out :** • The sensible heat carried away by the exhaust flue gases in kcals/hr and as a percentage of the energy input. ……….4 marks • The heat recovered by the combustion air in kcal/hr and as a percentage of the energy input. ……….3 marks b) Explain the concept and the advantage of a self-recuperative burner? ……….3 marks **Ans:** a) Fuel input = (330 litres/hr x 0.92 kg/litre) = 303.6 kg/hr Energy Input = (303.6 kg oil/hr x 10,200 kcals/kg oil) = 30,96,720 kcal/hr Excess air = [O_2 x 100/(21-O_2)] = (13.5 x 100)/(21 - 13.5)

	= 180 % Theoretical air required = 14 kg of air/kg of oil Actual mass of air required = 14 x (1 + 180 /100) = 39.2 kg air/kg of oil Mass of flue gas (m) = (39.2 + 1) = 40.2 kg flue gas/kg oil Specific heat of flue gas (Cp) = 0.25 kcal/kg.^{o}C **Sensible heat loss in the flue gas** = (m x Cp x ΔT)$_{flue\ gas}$ = (40.2 x 0.25 x (820-35)) = 7889.3 kcal/kg of oil (Or) = (7889.3 kcal/kg of oil x 303.6 kg oil/hr) = **2395176.3 kcal/hr** Sensible heat loss in the flue gas as % heat loss to input energy = (2395176.3 / 30,96,720) x 100 = **77.35 %** **Heat recovered by combustion air** = (39.2 x 0.23 x (215-35)) = 1622.88 kcal/kg of oil = (1622.88 kcal/kg oil x 303.6 kg oil/hr) = **492706.37 kcal/hr** Heat recovered by combustion air as % of input energy = (492706.37 kcal/hr/30,96,720 kcal/hr) x100 = **15.91 %** b) Self-recuperative burner (SRB) is based on traditional heat recovery techniques, in that, the products of combustion are drawn, through a concentric tube recuperator, around the burner body and used to pre-heat the combustion air. A major advantage of this type of system is that, it can be retro-fitted to an existing furnace structure, to increase production capability, without having to alter the existing exhaust gas ducting arrangements. SRBs are generally more suited to Heat-treatment furnaces, where exhaust gas temperatures are lower and there are no stock recuperation facilities.
L-5	a) An open cycle gas turbine was running with naphtha as fuel. The following are the data collected during the gas turbine operation: Fuel (Naphtha) consumption = 300 kg/hr GCV of naphtha fuel = 11,500 kcal/kg Overall Efficiency of gas turbine (which includes air compressor and alternator) = 22% Cost of naphtha fuel = Rs.40,000/Tonne a) Find out the output power and cost of fuel for generating one unit of electricity. ....6 marks b) The management has decided to install a waste heat boiler, to generate 2 TPH of saturated steam, at 4 kg/cm^2(g), with an enthalpy of 656 kcal/kg. Assuming that, 50% of the input heat is available in the turbine exhaust gases, how much steam can be generated if the feed water temperature is 30 ^{o}C. ....4 marks

	Ans: a) Heat input to turbine = (300 kg Naptha/hr x 11,500 kcal/kg) = 34,50,000 kcal/hr Efficiency of gas turbine = 22% **Gas turbine output power** = ((34,50,000 kcal/hr x 0.22)/ 860) = **882.56 kW** Cost of generating 882.56 units of electricity = (300 kg Naptha/hr x Rs.40/kg Naptha) = Rs.12000/hr **Cost of One unit of Electricity generation** = (Rs.12000 per hour/882.56 kWh per hour) = **Rs.13.6/kWh** b) Waste heat potential in existing gas turbine = (0.5 x 34,50,000 kcal/hr) = 17,25,000 kcal/hr. Heat required for raising 1 kg of steam *(feed water temp 30 °C)* = (656-30) kcal/kg steam = 626 kcal/kg steam Steam generation potential = (17,25,000 kcal per hour/626 kcal per kg steam) = 2755.6 kg steam/hr **= 2.7556 TPH**
L6	Explain **<u>any two</u>** of the following: (Each 5 Marks) 1. Regenerator (Page 222) 2. Heat Pipe (Page 223) 3. Gas Turbine cogeneration system (Page 192)

19th NATIONAL CERTIFICATION EXAMINATION
FOR
ENERGY MANAGERS & ENERGY AUDITORS – SEPTEMBER, 2018

PAPER – 2: ENERGY EFFICIENCY IN THERMAL UTILITIES

Section – I: OBJECTIVE TYPE **Marks: 50 x 1 = 50**

(i) Answer all **50** questions
(ii) Each question carries **One** mark
(iii) Please hatch the appropriate oval in the OMR answer sheet with **HB pencil only,** as per instructions

1. Density of liquid fuel is measured by an instrument called
   a) Anemometer **b) Hydrometer**
   c) Luxmeter d) All the above

2. The measured O_2 in flue gas is 5.5 % by volume, the excess air percentage will be
   a) 41 % b) 55.9 %
   c) 35.5 % d) None of the above

3. The efficiency of a reheating furnace, operating at 10 tonnes per hour consuming furnace oil of 230 kg/hour for reheating the material from 40 °C to 1100 °C (consider specific heat of material is 0.13 kCal / kg °C and calorific value of furnace oil is 10,000 kCal/kg) is ______.
   a) 60 % b) 70 %
   c) 80 % d) None of the above

4. In FBC boiler the combustion is carried out at a temperature
   a) Closer to saturated steam temperature
   b) Below ash fusion temperature of fuel used
   c) At adiabatic combustion temperature of fuel
   d) At and above ash fusion temperature of fuel

5. Turbine cylinder efficiency is given as a ratio of______________________
   a) **Actual enthalpy drop and isentropic enthalpy drop**
   b) Useful heat and power output
   c) Useful power and heat output
   d) All of the above

~~6. The effectiveness of a heat exchanger depends on~~
   ~~a) Specific heat of hot fluid~~ ~~b) Specific heat of cold fluid~~
   ~~c) Inlet temperature of hot fluid~~ ~~d) LMTD~~

Note: 1 Mark is awarded to all candidate who have attempted this question.

~~7. Efficiency evaluation requires~~
   ~~a) Ash in fuel~~ ~~b) O_2 in flue gas~~
   ~~c) Sulphur in fuel~~ ~~d) NOx in flue gas~~

Note: 1 Mark is awarded to all candidate who have attempted this question.

8. The evaporation ratio of a coal-fired boiler is 4. Steam enthalpy is 640 kCal/kg; feed water temperature is 55 ^{0}C, Calorific Value of coal is 4000 kCal/kg. The boiler efficiency is ________
   a) 49 % b) 82 %
   c) **58.5 %** d) 70 %

9. Removal of dissolved gases from the boiler feed water is called
   a) Degasification b) **Deaeration**
   c) Deoxidation d) None of the above

10. Which one of the following is a high temperature heat recovery device?
    a) **Regenerator** b) Heat pump
    c) Heat wheel d) Heat pipe

11. In reheating furnace, scale losses will
    a) **Increase with excess air** b) Decrease with the excess air
    c) Have no relation with excess air d) Increase with CO_2% in flue gas

12. Transfer of heat without a conveying medium is possible with
a) Conduction
b) **Radiation**
c) Convection
d) None of the above

13. Which of the following increases, when high pressure steam is discharged to atmosphere?
a) Sensible heat
b) Total enthalpy of steam
c) Saturation temperature
d) **Specific volume**

14. Removal of condensate from main steam line is done to prevent
a) Steam locking
b) Air locking
c) **Water hammer**
d) All of the above

15. For flash steam calculation, flash steam quantity available depends upon
a) **Condensate pressure and flash steam pressure**
b) Steam pressure
c) Steam enthalpy at atmospheric pressure
d) Total heat of flash steam

16. Air venting in a steam system is required because air is ___________.
a) A good conductor
b) **An insulator**
c) Inert
d) Diluent

17. Furnace wall heat loss does not depend on
a) Temperatures of external wall surfaces
b) Velocity of air around the furnace
c) Thermal conductivity of wall brick
d) **Material of stock to be heated**

18. In a CFBC boiler _________ are required to capture large recycled amount of bed material
a) Settling chambers
b) **Mechanical cyclones**
c) Bag filters
d) Scrubbers

19. Example for basic type of refractory is
a) Chrome
b) **Chrome magnesite**
c) Alumina
d) All the above

20. Which material is used to control SO_2 emissions in FBC boilers
a) CaO
b) **Lime stone**
c) Silica
d) Sand

21. The effectiveness of a heat exchanger does not depend on
a) Specific heat of hot fluid
b) Specific heat of cold fluid
c) Inlet temperature of hot fluid
d) **LMTD**

22. Which of the following fuel needs maximum amount of excess air for complete combustion?
a) Furnace oil
b) Natural gas
c) Pulverised coal
d) **Wood**

23. In a coal fired boiler, which parameter influences flame profile the most?
a) Fixed carbon
b) **Volatile matter**
c) Hydrogen
d) All of the above

24. Which one of the following boilers utilizes the combination of suspension and grate firing?
a) **Spreader stoker boiler**
b) Fluidized bed boiler
c) Traveling grate stoker boiler
d) Pulverized fuel boiler

25. In an oil fired steam boiler the Air to Fuel ratio by mass is 15:1 & evaporation ratio is 14:1. The flue gas to fuel ratio will be
a) 29:1
b) **16:1**
c) 1:1
d) 15:1

26. The maximum possible evaporation ratio of a boiler (From & At 100 °C basis) fired with coal having a calorific value of 4050 kcal/kg and operating at 80 % efficiency will be
a) 5
b) **6**
c) 7.5
d) 9.4

27. When solutions of differing concentrations are separated by a semi-permeable membrane, water from less concentrated solution passes through the membrane to dilute the liquid of high concentration. This is called
a) Reverse osmosis
b) Ion exchange
c) Softening
d) **Osmosis**

28. Radiation losses from the surface of a boiler practically
   a) Increase with increase in boiler loading
   b) Decrease with increase in boiler loading
   c) **Are independent of boiler loading**
   d) Are dependent on boiler loading

29. Desirable boiler water pH should be ?
   a) 5 - 7 b) **7 - 9**
   c) 9 - 11 d) None of the above

30. Soot deposition on boiler tubes is due to
   a) Poor water treatment b) High moisture content in fuel
   c) High excess air d) **Incomplete combustion**

31. If 10 % air is entrained in a steam system at 5 kg/cm^2g then the saturation temperature of steam will be
   a) **Less than the saturation temperature at 5 kg/cm^2g**
   b) More than the saturation temperature at 5 kg/cm^2g
   c) Equal to the saturation temperature at 5 kg/cm^2g
   d) Equal to the saturation temperature at 5.5 kg/cm^2g

32. In a pressure reduction valve, which of these does not change?
   a) Temperature b) Pressure
   c) Velocity d) **Enthalpy**

33. Steam at 6 bar has a sensible heat of 159.33 kcal/kg and latent heat of 498.59 kcal/kg. If the steam is 95 % dry then the total enthalpy is
   a) 625 kCal/kg b) 649.95 kCal/kg
   c) 553 kCal/kg d) **633 kCal/kg**

34. Select the wrong statement with respect to steam traps
   a) Discharges condensate as soon as it is formed
   b) Does not allow steam to escape
   c) Capable of discharging air and other incondensable gases
   d) **Does not allow condensate to escape**

35. Velocity of steam in steam pipe is directly proportional to _______________
   a) Number of bends in pipe b) **Specific volume of steam**
   c) Length of pipe d) Diameter of the pipe

36. In a typical industrial steam distribution, the commonly used trap for main steam pipe lines is
   a) Thermostatic trap b) Inverted bucket trap
   c) **Thermodynamic trap** d) Open bucket trap

37. For same inlet conditions of the steam, which of the following will generate the maximum mechanical power ?
   a) **Condensing turbine** b) Back pressure turbine
   c) Extraction-cum-condensing turbine d) Extraction-cum-back pressure turbine

38. In an oil fired heat treatment furnace, which of the following is not required to determine its efficiency by direct method ?
   a) Weight of input material b) **Oxygen percentage in flue gas**
   c) Fuel consumption d) Calorific value of fuel

39. In a coke fired cupola, carbon monoxide is produced in the
   a) Preheating zone b) **Reducing zone**
   c) Combustion zone d) Melting zone

40. Tuyeres is a part of the equipment associated with
   a) Induction furnace b) Re-heating furnace
   c) Electrical melting arc furnace d) **Cupola**

41. An increase in bulk density of a refractory increases its
   a) Thermal conductivity b) Heat capacity
   c) Resistance to slag penetration d) **All of the above**

42. The storage heat losses in a batch type furnace can be best reduced by
   a) Fire Clay brick b) **Ceramic fibre**
   c) High alumina brick d) High silica brick

43.	Emissivity is a measure of material's ability to		
	a) Only absorb heat	b) Only radiate heat	
	c) **Absorb and radiate heat**	d) None of the above	
44.	Which of the following depends on physical properties of fluids as well as geometry of the heat exchanger ?		
	a) **Overall heat transfer coefficient**	b) Fouling coefficient	
	c) LMTD	d) Effectiveness	
45.	The waste heat boiler application is not suitable for which of the following?		
	a) Gas turbine	b) Diesel engine	
	c) Oil fired furnaces	d) **Hot air dryers**	
46.	Moisture content in coal		
	a) Increases heat loss due to evaporation and superheating of water vapour		
	b) Helps in binding fines		
	c) Aids in radiation heat transfer		
	d) **All of the above**		
47.	With respect to properties of steam		
	a) The sensible heat decreases as the pressure increases		
	b) The latent heat increases as the pressure increases		
	c) The specific volume increases as the pressure increases		
	d) **The specific volume decreases as the pressure increases**		
48.	Oxidation of carbon to CO_2 yields 8084 kcal/kg of carbon. Oxidation of carbon to CO in the flue gas yields 2430 kcal/kg of carbon. Oxidation of CO to CO_2 will yield		
	a) **5654 kCal**	b) 5800 kCal	
	c) 5464 kCal	d) 540 kCal	
49.	The maximum loss that takes place in a fully condensing steam turbine power plant is		
	a) Flue gas loss	b) Steam distribution loss	
	c) Radiation and insulation loss	d) **Condenser losses**	
50.	The difference between mean solid and mean gas velocity in FBC boiler is called		
	a) Fluidization factor	b) **Slip velocity**	
	c) Settling velocity	d) Terminal velocity	

.... End of Section – I ....

Section - II: SHORT DESCRIPTIVE QUESTIONS **Marks: 8 x 5 = 40**

(i) Answer all **Eight** questionss

(ii) Each question carries **Five** marks

S1	Write short notes on wet and dry methods of preservation of boiler.
Ans	**Refer BEE Guide Book 2- Chapter 2, Page No: 54 - 55**
S2	Explain the phenomenon of water hammer in steam system and how it can be eliminated ?
Ans	**Refer BEE Guide Book 2- Chapter 3, Page No: 91**
S3	A counter flow double pipe heat exchanger using hot process liquid is used to heat water which flows at 20 m^3/hr. The process liquid enters the heat exchanger at 180 ^{0}C and leaves at 130 ^{0}C. The inlet and exit temperatures of water are 30 ^{0}C and 90 ^{0}C. Specific heat of water is 4.187 kJ/kg K. Calculate the heat transfer area if overall heat transfer coefficient is 820 W/m^2 K. What would be the percentage increase in the area if fluid flow were parallel assuming same overall heat transfer coefficient?

Ans	**Counter Flow** ▪ Water inlet temperature 30 ^{0}C ▪ Water outlet temperature 90 ^{0}C ▪ Flow rate of water 20 m^3/hr ▪ Heat content in water = 20000*(60)* 4.187=5024400 kJ/hr=1395.6 kW ▪ Process fluid inlet temperature = 180 ^{0}C ▪ Process fluid outlet temperature = 130 ^{0}C ▪ ΔT_1=90, ΔT_2 =100 ▪ T_{LMTD} = (ΔT_1- ΔT_2)/(ln(ΔT_1/ ΔT_2)) = 10/ln(100/90) = **94.91 ^{0}C** ▪ U = 820 W/m^{20}C ▪ H= UAT_{LMTD} = 1395.6*1000/(95*820) = **17.9 m^2** **Parallel flow:** ΔT_1=150, ΔT_2 =40 ▪ T_{LMTD} = (ΔT_1- ΔT_2)/(ln(ΔT_1/ ΔT_2)) = 110/ln(150/40) = **83.2 ^{0}C** ▪ U = 820 W/m^{20}C ▪ H= UAT_{LMTD} = 1395.6*1000/(83.2*820) = 20.45 m^2 % Increase in area = ((20.45-17.9)/17.9) x 100 = 14.24 % increase
S4	A continuous process industry is operating with a 2 MW DG Set with 80 % load to meet the power requirements of the plant. The specific fuel consumption of the DG set is 4 kWh/liter. On energy auditor's suggestion, a waste heat recovery boiler was installed to recover heat from exhaust gas and generating 800 kg/hr of saturated steam at 10 kg/cm^2. The waste heat recovery boiler operating data are given below. • Feed water temperature = 60 ^{o}C • Enthalpy of steam at 10 kg/cm^2 = 660 kCal/kg • Specific gravity of diesel = 0.85 • GCV of diesel = 10500 kCal/kg Calculate the following. (each carries 2.5 Marks) a) Efficiency of DG set before waste heat recovery boiler installation b) Cogeneration system efficiency after waste heat recovery boiler installation
Ans	Diesel consumption Litre / hour = ((2 x 1000) x 0.8)) / 4 = 400 litre / hour a) DG set efficiency $= \dfrac{\text{2000 kWh/hr x 0.8 loading x 860 kcal/kWh}}{\text{400 lit x 0.85 kg/lit x10500 kcal/kg}} \text{x100} = 38.54\ \%$ b) Co-gen System Efficiency after WHR boiler installation $\dfrac{\text{[2000 kW x 0.8 loading x 860 kcal/hr/kW + (800 kg steam /hr x (660-60) kcal/kg]}}{\text{[400 lit x 0.85 kg/lit x10500 kcal/kg]}} \text{x100} = 52\%$
S5	A coal fired thermic fluid heater is used to supply heat to a dryer. The hot oil circulation is supplied at 270 ^{o}C, with a flow of 100 m^3/hr and operating with temperature difference of 20 ^{o}C. Estimate the coal requirement if the thermal efficiency of the heater is 65 % and GCV of the coal is 4200 kCal/hr. Consider specific heat & density of the thermic fluid to be 0.55 kcal/kg ^{o}C& 820 kg/m^3 respectively.

Ans	Absorbed heat in thermic fluid = m * Cp * Δ T = (100 * 820) * 0.55 * 20 **= 902000 kcal/hr** Thermal efficiency of the heater = absorbed duty / input heat duty Mass of coal required = absorbed duty / (efficiency * calorific value of coal) = 902000 / (0.65 * 4200) **= 330.4 kg/hr**
S6	In a heat exchanger, steam is used to heat 3000 litres/hr of furnace oil from 30 ^oC to 100 ^oC. The specific heat of furnace oil is 0.22 kCal/ kg/^oC and the density of furnace oil is 0.95. How much steam per hour is needed if steam at 4 kg/cm^2 with latent heat of 510 kCal/kg is used ? If steam cost is Rs.4/kg and electrical energy cost is Rs.8/kWh, which type of heating would be more economical in this particular case? (assume no losses in electrical and steam heating process)
Ans	Total heat required = m Cp ΔT = (3000 x 0.95) x 0.22 x (100-30) = 43890 kcal/hr a) Amount of steam required = 43890/510 = 86 kg/hr Steam cost = 86 x Rs.4 = Rs. 344/hr b) Amount of electricity required = 43890/860 = 51 kWh = 51 x Rs. 8 = Rs.408/ hr Answer : Steam heating will be more economical
S7	Calculate the reduction in pressure drop in meters when pipe diameter is increased from 250 mm to 350 mm for a length of 500 meters. The water velocity is 2 m/s in the 250 mm diameter pipe, and friction factor is 0.005.
Ans	Pressure drop = $4fLV^2/ 2gD$ Pressure drop with250 mm = $(4 \times 0.005 \times 500 \times 2^2)/(2 \times 9.81 \times 0.250)$ = 8.155 m Velocity of water in pipe of 350 mm diameter = (0.25 x 0.25 x 2) /(0.35 x 0.35) = 1.02 m/s Pressure drop with350 mm = $(4 \times 0.005 \times 500 \times 1.02^2)/(2 \times 9.81 \times 0.350)$ = 1.515 m Pressure drop reduction = 8.155 – 1.515 = **6.64 m**

S8	In a process plant 200 kg/hr of hot condensate at 6 bar(g) having a sensible heat of 166 kCal/kg is discharged. The plant also requires low pressure steam at a pressure of 1 bar(g) for heating application. Find out the quantity of flash steam generated in the flash vessel in kg/hr. The condensate at a pressure of 1 bar(g) has a sensible heat of 120 kCal/ kg and a latent heat of 526 kCal/kg.
Ans	Flash steam available % = $\frac{S1 - S2}{L2} \times 100$ Where, S_1 = is the sensible heat of higher pressure steam S_2 = is the sensible heat of steam at lower pressure L_2 = is the latent heat of flash steam at lower pressure Flash steam generated = $\left(\frac{166 - 120}{526}\right) \times 200$ Kg/hr = 17.49 kg/hr

…………. End of Section – II ……………

Section - III: LONG DESCRIPTIVE QUESTIONS **Marks: 6 x 10 = 60**

(i) Answer all **Six** questions

(ii) Each question carries **Ten** marks

L1	a) Write short notes on the following (each carries 2.5 Marks) • Advantage of Micro turbine in Steam System • Trigeneration with example b) Why is individual trapping preferred over group trapping? (5 Marks)
Ans	a) • (Refer BEE Guide book 2, Chapter 7, Page No-209) • (Refer BEE Guide book 2, Chapter 7, Page No-208) b) (Refer BEE Guide book 2, Chapter 7, Page No-208)
L2	Explain the following (each carries 5 Marks) • Advantages of using ceramic fibre in furnaces • Advantages of using fluidized bed boilers
Ans	• (Refer BEE Guide book 2, Chapter 5, Page No:164-165) • (Refer BEE Guide book 2, Chapter 6, Page no: 182-183)
L3	An air preheater in a 90 TPH induced draft boiler was showing the following readings: i. Flue gas inlet temperature: 319.5 ^{0}C ii. Flue gas Outlet temperature: 160 ^{0}C iii. Air inlet temperature: 70 ^{0}C iv. Air outlet temperature: 210 ^{0}C

	The steam to fuel ratio is 12 and air to fuel ratio is 14. It was found that there was air ingress from atmosphere to flue gas side. Ambient air temperature was 30 ^{0}C. Assuming that the specific heat capacity of air and flue gas to be the same at 0.24 kcal/kg K and the amount of heat picked up by fresh air remains the same. Calculate the following: (each carries 5 Marks) a) The amount of air ingress into the flue gas path. b) The flue gas temperature after air preheater in case of no air leak to flue gas circuit.
Ans	a. Steam flow: 90TPH Steam to fuel ratio: 12 ➔ fuel consumed is 7.5 TPH Air to fuel ratio: 14➔ air used in boiler is 105 TPH Flue gas = Air + Fuel ➔ Flue gas = 105+7.5 = 112.5 TPH Air ingress is at 30 deg C. Making an energy balance around APH: we get 112.5 * 319.5 + 105 * 70 + x * 30 = 105 * 210 + (112.5+x) *160 Solving for x, we get air ingress to be 25 TPH **Flue Gas Temperature** b. ➔ 112.5 * 319.5 + 105 * 70 = 105*210+112.5* T Solving for T, we get the corrected flue gas temperature to be 189 °C
L4	As a part of energy conservation measure, APH (Air Pre-heater) is installed in a forced draft furnace. The APH is designed to pre-heat 240 m^3/min of combustion air to 250 ^{0}C. Flue gas enters the APH at 375 ^{0}C. Calculate the flue gas quantity leaving the stack and also determine the improvement in furnace efficiency after the installation of APH with the following data, Density of air : 1.15 kg/m^3 Specific heat of air : 0.24 kCal/kg ^{0}C Specific heat of flue gas : 0.2 kCal/kg ^{0}C Amount of fuel fired : 920 kg/hr Calorific value of fuel : 9850 kCal/kg Air to fuel ratio : 18 Efficiency of furnace : 80 % Ambient temperature : 30 ^{0}C
Ans	**Solution:** Amount of Air flow = 240 * 60 * 1.15 = 16560 kg/hr Amount of fuel = 16560 / 18 = 920 kg/hr Amount of flue gas = 16560 + 920 = 17480 kg/hr Heat gain by combustion air = 16560 * 0.24 * (250 – 30) = 874368 Kcal/hr Temperature difference in flue gas = 874368 / (17480 * 0.2) = 250 °C Flue gas leaves the stack at temp = 375 – 250 = 125 °C Efficiency of APH = Heat absorbed by air / Heat input * 100 = 874368 / (920* 9850) * 100

	= 9.6 % Overall efficiency after APH = 80 + 9.6 % = 89.6 %
L5	An oil fired Boiler is generating 100 TPH of steam at 85 % efficiency and operating 330 days in a year. The management has installed a water treatment plant with Rs. 2 Crore investment for reducing the Total Dissolved Solids (TDS) in boiler feed from 450 ppm to 150 ppm. The maximum permissible limit of TDS in the boiler is 3000 ppm and make up water is 10 %. The temperature of blowdown water is 175 ^{0}C and the boiler feed water temperature is 45 ^{0}C. The calorific value of fuel oil is 10,200 kCal/kg. Calculate the payback period if the cost of fuel is Rs. 45,000 per ton.
Ans	Blow down % = $\dfrac{\text{Feed water TDS * \% make up water * 100}}{\text{(maximum permissible TDS in boiler water – Feed water TDS)}}$ Initial blow down = 450 * 10 / (3000 – 450) Initial blow down = 1.764 % Improved blow down = 150 * 10 / (3000 – 150) Improved blow down = 0.526 % Reduction in blow down = 1.76 – 0.526 Reduction in blow down = 1.238 % Reduction in blow down = 1.238 * 100 * 1000 / 100 Reduction in blow down = 1238 kg/hr Specific heat of water is 1 kcal/kg°C Heat savings = m * Cp * (T_1 – T_2) = 1238 * 1 * (175 – 45) Heat savings = 160940 kcal/hr Fuel Oil saving = 160940 / (10200 * 0.85) = 18.6 kg/hr = 18.6 * 24 * 330 / 1000 = 147 MT / annum Fuel Oil – cost savings = 147* 45000 = Rs. 66 lakh Investment on water treatment plant = Rs. 2 Crore Payback period = 2 / 0.66 Payback period = 3.0 years (or) 36 months
L6	In a leather industry, a leather drier requires 80 m^3/min of air at 92 ^{0}C, which is heated by wood fired thermic fluid heater. The density of air is 1.2 kg/m^3 and specific heat of air is 0.24 kcal/kg ^{0}C. The inlet air temperature to the drier is 32 ^{0}C and the drier is operating for 8 hrs per day. The efficiency of the wood fired heater and its distribution piping system is 50 %. The gross calorific value and the cost of purchased wood are 2000 kCal/kg and Rs. 5000 per ton. The auxiliary power consumption for operating the thermic fluid heater is 10 kW. The energy auditor recommended replacing the existing drying system with a 40 kW infrared electric heater drier. The kW loading of the proposed drier will be 70 % over an 8 hour plant operating period. The investment for the new drier is Rs. 10 Lakhs. If the cost of electricity is Rs. 7/kWh, calculate the following : a) Find out the annual energy cost savings of replacement of thermic fluid system with infra-red heater ? (7 Marks) b) Find out the payback period. (3 Marks)

Ans	**Cost of wood fired thermic fluid heater operation** Air flow rate (vol) = 80 m3/min x 60 = 4800 m3/hr Air flow rate (mass) = 4800 x 1.2 = **5760 kg/hr** Sensible heat of air = m x Cp x T = 5760 x 0.24 x (92-32) = **82944 kcal/hr** Efficiency of wood fired heater =50% Wood consumption = 82944/(2000 x0.5) per hr=**83 kg per day** Cost of wood **per day** = 83 xRs 5 x 8 hour = **Rs 3320 per day** Cost of Auxiliary electricity = **10 kW x 8 hrs x 7 = Rs.560** **Total cost of operation = 3880 Rs.** **Cost of Infra-red heater operation** Electric heater rating= 40 kw Electricity consumption per day= 40 kw x 0.7 x8hr = 224 kwh per day = 224 x Rs 7= **Rs 1568 per day** Cost saving potential = 3880- 1568 = Rs2312 Annual saving potential = 2312 x 300 days = **Rs. 6.94 lakhs** **Investment= 10 lakhs** **Payback period= 10/6.94= 17 months or 1.4 years** **Or** Annual saving potential = 2312 x 365 days = **Rs. 8.44 lakhs** **Investment= 10 lakhs** **Payback period= 10/8.44= 14 months or 1.2 years**

………….. End of Section – III ……………

Regn No: ____________________

Name : ____________________
(To be written by the candidate)

18th NATIONAL CERTIFICATION EXAMINATION FOR ENERGY MANAGERS & ENERGY AUDITORS – September, 2017

PAPER – 2: Energy Efficiency in Thermal Utilities			
Date: 23.09.2017	Timings: 14:00-17:00 HRS	Duration: 3 HRS	Max. Marks: 150

General instructions:

- *Please check that this question paper contains **8** printed pages*
- *Please check that this question paper contains **64** questions*
- *The question paper is divided into three sections*
- *All questions in all three sections are compulsory*
- ***All parts of a question should be answered at one place***

Section – I: OBJECTIVE TYPE **Marks: 50 x 1 = 50**

a) Answer all **50** questions
b) Each question carries **one** mark
c) Please hatch the appropriate oval in the OMR answer sheet with Black Pen or HB pencil

1.	In a Heat exchanger with a high LMTD results in a) higher heat transfer area **b) lower heat transfer area** c) higher u-factor d) none of the above
2.	" Heat Loss = Heat gain " is the principle of ____ a) Boiler **b) Heat Exchanger** c) Steam traps d) All of the above
3.	Flash steam quantity per kg of condensate depends upon a) condensate pressure only b) condensate pressure and flow **c) condensate pressure and flash steam pressure** d) none of the above
4.	Which of the following waste heat recovery systems is of thermal storage type?

	a) ceramic recuperator b) metallic recuperator **c) regenerative burner** d) waste heat boiler
5.	A boiler trial indicated 2% O_2 at boiler exit and 7% O_2 at stack. The in-leak air quantity between these two measurement is a) 25**%** **b) 40%** c) 50% **d) none of the above**
6.	The concentration of solids in a boiler is controlled by a) steam venting **b) blow down** c) air venting d) deaeration
7.	Insulating material made by blending and melting of alumina and silica is known as **a) ceramic fibre** b) high alumina brick c) fire brick d) insulating brick
8.	Tangential firing is used in which type of boiler: a) CFBC b) Chain Grate c) Spreader Stoker **d) Pulverised Fuel**
9.	_____ is required for the simple estimation of flame temperature of the fuel. **a) Ultimate analysis** b) Proximate analysis c) Size of the coal d) All of the above
10.	Overall heat transfer co-efficient in Heat exchangers depends on ____. a) Conductivity of the wall separating the two fluids b) Convective coefficients of hot and cold fluids c) Fouling coefficients **d) All of the above**
11.	The key property of bio mass fuel which influences storage, handling and transportation a) Calorific Value b) Percentage of Ash **c) Bulk Density** d) None of the above
12.	Which of the following contributes to spluttering of flame at burner tip during combustion of fuel oil? a) ash content b) **water content** c) sulphur content d) humidity of air
13.	When 100 kg of fuel with 60% carbon is burnt with theoretical air, the mass of CO_2 released will be a) 319 kg b) 4400 kg c) 4500 kg **d) 220 kg**
14.	Which of the following heat recovery equipment works on a vapour compression cycle? a) thermo-compressor b) heat wheel

	c) heat pump d) heat pipe
15.	Which of the following releases large amount of heat per kg during combustion? **a) Hydrogen** b) Carbon c) Sulphur d) Nitrogen
16.	Auxiliary power consumption for coal preparation will be highest in a; a) stoker fired boiler b) AFBC boiler c) CFBC boiler **d) pulverized coal fired boiler**
17.	In a heat exchanger, for the same heat duty, higher the heat transfer coefficient; a) higher will be the heat transfer area needed b) higher will be the LMTD **c) lower will be the heat transfer area needed** d) lower will be the LMTD
18.	Which of the following increases, when steam is passed through PRV? **a) specific volume** b) enthalpy of steam c) sensible heat d) saturation temperature
19.	Which of the following is not true with respect to improper sizing of coal a) results in poor combustion **b) lowers excess air resulting in lesser stack loss** c) increases un-burnt in ash d) lowers thermal efficiency
20.	When solutions of differing concentrations are separated by a semi-permeable membrane, water from less concentrated solution passes through the membrane to dilute the liquid of high concentration. This is called a) reverse osmosis b) ion exchange c) softening **d) osmosis**
21.	_______ is used as heat carrier in thermic fluid heaters a) steam **b) mineral oil** c) water d) all of the above
22.	Dissolved CO_2 in boiler feed water when left untreated would result in occurrence of ________in boiler tubes a)creep **b) water side corrosion** c)scale d)water hammer
23.	In a counter-flow heat exchanger, cold fluid enters at 30°C and leaves at 50°C, whereas the hot fluid enters at 150°C and leaves at 130°C. The LMTD is

	a) 100°C b) 280°C c) 0°C d) 20°C
24.	Which of the following is not measured in the ultimate analysis of a fuel ? a) oxygen **b) fixed carbon** c) sulphur d) nitrogen
25.	Ceramic fibre gives the maximum energy savings when used in a) continuous furnace **b) batch furnace** c) arc furnace d) induction furnace
26.	In industrial applications the commonly used trap for main steam lines is a) thermostatic trap b) inverted bucket trap **c) thermodynamic trap** d) open bucket trap
27.	Fluidized bed combustion takes place in the temperature range of a) above 1000^0C b) below 500^0C c) 600-700^0C **d) 800-900^0C**
28.	In a glass industry waste heat is used for power generation. This type of cogeneration is called a) topping cycle **b) bottoming cycle** c) combined cycle d) none of the above
29.	Select the odd one among the following a) condenser b) distillation column c) evaporator **d) cooling tower**
30.	In a boiler, air preheater is installed a) before the economizer **c) after economizer** b) before superheater d) after ESP
31.	A pinch analysis can result in a) reduction in cooling water b) reduction in steam c) increase in cooling water **d) both a & b**
32.	The main contributor for temporary hardness in Boiler water is ____. a) calcium chloride b) magnesium sulphate **c) calcium bicarbonate** d) calcium nitrate

33.	The amount of oxygen required to burn 0.5 kg of Sulphur is a) 1 b) 16 c) 32 **d) 0.5**
34.	_____ is required to accommodate expansion of steam lines. a) prv **b) expansion loop** c) steam trap d) air vent
35.	Steam mains should be run with a falling slope of … in the direction of steam flow for effective line condensate drainage a) 50 mm in 30 meters **b) 125 mm in 30 meters** c) 250 mm in 30 meters d) 350 mm in 30 meters
36.	Degasser in water treatment is used to remove a) Dissolved oxygen and other gas **b) carbonic acid** b) Sulphuric acid d) dissolved CO_2
37.	In a boiler Theoretical Air to fuel ratio is 15:1. If 10% excess air is supplied, Flue gas to Fuel ratio will be ____ a) 16:1 **b) 17.5:1** c) 16.5:1 d) 17:1
38.	Increased Sulphur percentage in furnace oil **a)sets lower flue gas temperature limit** b) improves viscosity c) does not add to heat value d) forms soot
39.	Which among the following is most viscous fuel? **a) furnace oil** b) HSD c) kerosene d) Light Diesel oil
40.	The turbine heat rate is expressed as

	a) kWh/kcal b) kg/kcal **c)kcal/kWh** d) none of the above
41.	Heat loss through openings in furnaces is directly proportional to a) fourth power of furnace temperature b) square of absolute furnace temperature c) absolute furnace temperature **d) fourth power of absolute furnace temperature**
42.	Which of the following is an example of a basic refractory a) Alumino-silicate b) chrome b) **Magnesite** d)pure alumina
43.	Which property of the refractory determines the deformation under stress? **a) creep** b) refractoriness under load (rul) c) porosity d) pyrometric cone equivalent (PCE)
44.	Electro static precipitator in FBC boiler is used for ________ a) Bottom ash removal **b) Fly ash removal** c) SO_2 removal d) CO_2 removal
45.	Heat rate is likely to be the least for _________ a) back pressure turbine **b) condensing turbine** c)extraction condensing turbine d) double extraction turbine
46.	Which of the following is true of plate heat exchangers a) close approach b) expandable area c) Counter current **d) All of the above**
47.	In FBC boilers fluidization depends largely on --------- i) Particle size ii) Air velocity iii) Bed Material iv) Size of Boiler a) i & iii b) ii & iii **c) i & ii** d) i,ii,iii,iv
48.	When the boiler bed temperature exceeds beyond 950°C, the result is: a) Low steam temperature **b) clinker formation** c) Melting of lime stones d) Ash carry over
49.	Automatic blowdown controls for boilers work by sensing

	a) TDS b) conductivity c) pH **d) conductivity and pH**
50.	Latent heat of steam at the critical point is a) infinite b) 540 kcal **c) zero** d) none of the above

-------- End of Section - I ---------

Section - II: SHORT DESCRIPTIVE QUESTIONS Marks: 8 x 5 = 40

(i) Answer all **Eight** questions
(ii) Each question carries **Five** marks

S-1	Explain the working of Thermic fluid heating system and why it is preferred to steam heating in some cases?
Ans	**Thermic Fluid Heaters:** • At high temperatures, steam requires a corresponding high operating pressure and establishing high temperatures with steam can be very cumbersome and expensive in some cases. • In thermic fluid heaters, a special type of oil-synthetic / mineral is used as heat carrier. This fluid can be heated up to 300^{o}C at atmospheric pressure. In comparison steam would require a pressure of 85 bar to obtain this temperature. ……………………..2.5 marks **Advantages:** – High temperature operation at atmospheric pressure – Optional temperature level set points – No supply or treatment of hot water and hence no heat loss due to condensate flash steam – No risk of corrosion – Easy to operate **Functioning of Thermic Fluid Heaters** • Heat is transferred to the fluid through radiation. The hot thermic-fluid is circulated to various process equipments such as dryers, heaters, de-odouriser etc. where it gives up the heat. The return oil at a temperature 10 to 20 ^{0}C less, comes back to the thermic-fluid heater to get heated up again. The circulation is carried out by a thermic fluid circulation pump. • The thermic-fluid heater operates between two temperature ranges. Once the upper limit is reached the burner is switched OFF or goes into the low fire mode. In the case of solid fuel fired system the ID fan switches OFF on

	reaching the upper limit. When the temperature reaches the lower limit due to heat transfer in the process, the burners come ON again and in case of solid fuels, the ID fan comes ON again. • Since the thermic fluid heaters operate at a high temperature (250 – 300 ^{0}C), the leaving exhaust gas temperatures are more than the fluid temperature. Hence, the heat loss through the flue gas is a major component of fuel losses. This offers potential for heat recovery if there is a suitable application. • The capacity is specified in terms of Lakh kilo calories per hour or Million kilo calories per hour. **(Pg no 56 of Book 2 for explanation)** ……………………..2.5 marks
S-2	In a car manufacture company, Propane is used as fuel in heaters for preheating paints. Calculate the Air to Fuel ratio for complete combustion of C_3H_8 (Propane), if 15% excess air is supplied to the heater.
Ans	**$C_3H_8 + 5\ O_2 \dashrightarrow 3\ CO_2 + 4\ H_2O$** ……………………..1 mark **1 mole of propane requires 5 moles of Oxygen.** **Molecular weight of Propane is 44 Kg per mole.** ……………………..1 mark **44 Kg of Propane requires 160 Kg of Oxygen.** **Theoretical air required for combustion = 160 / 0.23 = 695.6 Kg/hr** ……………………..1.5 marks **Excess air supplied is 15 %.** **Actual air supplied for combustion is = 695.6 * 1.15** **= 800 Kg/hr of air** **Air to Fuel ratio = 800 / 44** **= 18.18 or 18.2** ……………………..1.5 marks
S-3	To meet a process plant's heat and power requirements, high pressure steam at 70 MT/hr passes through a back pressure steam turbine, for power generation and the exhaust

<table>
<tr><td></td><td>steam is sent for thermal process requirements in the plant. With the following operating data, calculate the heat to power ratio in kW/kW if the turbine and generator efficiencies are 90% and 92% respectively.

<table><tr><th>Steam Inlet conditions</th><th>Steam outlet conditions</th></tr><tr><td>Pressure = 50 bar
Temperature = 530°C
Enthalpy of steam = 3515 kJ/kg</td><td>Pressure = 10 bar
Temperature = 280°C
Enthalpy = 3020 kJ/kg
Enthalpy of water = 782 kJ/kg</td></tr></table></td></tr>
<tr><td>Ans</td><td>– Power generated = 70 * 1000 * (3515 - 3020) * 0.90 * 0.92 / 3600
= 7969.5 kW
……………………..2 marks
– Heat input to process = 70 * 1000 * (3020-782) / 3600 = 43517 kW
– ……………………..2 marks
– Heat to power ratio = 43517 / 7969.5 = 5.46 kW/kW
……………………..1 mark</td></tr>
<tr><td>S-4</td><td>a) Explain why de-superheating is done after pressure reduction in PRVs?

b) Why is correction factor required for estimation of LMTD?</td></tr>
<tr><td>Ans</td><td>a) A reduction in steam pressure through a pressure reducing valve (PRV) is an isenthalpic process. Saturated steam when reduced to a lower pressure results in super heated steam. Since process requires only saturated steam, de-superheating is often required, to compensate for superheat gained in PRV application due to isenthalpic expansion.

……………………..2.5 marks

b) In multi pass shell and tube heat exchangers, the flow pattern is a mixture of co-current and counter current flow, as the two streams flow through the exchanger in the same direction on same passes and in the opposite on others. For these reasons, the mean temperature differences is not equal to the logarithmic mean. However it is convenient to retain the LMTD by introducing a correction factor, F which is appropriately termed as the LMTD correction factor.

……………………..2.5 marks</td></tr>
<tr><td>S-5</td><td>What happens to steam properties such as saturation temperature, enthalpy of saturated water, latent heat of steam, enthalpy of steam and specific volume of steam, if the steam pressure is increased?</td></tr>
<tr><td>Ans</td><td>a) Saturation Temperature increases
b) Enthalpy of saturated water Increases.
c) Latent heat of steam decreases</td></tr>
</table>

	d) Enthalpy of steam increases e) Specific Volume decreases ……………………..5 marks (each point carries one mark respectively)
S-6	Two identical biomass fired boilers of capacity 10 TPH are operated in a chemical industry. They each have a full load efficiency of 80%. The part load efficiencies at 70% and 40% load are 75% and 68% respectively. For meeting 14 TPH requirement of steam, would you prefer to run both the boilers at 7 TPH capacity or one at full load capacity and other at 40% capacity. Estimate the % savings in the preferred case.
Ans	**Fuel energy required when both the boilers are run at 7 TPH load** ***Governing equation to be used :*** ***(Fuel reqd) = [(Qty stm) * (Enth steam – Enth feedwater)] / [(GCV Fuel) * (Effy boiler)]*** ***(Fuel reqd) = [(Qty stm) * (Δh) / (Effy boiler)]*** ***Where : Δh = is same in both cases = [Enth steam – Enth feed-water) / (GCV Fuel)]*** ***Fuel required* = (2*7*Δh) / (0.75) = 18.67 Δh** ……………………..1 mark **Fuel energy required when one boiler is running at full load and the other at part load of 40%** ***Fuel required* = [(10*Δh) / (0.8)] + [(4*Δh) / (0.68)]= 18.38 Δh** ……………………..2 marks **The case where one boiler is running at full load and the other at part load of 40% is preferred** ……………………..1 marks • **% savings = [(18.67 Δh) – (18.38 Δh)] * 100 / (18.67 Δh)** **= 1.55%** ……………………..1 mark
S-7	A reheating furnace is operating with deteriorated wall insulation. The existing average outer surface temperature of the furnace (of area = 100 m^2) with surrounding ambient air temperature of 40ºC, is recorded to be 120ºC. After revamping the refractory, the furnace outer surface temperature reduces to 50ºC. If the fuel oil (GCV = 11,000 kcal/kg) cost is Rs. 25,000 per tonne, and efficiency of the furnace is 35%, estimate annual savings for 300 working days per year.
Ans	Rate of heat loss from furnace surface (existing) S = [10+(Ts – Ta) / 20] x (Ts- Ta) kcals/hr/m^2 Heat loss = S x A $= 100 m^2 \times [10+\left(\frac{120-40}{20}\right)] (120-40)$ kcals/hr /m^2 = 112.0 x 10^3 kcal/hr ……………………..1 mark

	Rate of heat loss from furnace surface after revamping insulation refractory $= 100\ [\ 10 + \frac{50-40}{20}\ ]\ (50\text{-}40)$ $= 10.5 \times 10^3$ kcal/hr ……………………1 mark Energy savings kcal/hr = $(112\text{-}10.5) \times 10^3$ = 101.5×10^3 kcal/hr Annual energy savings = $(112\text{-}10.5) \times 10^3 \times 300 \times 24$ = 7.308×10^8 kcal/yr ……………………1 mark Annual fuel oil savings = $\frac{7.308x10^8}{0.35x11000}$ = 1.9×10^5 kg of fuel …………………… 1 mark Annual Cost savings = $\frac{1.9x10^5 x25000}{1000}$ = Rs.4.75×10^6 ……………………1 mark
S 8	The efficiency of a boiler on GCV basis is 85%. The fuel contains 1.0 % moisture and 12 % hydrogen. The GCV of fuel is 10,500 Kcal/kg. What is the boiler efficiency on the basis of net calorific value?
	NCV = GCV – [9 x $\frac{\text{\%age of Hydrogen in fuel}}{100}$ + $\frac{\text{\%age of moisture in fuel}}{100}$] x584 NCV = $10500 - [\ 9 \times \frac{12}{100} + \frac{1.0}{100}\ ] \times 584$ = 10500 – [9 x 0.12 + 0.01] x 584 = 10500 - 636.56 = 9863.44 = 9863 kcal / kg ……………………3 marks Boiler efficiency on NCV = $\frac{85}{9863} \times 10500$ = 90.5% ……………………2 marks

-------- End of Section - II ---------

Section - III: LONG DESCRIPTIVE QUESTIONS **Marks: 6 x 10 = 60**

(i) Answer all **SIX questions**
(ii) Each question carries **Ten** marks

L-1

In an engineering industry, an electrically heated furnace of efficiency 80%, is used for annealing of the components. The annealing cycle and corresponding energy consumption as follows.

S.No	Heat treatment cycle	Temperature ^0C	Time hrs	Power drawn in kW
1	Heat -Up	30 - 850	4	500
2	Holding at	850	4	100
3	Cooling	850 - 60	4	20

The electrical energy drawn in each sub-cycle is uniform and plant operates 50 batches per month. The cost of electricity is Rs.8/kWh.
The management has decided to replace the electric furnace with FO oil fired furnace with efficiency of 50%. The cost of F.O is Rs.30/kg. Calculate cost savings and payback period of converting from electric to oil fired furnace. Investment for FO fired furnace is Rs.25 lakhs. The GCV of F.O is 10,000 kcal/kg

Ans

Energy consumption per treatment batch :

– Heat up time = 500 x 4 = 2000kWh; …………………..1 mark
– Holding time = 100 x 4 = 400 kWh …………………..1 mark
– Cooling time = 20 x 4 = 80 kWh …………………..1 mark
– Total energy consumption per batch = 2480 kWh …………………..1 mark
– Monthly energy consumption by electric annealing furnace including losses = 2480 x 50
= 1,24,000 kWh / month
……………………1 mark
– Actual consumption by the components at electrical furnace efficiency of 80% = (124000 x 0.8)
= 99,200 kWh / month
……………………1 mark
– Eqvt FO required to be supplied to the oil fired furnace at an efficiency of 50% = 99200 x 860 / (10000 x 0.5)
= 17062.4 kg / mth
……………………1.5 marks
– Annual Cost of = [(124000 x 8) – (17062.4 x 30)] x 12
= Rs.57,61,536 / yr
……………………1.5 marks
– Payback period = 2500000 / 5761536 = 5.2 months
……………………1 mark

L-2

Write short notes on any two of the following
a. Wet preservation method for boilers
b. Reverse osmosis
c. Reciprocating engine co-generation system

Ans	a) **Wet preservation method for boilers:** In the wet method the boiler is filled to the normal level with water at a pH of 10.5 to 11. Hydrazine to the extent of 200 ppm is to be dosed with the water. The unit is to be steamed in service to ensure uniform concentration of boiler water throughout the unit and to eliminate dissolved oxygen from water. Sodium sulphite (Na_2SO_3), which acts as a de-oxygenerator, can also be used as an alternative to hydrazine and the sulphite concentration has to be maintained at 300-400 ppm. Analysis of boiler water should be carried out frequently. If the hydrazine concentration in water happens to drop below 50 ppm, the water in the drum should be lowered to the normal operating level and an appropriate quantity of chemicals should be dosed to bring back 200 the concentration of hydrazine or sodium sulphite. The boiler should be steamed to circulate chemicals to uniform concentration. …………………..5 marks b) **Reverse osmosis:** When solutions of differing concentrations are separated by a semi-permeable membrane, water from less concentrated solution passes through the membrane to dilute the liquid of high concentration, which is called osmosis. If the solution of high concentration is pressurized, the process is reversed and the water from the solution of high concentration flows to the weaker solution. This is known as reverse osmosis. …………………..5 marks c) **Reciprocating engine co-generation system:** Also known as internal combustion (I. C.) engines, these cogeneration systems have high power generation efficiencies in comparison with other prime movers. There are two sources of heat for recovery: exhaust gas at high temperature and engine jacket cooling water system at low temperature. As heat recovery can be quite efficient for smaller systems, these systems are more popular with smaller energy consuming facilities, particularly those having a greater need for electricity than thermal energy and where the quality of heat required is not high, e.g. low pressure steam or hot water. …………………..5 marks (Consider any two of the above)
L3	A fluidized bed boiler generates 24TPH at 22 kg/cm^2(g), out of which, 18 TPH is going to the back pressure turbine and exhausts from it at 5kg/cm^2(g) to meet the process steam requirement in the plant. The balance steam from the boiler is passed through a PRDS to supply 10 kg/cm^2(g) steam at dry saturated condition to another process. DM water at 105^{0}C is used for de-superheating in PRDS. Given data: a) Mechanical Efficiency of steam turbine = 95 % b) Losses in gear transmission = 4% c) Efficiency of alternator = 96 % d) The total heat of steam at turbine inlet condition at 22 kg/cm^2(g) = 708 kcal/kg e) The total heat of steam at turbine outlet condition at 5 kg/cm^2 (g) = 658 kcal/kg f) The total heat of the steam at PRDS exit at 10kg/cm^2(g) = 670 kcal/kg Calculate 1. Power generation from back pressure turbine 2. Steam flow rate going to process at the exit of PRDS
ANS	<u>1: Power generation from back pressure turbine:</u> Enthalpy drop across the turbine per kg of inlet steam = (h1-h2) = (708-658)= 50 kcal/kg

<table>
<tr><td></td><td>

……………………1 mark

Total steam flow rate through turbine = 18,000 kg/hr
Total enthalpy drop across the turbine =18,000*50
= 900000 kcal/hr

……………………1 mark

Mechanical Efficiency of steam turbine = 95%
Efficiency of alternator = 96 %
% losses in gear transmission = 4%

Over all efficiency of the turbo alternator = 0.95 x 0.96 x 0.96
= 0.8755 = 87.55%

……………………2 marks

Energy output of turbine = 900000 x 0.8755
= 787950

……………………1 mark

Power output of the alternator = 787950/ 860 = 916 kW

……………………1 mark

<u>2: Steam Flow rate going to process at the exit of PRDS:</u>

Flow rate of DM water = m
Heat content of steam at exit of PRDS = Heat supplied by water and steam to PRDS
(6000 + m) x 670 = (6000 x 708) + (m x 105)
m = 403.54 kg/ hr = 403.54 kg/hr

……………………3 marks

Steam flow at outlet of PRDS = 6000 + 403.54 = 6403.54 kg / hr

……………………1 mark
</td></tr>
<tr><td>**L4**</td><td>

In a chlor-alkali plant, 100 TPD caustic solution at 30% concentration is dried to 55% concentration in a single effect evaporator, where the ratio of steam input to moisture removal is 1.0 kg/kg. It is proposed to be replaced by a triple effect evaporator at an investment cost of Rs. 5 crore, for which the ratio of steam input to moisture removal is 0.45 kg/kg. Steam for the evaporator is generated from an oil fired boiler at an evaporation ratio of 14.

Calculate ~~annual~~ fuel savings in TPD.
</td></tr>
<tr><td>Ans</td><td>

% salt concentration at inlet = 30%
% salt concentration at outlet = 55%
Input quantity of caustic solution to drier = 100 TPD
Amount of bone dry salt at drier inlet = 100x 0.3 = 30 TPD ....1 mark
Amount of water at drier inlet = 100 - 30 = 70 TPD ....1 mark
Flow rate of salt solution at drier outlet = 30 / 0.55 = 54.5 TPD ....1 mark
Amount of water at drier outlet = 54.5 - 30 = 24.5 TPD ....1 mark
Amount of water removed = 70 - 24.5 = 45.5 TPD ....1 mark
Ratio of steam / moisture for single effect = 1.0 ....1 mark
Amount of steam required for single effect = 45.5 TPD
Ratio of steam / moisture for triple effect = 0.45
Amount of steam required for triple effect = 45.5 x 0.45 = 20.475 TPD ....1 mark
Amount of steam saved by triple effect = 45.5 – 20.45 = **25.05 TPD**.............1 mark
Evaporation ratio = 14
Amount of fuel savings = 25.05 / 14 = **1.789 TPD**……………2 marks
</td></tr>
</table>

L-5 Write short notes on following refractory properties and their significance.
a) Porosity b) Bulk density c) Pyrometric cone equivalent d) Thermal conductivity

Ans

Porosity

Low porosity is desirable as it would prevent easy penetration of refractory and also larger number of small pores are preferred over small number of large pores

……………….2.5 marks

Bulk density

Increase in bulk density increases its volume stability, heat capacity and resistance to slag penetration

……………….2.5 marks

Pyrometric Cone Equivalent (PCE)

temperature at which refractory will deform under its own weight is its softening temperature indicated by PCE .

……………….2.5 marks

Thermal conductivity

It is the heat loss per unit area per unit insulation thickness per unit temperature difference W-m2/m°C or W-m/°C. Thermal conductivity of materials increases with temperature. So thermal conductivity is always specified at the mean temperature (mean of hot and cold face temperatures) of the insulation material

……………….2.5 marks

Refer Book 2, Page no 156 – 157

L-6 In a Crude Oil refining unit, a counter-flow shell & tube heat exchanger is used to preheat LDO (Light Diesel Oil) flowing at 60 m^3/hr at 50°C using steam at 8 kg/cm^2_g as a heating medium. Steam enters the heat exchanger through a pipe of 6" diameter. Density and Specific heat of LDO is 830 kg/m^3 & 0.7 kcal/kg°C respectively.

Properties of steam at 8 kg/cm^2 is given below,

Pressure, (kg/cm^2_g)	Temperature, (°C)	Specific volume (m^3/kg)	Enthalpy (kcal/kg)		
			Water	Evaporation	Steam
8.0	170	0.22	170	490	660

a. Calculate the mass flow rate of Steam, if the maximum permissible velocity in the pipeline is 25 m/sec.

b. Temperature of the Fuel oil, after preheating in the heat exchanger

Ans

Steam Flow rate calculation:

Diameter of the pipe = 6 inch

= 6 * 2.54

= 15.24 cm

	...................1 mark
Area of the pipe	$= 3.14 * D^2 / 4$
	$= 3.14 * (15.24)^2 / 4$
	$= 182.3\ cm^2$
	$= 0.0182\ m^2$
Volume flow rate of steam	= Area * Velocity
Velocity permissible	= 25 m/sec
Volumetric flow rate of steam	= 0.0182 * 25
	$= 0.455\ m^3/s * 3600$
	$= 1638\ m^3/hr$
	...................2 marks
Specific volume of steam	$= 0.22\ m^3/kg$
Mass flow rate of steam	= 1638 / 0.22
	= 7445 kg/hr
a. ***Mass flow rate of steam***	= 7.445 TPH
	...................1 mark
Temperature of the Fuel oil (LDO)	
Heat transfer rate of Steam	= m * H
	= 7445 * 490
	= 3648050 kcal/hr
	...................2 marks
Heat transfer rate of Steam	= heat transfer rate of LDO
Heat transfer rate of LDO	= 3648050 kcal/hr
Heat transfer rate of LDO	$= m * Cp * (T_1 – T_2)$
	= 60 * 830 * 0.7 * (T – 50)
	= 3648050 / (60 * 830 * 0.7)
Delta Temperature	= 104.65 °C
	...................2 marks
Outlet Temperature of LDO	= (104.65 + 50)°C

	= 154.65 °C ***b) Outlet temperature of LDO = 154.65 °C*** ....2 marks

…………. End of Section – III …………

REGULAR **Paper 2 – Set A**

Regn No: ___________________

Name : ___________________
(To be written by the candidate)

17th NATIONAL CERTIFICATION EXAMINATION FOR ENERGY MANAGERS & ENERGY AUDITORS – September, 2016

PAPER – 2: Energy Efficiency in Thermal Utilities		
Date: 24.09.2016	**Timings: 1400-1700 HRS**	**Duration: 3 HRS**

General instructions:

- *Please check that this question paper contains **8** printed pages*
- *Please check that this question paper contains **64** questions*
- *The question paper is divided into three sections*
- *All questions in all three sections are compulsory*
- ***All parts of a question should be answered at one place***

Section – I: OBJECTIVE TYPE

1.	The large difference between GCV and NCV of gaseous fuels is due to their a) large moisture content b) negligible moisture content c) low hydrogen content d) **large hydrogen content**
2.	Which of the following contributes to spluttering of flame at burner tip during combustion of fuel oil? a) ash content **b) water content** c) sulphur content d) humidity of air
3.	When pure hydrogen is burned, with theoretical air, the volume percentage of nitrogen in flue gas on dry basis will be **a) 100%** b) 79% c) 21% d) 0%
4.	For coal fired system the flame length is dictated by a) moisture **b) volatile matter**. c) ash content. d) fixed carbon
5.	Dissolved CO_2 in boiler feed water when left untreated would result in occurrence of in boiler tubes a) creep **b) water side corrosion** c) scale d) water hammer

6.	At saturation temp, there can be a) Hot water b) Wet steam c) Saturated steam **d) all of them are possible**
7.	Water flows at a rate of 30 m^3/hr. at 15^oC in a 150 mm bore pipe horizontally. What is the velocity of water flow in the pipe? **a) 0.47 m/s** b) 0.94 m/s c) 1.88 m/s d) none of the above
8.	Which of the following is not true of condensate recovery? a) reduces water charges b) reduces fuel costs c) increases boiler output **d) increases boiler blow down**
9.	Chemical used for dozing in boiler drum to reduce dissolved gases is **a) hydrazine** b) chlorine c) alum d) all of the above
10.	Which of the following is not a property of ceramic fibre ? a) low thermal conductivity b) light weight **c) high heat capacity** d) thermal shock resistant
11.	In a reheating furnace, soaking time of a cycle depends typically on; a) excess air level b) preheat temperature of charge **c) thickness of the charged material** d) furnace atmosphere
12.	Higher excess air in an oil fired furnace would result in a) increased furnace temperature b) increase in CO_2 presence in flue gas **c) reduced flame temperature** d) increased flame length
13.	In a pressure reduction valve, which of these does not change? a) Temperature b) Pressure c) **Enthalpy** d) None of above
14.	In a counter-flow heat exchanger, cold fluid enters at 30°C and leaves at 50°C, whereas the hot fluid enters at 150°C and leaves at 130°C. The LMTD is **a) 100°C** b) 280°C c) 0°C d) 20
15.	Deaerator is a ____________________ Heat exchanger. a) Shell and tube type b) Plate type **c) Direct contact type** d) Run Around Coil type
16.	Pinch analysis uses the _____ law of thermodynamics a) First b) Second c)Third **d) Both (a) & (b)**

17.	What is the most effective way to avoid ambient air infiltration into a continuous reheating furnace? a)maintain negative pressure in furnace b) increase the chimney height c) operate at about 90%capacity **d) maintain slightly positive pressure in the furnace**
18.	Select the wrong statement with respect to furnace operations a) the burner flame should not touch the stock b) air infiltration leads to oxidation of billets **c) ceramic fibre linings are used in the exterior of the furnace** d) heat loss through openings is proportional to T^4
19.	The heat recovery device in which high conductivity bricks are used for storing heat is a) heat pipe b) heat pump c) thermo compressor **d) regenerator**
20.	The exhaust from which of the following is not suitable for waste heat boiler application? a) gas turbine **b) hot air dryer** c) diesel engine d) furnace
21.	Desirable boiler water pH should be? a) 5-7 **b) 7-9** c) 9-11 d) None of the above
22.	Which of the following has the lowest stoichiometric oxygen demand (kg/kg of fuel)? a) Hydrogen b) Carbon c) **Sulphur** d) Nitrogen
23.	Which of the following is used for controlling pressure in a natural draft furnace? a) Forced draft fan b)Induced draft fan **c) Dampers** d)Both (a) & (b)
24.	The head loss due to friction in a pipe is a) directly proportional to the diameter b) directly proportional to the gravitational constant c) inversely proportional to the velocity **d) directly proportional to the square of velocity**
25.	Which trap is preferred in discharge of condensate recovery from process equipment? **a) Float trap** b) Thermodynamic trap c) Thermostatic trap d) All of the above
26.	Enthalpy of Evaporation of any vapour at its Critical Point will be

	a) Maximum **b) Zero** c) Less than zero d) Unpredictable
27.	Corrosion in stack, Air Pre-Heater, Economizer is mainly influenced by _____ **a)Sulphur content in fuel** b) Ash content in fuel **c)** Moisture content in fuel d) All of the above
28.	Which of the following fuels has the least viscosity? a) Furnace Oil b) Diesel **c) Kerosene** d) Crude Oil
29.	Select the odd one among the following a) Condenser b) Distillation tower c) Evaporator **d) Economiser**
30.	Which of the following depends on physical properties of fluids as well as geometry of the heat exchanger? a**) Overall heat transfer coefficient** b) Fouling coefficient c) LMTD (Log Mean Temperature Difference d) Effectiveness
31.	In a boiler Air preheater is installed a) Before the economizer **b) after economizer** c) after ESP d) Before superheater
32.	Sulphur percentage in furnace oi **a) sets lower flue gas temperature limit** b) improves viscosity c) does not add to heat value d) forms soot
33.	Controlled wetting of coal (during the coal preparation) would result in a) reduction in flue gas exit temperature **b) decrease in the percentage of unburnt carbon** c) improper combustion d) increase in the fines of coal
34.	Which of the following is considered in the calculation of 'Evaporation ratio'? a) calorific value of fuel b) latent heat of steam **c) fuel quantity** d) all of the above
35.	Which causes alkaline hardness **a) bicarbonates of Ca and Mg** c) Chlorides of Mg and Ca c) Silicates d) nitrates of Ca and Mg

36.	1% of the fuel is saved in boiler fuel consumption, if the feed water temperature is increased by 4^0C b) 9^oC **c) 6^oC** d) 10^oC
37.	Velocity of steam in steam pipe is directly proportional to; a) number of bends in pipe **b) specific volume of steam** c) length of pipe d) diameter of the pipe
38.	The working media in a thermo-compressor is a) electricity b) compressed air c) high temperature oil **d) steam**
39.	The turbine heat rate is expressed as a) kWh/kCal b) kg/kCal **c) kCal/kWh** d) none of the above
40.	A rise in conductivity of boiler feed water indicates a) drop in the total dissolved solids in boiler water b) more steam generation **c) rise in the total dissolved solids in boiler water** d) greater purity of feed water
41.	The insulation used for temperatures more than 350^oC a) Polyurethane b) polystyrene **c) Calcium silicate** d) magnesia
42.	Which of these is not true of 'critical point' of steam/water mixture? a) the temperature at critical point is 374.15^oC b) the pressure at critical point is 221.2 bar c) saturated liquid and saturated vapour lines meet at critical point **d) enthalpy of evaporation is maximum at critical point**
43.	The effectiveness of insulation with ingress of moisture would a) increase **b) decrease** c) may increase or decrease depending on temperature and thickness of insulation d) remain unaffected
44.	The major limitation of metallic recuperator is ------- a) limitation of handling CO_x, NO_x etc. **b) limitation of reduced life for handling temperature more than 1000^oC** c) manufacturing difficulty of the required design d) none of the above
45.	In a turbine, the thermodynamic process taking place is a) contraction **b) expansion** c) condensation d) all the above

46.	In an FBC boiler with low ash fusion coal, if the bed temperature exceeds 950°C, the result is: a) Low steam temperature **b) clinker formation** c) Melting of lime stones d) Ash carry over
47.	Electrical energy consumption for coal sizing will be maximum for a) stoker fired boiler b) AFBC boiler c) CFBC boiler **d) pulverised coal boiler**
48.	Ideal furnace for melting & alloying of special steels is **a) induction furnace** b) Cupola furnace c) rotary hearth d) recirculating bogie furnace
49.	Arrange the following fuels by their GCV in decreasing order- (p) Rice husk, (q) Diesel, (r) Grade-C Coal, (s) Hydrogen **a) s-q-r-p** b) p-q-r-s c) r-s-q-p d) q-r-s-p
50.	Water logging of 2 m lift of condensate at trap discharge will result in back pressure of ____ a) 0.02 kg/cm^2 b) **0.2 kg/cm^2** c)2 kg/cm^2 d) 20 kg/cm^2

-------- *End of Section - I* ---------

Section - II: SHORT DESCRIPTIVE QUESTIONS

S-1	In a plant, a boiler is generating saturated steam of 10 TPH at a pressure of 7 kg/cm^2(g) with furnace oil as a fuel. Feed water temperature = 60°C Evaporation ratio = 14. Calorific value of FO = 10000 kcal/kg Specific gravity of FO = 0.95. Enthalpy of steam at 7 kg/cm^2(g) = 660 kcal/kg Find out the efficiency of the boiler by direct method and volume of furnace oil tank (in m^3) required for 120 hrs of operation
Ans	$\text{Effy}\eta = \frac{E.R \times (h_g - h_f)}{GCV} = \frac{14 \times (660-60)}{10000} = 84\%$ ***(Note: Deduct 1 mark if 60 is not subtracted from 660)*** Furnace oil requirement = 10 / 14 = 0.714 TPH = 714 kg/hr For 120 hrs of operation, Furnace Oil requirement = 714 x 120 = 85680 kg Oil tank volume = 85680 / (0.950/(1/1000)) = 90.189 m^3 OR $\text{Effy}\eta = \frac{E.R \times (h_g - h_f)}{GCV} = \frac{14 \times (660-60)}{10000} = 84\%$ Furnace oil requirement = 10 / 14 = 0.714 TPH = 714 kg/hr = 714 / 0.95 = 751.57 ltr/hr For 120 hrs of operation, oil requirement = 751.57 x 120 = 90189 ltr Oil tank volume = 90189 / 1000 = 90.189 m^3
S-2	In a process plant, 30 TPH of steam after pressure reduction with pressure reducing valve to 20 kg/cm^2 gets superheated. The temperature of steam is 280^{o}C. The management wants to install a de-superheater to convert superheated steam into saturated steam at 20 kg/cm^2 for process use, and its saturation temperature is 210^{o}C. Calculate quantity of water at 30^{o}C to be injected in de-super-heater to get the desired

	saturated steam using the following data. Specific heat of superheated steam = 0.45 kcal/Kg^{o}C, Latent heat of steam at 20kg/cm^2 = 450 kcal/kg
Ans	Quantity of heat available above saturation = 30,000 x 0.45 x (280-210) = 9,45,000 kCal/hr Quantity of water required in de-superheater = Q x{1x (210-30) + 450}= 945000 = 1500 Kg/hr
S-3	A steam pipe of 100mm diameter is insulated with mineral wool. As a part of energy saving measure, the insulation is upgraded with efficient Calcium silicate insulation. Calculate the percentage reduction in heat loss due to above measure with the following data, Boiler efficiency : 80% Surface temperature with mineral wool : 95°C Surface temperature with calcium silicate : 55°C Ambient temperature : 25°C
Ans	Heat loss thru non-insulated pipe = [10 + (95 – 25) / 20] * (95 – 25)] = 945 kcal/hr-m^2 Heat loss thru insulated pipe = [10 + (55 – 25) / 20] * (55 – 25)] = 345 kcal/hr-m^2 % Reduction in heat loss = (945 – 345)*100 / 945 = 63.5 %
S-4	a) List any six losses in a Boiler b) Name two sources of wet flue gas loss in a coal fired boiler

Ans	**a)** 1. Dry flue gas, L_1 2. Loss due to hydrogen in fuel, L_2 3. Loss due to moisture in fuel, L_3 4. Loss due to moisture in air, L_4 5. Partial combustion of C to CO, L_5 6. Surface heat losses, L_6 7. Loss due to Unburnt in fly ash, L_7 8. Loss due to Unburnt in bottom ash, L_8 **(b)** **Moisture in air, Moisture in fuel and H_2 in fuel.**
S-5	(a) Calculate the blow down rate for a boiler with an evaporation rate of 5 tons/hr, if the maximum permissible TDS in boiler water is 3000 ppm and with 18 % make up water addition. The feed water TDS is around 400 ppm. (b) Briefly explain temporary hardness and permanent hardness in boiler water
Ans	a) Blow down (%) $= \dfrac{Feed\ \ water\ \ TDS\ \ x\ \%\ Makeup}{Permissible\ \ TDS\ \ in\ \ Boiler\ \ -FeedwaterTDS}$ Percentage blow down = 400 x 18/(3000 – 400) = 2.77 % If boiler evaporation rate is 5000 kg/hr then required blow down rate is: = 5000 x 2.77/100 = 138.5 kg /hr (b) Ref Book-2 :; Page Nos. 45 & 46 Temporary hardness ; It is the hardness that can be removed by boiling. Calcium and magnesium bi carbonate dissolve in water to form an alkaline solution and these salts are called alkaline hardness. They decompose upon heating releasing carbon dioxide and forming a soft sludge which settles out. Permanent hardness: calcium and magnesium sulphates and chlorides, nitrates etc when dissolved in water are chemically neutral and are known as non alkaline hardness. These are called permanent hardness and form hard scale on the boiler surface which are difficult to remove.
S-6	List down any five good practices in Furnaces for energy efficiency

Ans	a) Improve capacity Utilisation b) Minimise Excess air c) Minimise heat loss due to radiation, walls and openings d) Adopt Waste heat recovery e) Ensure Complete combustion f) Maintain Furnace in slightly positive pressure g) Adopt Variable frequency drives for fans h) Optimise cycle time. i) Emissivity Coatings ***Any five of the above can be awarded marks, 1 mark each.***
S-7	A cogeneration plant has an electrical output of 5 MW with a back pressure turbine which has a input steam conditions to the turbine as 32 TPH with Enthalpy of 3418 KJ/kg @ 64 ata and 500^{o}C and the exit conditions of steam at the end of the back pressure turbine is 186^{o}C, with enthalpy of 2835.8 KJ/kg. After the process heating, all the condensate @ 73^{0}C returns to the boiler. Calculate the Heat to power Ratio and Energy Utilization factor of the process. Fuel consumption of the boiler is 8.2 TPH Coal at 4800 GCV.
Ans	Heat to power Ratio = 32*((2835.8/4.18)-73)/(5*860) = 4.5 Energy Utilization Factor = (32* ((2835.8/4.18)-73) + 5*860))/(8.2*4800) =68.7%
S-8	Two identical oil fired boilers of capacity 100 TPH are operated in a refinery. They have a full load efficiency of 90%. The part load efficiencies at 70% and 40% load are 75% and 65% respectively. For meeting 140 TPH requirement of steam, which one of the case would you prefer to run and estimate the % savings in the preferred case. The enthalpy of steam generated is 550 Kcal/kg and feed water enters the boiler at 50°C in all the cases. Calorific value of the fuel oil is 10,000 Kcal/hr. Case 1: both the boilers operated at 70 TPH capacity each. Case 2: one at full load capacity and other at 40% capacity.
Ans	Case-1: Amount of Fuel energy required when both the boilers are run at 70% load i.e, at 70 TPH load Enthalpy change = (550 – 50) = 500 Kcal/kg = (2 * 70 * 1000 * 500)/ (0.75 * 10000) = 9333 Kg/hr (or) 9.33 Tons/hr Case-2: Amount of Fuel required when one boilers is running at full load at 100 TPH and other at part load of 40 TPH

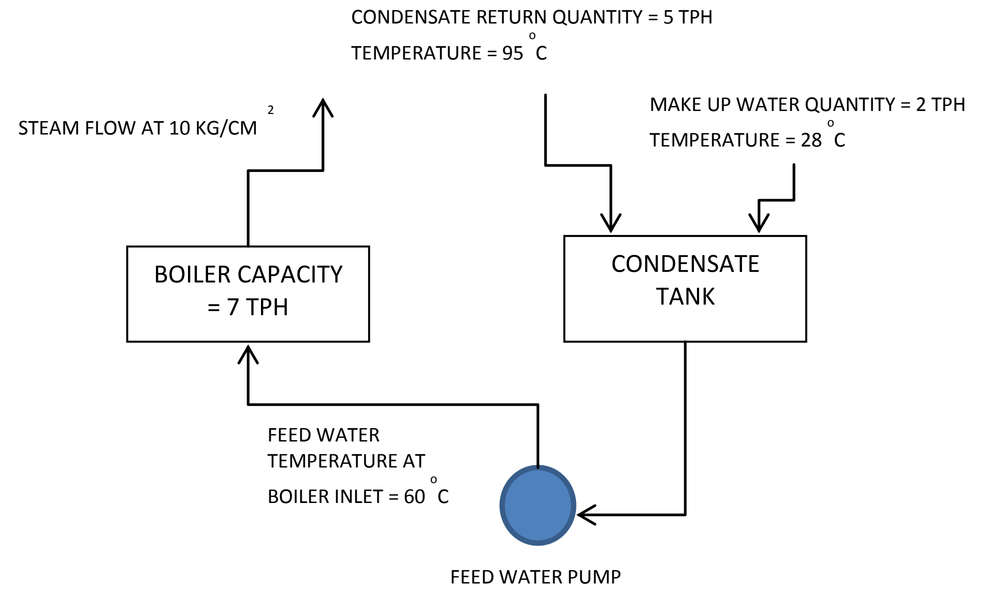
	Enthalpy change = (550 – 50) = 500 Kcal/kg = (100 * 1000 * 500) / (0.9*10000) + (40 * 1000 * 500) / (0.65*10000) = 5555 + 3076.9 = 8.63 Tons/hr Fuel required for Case 2 is less & hence Case 2 is preferred % Fuel Savings = (9.33 – 8.63) / 9.33 x 100 = 7.5 %

-------- End of Section - II ---------

Section - III: LONG DESCRIPTIVE QUESTIONS

L-1	A gaseous fuel has volumetric composition as CH_4 – 70 % & C_2H_6 – 30%. The Gross Calorific Value of CH_4 & C_2H_6 is 45000 kJ/Nm^3 & 70000 kJ/Nm^3 respectively. Find out the Net Calorific Value of gaseous fuel in kJ/Nm^3. (Latent heat of water vapor – 2445 kJ/kg)
Ans	$CH_4 + 2O_2 = CO_2 + 2H_2O$ 1 Nm^3 of CH_4 + 2 Nm^3 of O_2 = 1 Nm^3 of CO_2 + 2 Nm^3 of H_2O Hence, 0.70 Nm^3 of CH_4 will generate 0.70 x 2 = 1.4 Nm^3 of H_2O $C_2H_6 + 3.5\ O_2 = 2CO_2 + 3H_2O$ 1 Nm^3 of C_2H_6 + 3.5 Nm^3 of O_2 = 2 Nm^3 of CO_2 + 3 Nm^3 of H_2O Hence, 0.3 Nm^3 of C_2H_6 will generate 0.30 x 3 = 0.9 Nm^3 of H_2O Volume of water vapor = 1.4 + 0.9 = 2.3 Nm^3/Nm^3 of fuel (We know that mass of 22.4 Nm^3 of H_2O = 18 kg i.e. mass of 1 kMol) Mass of Water vapor, Mm = 2.3 x 18 / 22.4 = 1.85 kg/Nm^3 of fuel GCV of gaseous Fuel = (70% x 45000) + (30% x 70000) = 52500 kJ/Nm^3 NCV = GCV – (Mm x 2245) = 52500 – (1.85 x 2245) = 48346 kJ/Nm^3 = 4.13 %
L-2	A Textile plant has an extensive steam distribution network and the steam condensate is not being recovered. The plant management is planning to recover the condensate and generate flash steam for use as low pressure process steam for fuel savings. The following are the parameters about the system. Condensate quantity = 1000 kg/hr Condensate Pressure = 10 bar Cost of steam = Rs 1100/ Ton Annual operating hours = 8000 Low pressure process steam (flash steam) pressure = 2 bar Sensible heat of condensate at 10 bar = 188 kCal/kg Sensible heat of condensate at 2 bar = 135 kCal/kg Latent heat of steam at 2 bar = 518 kCal/kg Boiler Efficiency = 82 % GCV of fuel oil = 10,200 kCal/kg Specific Gravity of fuel oil = 0.92

	Condensate temperature when recovered = 95 ^oC Make up water temperature = 35 ^oC Calculate the Quantity of flash steam which can be recovered, and the annual fuel oil savings on account of condensate recovery
Ans	a) Flash steam available % = S1- S2/(L2) Where: S1 is the sensible heat of higher pressure condensate. S2 is the sensible heat of the lower pressure condensate L2 is the latent heat of flash steam (at lower pressure). % of Flash steam recoverable = (188 – 135) / 518 = 10.2 % Quantity of flash steam recovered from condensate = 1000 x 0.102 = 102 kg/hr Condensate available for recovery after flash steam = 1000 – 102 = 898 kg/hr Heat recovered = 898 x (95 – 35) = 53880 kCal/hr Annual fuel oil saving = 53880 x 8000 / (0.82 x 10200) = 51.2 tons/yr
L3	**Analyse the diagram as given below and calculate:** (i) Boiler Efficiency by direct method (ii) Water Temperature in the condensate tank (iii) Estimate fuel loss due to non-recovery of 2 TPH condensate, assuming the boiler efficiency to be the same Given data: Enthalpy of steam at 10kg/cm2 = 665 kCal/kg Furnace Oil consumption = 600 liters/hr Specific Gravity of furnace oil = 0.89 G.C.V. of furnace oil = 10,000 kCal/kg



ANS	Oil Consumption = 600 x 0.89 = 534 kg/hr 1) Boiler Efficiency = 7000 (665 - 60) X 100/ 534 X 10000 = 79.3 % 2) Feed water temperature in condensate tank = [5000 x 95 + 2000 x 28]/ 7000 = 75.85°C = 76 °C 3) Fuel Loss = [7000 x (76 – 60)]/ 10000 x 0.793 = 14 kg/hr
L4	A heat exchanger is to be designed to condense the hydrocarbon vapor mixture from a distillation column at the rate of 11.0 kg/sec which is available at its saturation temperature of 120°C. The latent heat of condensation of the hydrocarbon vapor mixture is 450 kJ/kg. The cooling water at 32°C is used in counter-current direction at the rate of 58 kg/sec to condense the vapor mixture. The specific heat of cooling water is 4.18 kJ/kg °C. Determine LMTD and area of the heat exchanger surface if the overall heat transfer co-efficient is 600 J/m^{2}s°C.
Ans	Heat removal rate from hydrocarbon vapour mixture = heat gain rate in cooling water Q x h = M * cp* (T2-T1) 11.0 x 450 = 58 x 4.18 x (T2 – 32) T2 = 52.4 °C Water leaves the exchanger at 52.4°C LMTD = (120-32)-(120-52.4)/ln(120-32)/(120-52.4) LMTD of counter flow pattern = 77.4°C Q = m*Cp* deltaT = U * A *LMTD 58 * 4.18 * (52.4 – 32) * 1000 = 600 * A * 77.4 A = 106.5 m^2

	Area of the heat exchanger surface is 106.5 m^2
L-5	a) Explain the process of Mechanical de-aeration and chemical de-aeration b) How does an energy auditor assess the performance of steam trap during energy audit?
Ans	**a)** **Mechanical de-aeration** Mechanical de-aeration for the removal of these dissolved gases is typically utilized prior to the addition of chemical oxygen scavengers. Mechanical de-aeration is based on Charles' and Henry's laws of physics. Simplified, these laws state that removal of oxygen and carbon dioxide can be accomplished by heating the boiler feed water, which reduces the concentration of oxygen and carbon dioxide in the atmosphere surrounding the feed water. Mechanical de-aeration can be the most economical. They operate at the boiling point of water at the pressure in the de-aerator. They can be of vacuum or pressure type. The vacuum type of de-aerator operates below atmospheric pressure, at about 82°C, can reduce the oxygen content in water to less than 0.02 mg/litre. Vacuum pumps or steam ejectors are required to maintain the vacuum. The pressure-type de-aerators operates by allowing steam into the feed water through a pressure control valve to maintain the desired operating pressure, and hence temperature at a minimum of 105°C. The steam raises the water temperature causing the release of O_2 and CO_2 gases that are then vented from the system. This type can reduce the oxygen content to 0.005 mg/litre. Where excess low-pressure steam is available, the operating pressure can be selected to make use of this steam and hence improve fuel economy. In boiler systems, steam is preferred for de-aeration because: • Steam is essentially free from O_2 and CO_2 • Steam is readily available • Steam adds the heat required to complete the reaction. **Chemical de-aeration** While the most efficient mechanical deaerators reduce oxygen to very low levels (0.005 mg/litre), even trace amounts of oxygen may cause corrosion damage to a system. Consequently, good operating practice requires removal of that trace oxygen with a chemical oxygen scavenger such as sodium sulfite or hydrazine. Sodium sulphite reacts with oxygen to form sodium sulphate, which increases the TDS in the boiler water and hence increases the blow down requirements and make-up water quality. Hydrazine reacts with oxygen to form nitrogen and water. It is invariably used in high pressures boilers when low boiler water solids are necessary, as it does not increase the TDS of the boiler water. **Ref page no 47** **b)**

	Steam trap performance assessment is basically concerned with answering the following two questions: • Is the trap working correctly or not? • If not, has the trap failed in the open or closed position? Traps that fail 'open' result in a loss of steam and its energy. Where condensate is not returned, the water is lost as well. The result is significant economic loss, directly via increased boiler plant costs, and potentially indirectly, via decreased steam heating capacity. Traps that fail 'closed' do not result in energy or water losses, but can result in significantly reduced heating capacity and/or damage to steam heating equipment. **The three performance test methods of steam traps are** **1. Visual testing,** **2. Sound Testing** **3. Temperature testing** **Ref page no 95**
L-6	Answer the followings: (a) Explain why dry saturated steam is preferred over wet or superheated steam for industrial process heating. (b) Why should one use dry saturated steam at the lowest possible pressure for indirect steam heating? (c) What are the two major advantages of direct injection of steam for heating of liquid? (d) Why drain points are required in a steam system? (e) What is flash steam?
Ans	a) Dry saturated steam is the preferred choice because: • Wet steam has a lower heat content than dry steam. • Superheated steam gives up heat at a slower rate than saturated steam. • Dry steam alone condenses quickly, thereby providing a higher heat transfer rate. b) The latent heat of steam increases with reduction of steam pressure and it is only the latent heat that is transferred during indirect heating applications. c) • No condensate recovery system is necessary • The heating is quick, and the sensible heat in the steam is also used up along with the latent heat, making the system thermally more efficient. d) The drain points help in removing water in pipes due to condensation of steam. e) Flash steam is produced when condensate at a high pressure is released to a lower pressure. …

…………. End of Section – III …………..

Regn No: ____________________

Name : ____________________

(To be written by the candidate)

16^{th} NATIONAL CERTIFICATION EXAMINATION
FOR
ENERGY MANAGERS & ENERGY AUDITORS – September, 2015

PAPER – 2: Energy Efficiency in Thermal Utilities			
Date: 19.09.2015	**Timings: 1400-1700 HRS**	**Duration: 3 HRS**	**Max. Marks: 150**

General instructions:

- *Please check that this question paper contains **8** printed pages*
- *Please check that this question paper contains **64** questions*
- *The question paper is divided into three sections*
- *All questions in all three sections are compulsory*
- ***All parts of a question should be answered at one place***

Section – I: OBJECTIVE TYPE **Marks: 50 x 1 = 50**

a) Answer all **50** questions
b) Each question carries **one** mark
c) Please hatch the appropriate oval in the OMR answer sheet with Black Pen or HB pencil

1.	Which one of the following is not true with respect to the role of nitrogen in the combustion of any fuel a) produces oxides of nitrogen b) <u>reduces the volume of combustion by-products</u> c) dilutes the flue gases d) carries useful heat in flue gases
2.	Which one of the following fuel has the highest hydrogen content and lowest sulphur content a) coal b) fuel oil <u>c) natural gas</u> d) LSHS
3.	Which of the following yields a low CO_2 reading a) soot deposits on boiler tubes b) flue gas bypass in air pre-heater c) proper air-fuel mixture <u>d) air ingress in flue gas duct</u>
4.	Which of the following salt causes temporary hardness in water a) calcium sulphate <u>b) calcium bicarbonate</u> c) calcium chloride d) calcium nitrate

5.	Which of the following requires the largest amount of oxygen/kg of substance for combustion a) carbon b) hydrogen c) sulphur d) nitrogen
6.	Which of the following is not required for determining economic thickness of steam line a) cost of fuel b) boiler efficiency c) enthalpy of steam d) calorific value of fuel
7.	Which of the following has the lowest stoichiometric oxygen demand (kg/kg of fuel) a) hydrogen b) carbon c) sulphur d) methane
8.	Which of the following depends on physical properties of fluids as well as geometry of the heat exchanger a) overall heat transfer coefficient b) fouling coefficient c) LMTD (Log Mean Temperature Difference) d) effectiveness
9.	Which of the following contribute to spontaneous combustion of coal a) low Volatile matter b) low fixed carbon c) less ash d) none of the above
10.	Which of the following can be used as desiccant in boiler preservation a) silica gel b) activated carbon c) un-slaked lime d) all of the above
11.	Which of the following boiler water treatment ensures complete removal of salts a) demineralization b) softening c) de-aeration d) all of the above
12.	Which of the following boiler utilizes the combination of suspension firing and great firing a) traveling grate stoker boiler b) packaged boiler c) spreader stoker boiler d) pulverized fuel boiler
13.	Which of the component is common to supercritical boiler and sub critical boiler for power generation a) economizer b) water walls c) re-heaters d) all of the above
14.	Which fuel among the following needs temperature control during storage a) coal b) furnace oil c) diesel oil d) kerosene
15.	What happens when the float in a float trap develops a puncture a) loss of condensate b) loss of live steam c) fails to open d) fails to close
16.	Transfer of heat without a conveying medium is possible with a) conduction b) radiation c) convection d) none of the above
17.	The velocity of steam in steam pipe is directly proportional to a) number of bends in pipe b) 5^{th} power of the diameter of pipe c) length of pipe d) specific volume of steam
18.	The unit of overall heat transfer coefficient is a) W/m^2 K b) W^2/m^2 K c) W^2/m^3 K d) W/m^3 K

19.	The thermal resistance of an insulation a) decreases with increased thermal conductivity b) increases with increased thermal conductivity c) decreases with decreased thermal conductivity d) has no relation with thermal conductivity
20.	The stoichiometric amount of air required to burn 1 kg of methane is a) 69.57 b) 4 c) 17.39 d) 16
21.	The parameter assumed to remain constant during LMTD calculation of a Heat exchanger is a) temperature drop b) heat transfer area c) specific heat of fluids d) none of the above
22.	The material used to control SO_x in the FBC boiler is a) limestone b) alumina c) silica d) fly ash
23.	The heat loss in a furnace depends on a) emissivity of walls b) conductivity of refractory c) wall thickness d) all of the above
24.	The chemical used to prevent oxidation in boiler feedwater is a) sodium sulphite b) sodium phosphate c) calcium phosphate d) magnesium phosphate
25.	The best time for intermittent blow down in a boiler a) High load under full pressure b) low load under full pressure c) high load under partial pressure d) low load under partial pressure
26.	The amount of CO_2 produced in complete combustion of 18 Kg of carbon a) 50 b) 44 c) 66 d) 792
27.	Scale losses in reheating furnaces will a) increase with excess air b) decrease with excess air c) have no relation with excess air d) increase with CO in combustion gases
28.	Removal of condensate from main steam line is done to prevent a) steam locking b) air locking c) water hammer d) all of the above
29.	Presence of _____ in flue gas confirms incomplete combustion in furnace a) CO b) NOx c) SOx d) all of the above
30.	Portable fyrite is used for the measurement of a) CO_2 content in flue gas b) O_2 content in flue gas c) stack temperature d) both (a) & (b)
31.	On an inverted bucket trap, what happens to the bucket as the trap fills with water a) it rises b) it inclines c) it sinks d) it remains stationary

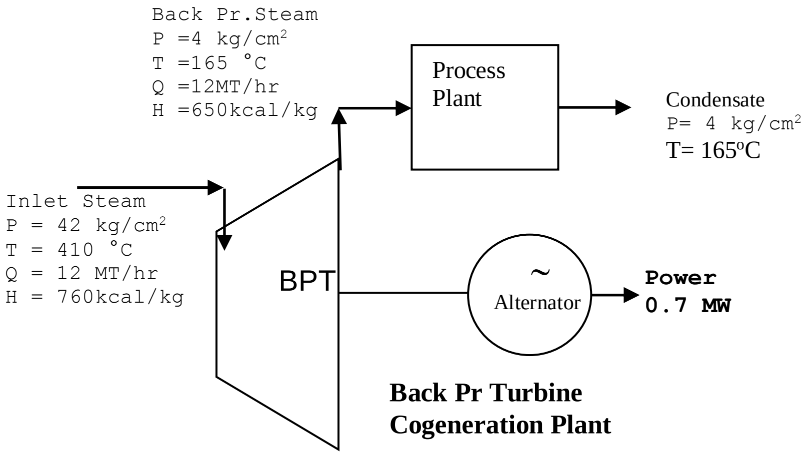
32.	NO_x formation in FBC boilers is minimised because of a) higher velocity of flue gas in combustion chamber b) higher pressure of the air supplied <u>c) lower temperatures in the bed and combustion chamber</u> d) higher contact of solid particles in the flue gas
33.	In which zone of cupola furnace does the conversion of CO_2 to CO take place? a) combustion zone b) melting zone <u>c) reduction zone</u> d) preheating zone
34.	In a fire-tube boiler, soot forms on a) outside tube surface <u>b) inside tube surface</u> c) waterside surface d) water wall surface
35.	If the volatile matter in coal is low, which of the following equipment is the best waste heat recovery option in a boiler a) economiser <u>b) air preheater</u> c) deaerator d) heat pipe
36.	Hydrometer is used for the measurement of a) viscosity <u>b) density</u> c) water content d) humidity
37.	Heat transfer rate for indirect heating application will be less if we heat with a) saturated steam b) dry steam <u>c) superheated steam</u> d) high pressure steam
38.	Furnace wall heat loss depends on a) temperatures of external wall surfaces b) velocity of air around the furnace c) thermal conductivity of wall brick <u>d) all of the above</u>
39.	For flash steam calculation, flash steam quantity available depends upon <u>a) condensate pressure and flash steam pressure</u> b) steam pressure c) steam enthalpy at atmospheric pressure d) total heat of flash steam
40.	Enthalpy of evaporation of any vapour at its critical point will be a) more than zero <u>b) zero</u> c) less than zero d) unpredictable
41.	Corrosion in chimney, air pre-heater and economizer is mainly influenced by <u>a) sulphur content in fuel</u> b) ash content in fuel c) moisture content in fuel d) all of the above
42.	Condensate at pressure of 4 kg/cm2 and 160°C temperature when exposed to atmosphere will a) become super heated <u>b) partly convert to flash steam</u> c) remain as condensate d) fully convert to flash steam
43.	Coal size of 75% below 75 micron is required for use in a) spreader stoker boiler b) chain grate stoker boiler c) fluidized bed boiler <u>d) pulverized fuel boiler</u>
44.	Ceramic coating is used in furnaces because it enhances

	a) conductivity b) convective heat transfer coefficient c) emissivity d) radiation factor
45.	As the pressure of water increases from 1kg/cm^2 to 8 kg/cm^2, the values of enthalpy of steam and enthalpy of evaporation respectively a) increases & remains the same b) increases & decreases c) decreases & increases d) decreases & remains the same
46.	An increase in bulk density of a refractory increases its a) volume stability b) heat capacity c) Resistance to slag penetration d) all of the above
47.	A small quantity of leakage of stored Liquid LPG evaporates to produce about ____ times of volume of gas. a) 100 b) 150 c) 250 d) 350
48.	A high carbon monoxide reading indicates a) moisture in the fuel b) high furnace temperature c) high excess air d) none of the above
49.	2 m lift of condensate in steam pipe will result in back pressure of a) 0.02 bar b) 0.2 bar c) 2 bar d) 20 bar
50.	_____ gives an estimate of heating value of coal a) ash content b) moisture content c) fixed carbon d) volatile matter

-------- *End of Section*

Section - II: SHORT DESCRIPTIVE QUESTIONS **Marks: 8 x 5 = 40**

(i) Answer all eight questions
(ii) Each question carries five marks

S-1	Determine the Energy Utilization Factor (EUF) from the following back pressure cogeneration plant diagram and data given. 

	Solution: Input heat to turbine = 12,000 x 760 = 91,20,000 Kcal/hr ….(1 mark) Useful heat to process Plant = 12,000 x 650-165 = 5820,000 Kcal/hr ….(1 mark) Useful Electrical output in alternator = 700x860= 602000 Kcal/hr ….(1 mark) Energy Utilization Factor (EUF) = [(602000+5820,000) /91,20,000] x 100 = 70.42% ….(2 marks)
S-2	For combustion of 500 kg/hr of natural gas containing 100% methane, calculate the percentage of CO_2 in the flue gas while 15% excess air is supplied.
	Ans: $CH_4 + 2\ O_2 \rightarrow CO_2 + 2H_2O$ 1 mole of Methane requires 2 moles of Oxygen. 16 Kg of Methane requires 64 Kg of Oxygen. 16 Kg of Methane produces 44 Kg of CO_2. 500 Kg/hr of Methane requires 2000 Kg/hr of Oxygen. 500 Kg/hr of Methane produce 1375 Kg/hr of CO_2. …. (1 mark) Theoretical air required for combustion = 2000 / 0.23 = 8696 Kg/hr …. (1 mark) Considering 15% excess air, Actual air supplied for combustion is = 8696 * 1.15 = 10,000.4 Kg/hr of air …. (1 mark) Flue gas generation with 15% excess air = 500 + 10,000.4 = 10,500.4 Kg/hr …. (1 mark) % CO_2 in the flue gas = (1375 / 10,500.4)x 100 = 13.1 % …. (1 mark)

S-3	In a sugar mill, a process requires 5000 kg/hr of dry saturated steam at 7 kg/cm^2 (g). For the flow velocity not to exceed 28 m/s, determine the pipe diameter size for distribution of steam. Specific volume at 7 kg/cm^2 = 0.24 m^3/kg.

Ans:

The velocity of steam maximum = 28 m/s
Specific volume at 7 kg/cm^2 = 0.24 m^3/kg

Mass flow rate = 5000 kg/hr
= 5000/3600 = 1.389 kg/sec

Volumetric flow = 1.389 x 0.24 = 0.333 m^3/sec

…. (1 mark)

Therefore, using:

Volumetric flow rate(m^3/s) = Velocity (m/s) x Cross sectional area (m^2)

…. (1 mark)

$$D = \sqrt{\frac{4 \times Volumetric\ flowrate}{\prod \times Flow\, velocity}}$$

$$D = \sqrt{\frac{4 \times 0.333}{\prod \times 28}}$$

$$D = 0.123\, m\, or\, 123\, mm$$

…. (3 marks)

Since the steam velocity must not exceed 28 m/s, the pipe size must be at least 123 mm; the nearest commercially available size, 150 mm, would be selected.

S-4	Paddy husk is being used as a combustion fuel in a water tube boiler. The ultimate analysis of fuel is given below. Calculate theoretical amount of air required per 100 kg of husk for the combustion from the following data.

Ultimate Analysis of Typical Agro Residues	%
Moisture	10.8
Mineral Matter	16.7
Carbon	34.0
Hydrogen	5.0
Nitrogen	0.9
Sulphur	0.1
Oxygen	32.5

Ans:

Considering a sample of 100 kg of paddy husk.

Component in fuel	% (wt) in fuel	Equation	Specific stoichiometric oxygen required	Actual stoichiometric oxygen required
Carbon	34	$C + O_2 = CO_2$ 12 + 32 = 44	2.67 (32/12)	90.78 (34 x 2.67)
Hydrogen	5	$H_2 + 0.5\ O_2 = H_2O$ 2 + 16 = 18	8.0 (16/2)	40.0 (5 x 8)
Sulphur	0.1	$S + O_2 = SO_2$ 32 + 32 = 64	1.0 (32/32)	0.1 (0.1 x 1)
Oxygen	32.5			(-)32.5
Nitrogen	0.9			-
Moisture	10.8			-
Mineral matter	16.7			-
Total	100			98.38

….. (4 marks)

Total Oxygen required = 98.38 kg oxygen / 100 kg fuel

Therefore theoretical quantity of dry air reqd. = 98.38 / 0.23 =427.7 kg air / 100 kg fuel

(air contains 23% oxygen by wt.)

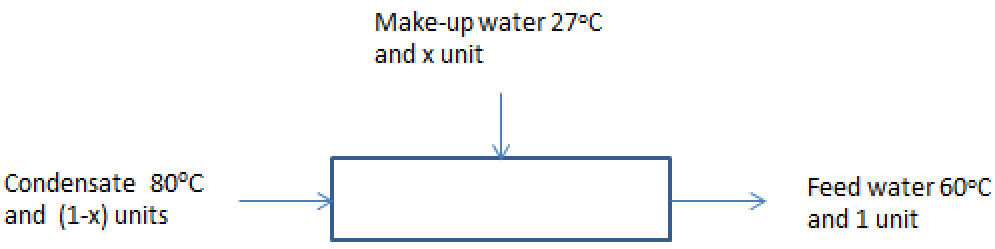
….. (1 mark)

S-5 (a) Why should LPG cylinders not be stored in basements or cellars?

(b) Why should the stack temperature of furnace oil fired boilers not be maintained below 160-170°C?

Ans:

(a) LPG is a predominant mixture of propane and butane. Both propane and butane are denser than air. Consequently, the vapour flows along the ground into drains and sinks to the lowest level of the surroundings and gets ignited at a considerable distance from the source of leakage. Escape of even small quantities of LPG can give rise to large volume of vapour mixture and can cause considerable hazard. Hence there should be adequate

	ground level ventilation where LPG cylinders are stored. For this reason LPG cylinders should not be stored in cellars or basements, which have no ventilation at ground levels. ….(2.5 marks) (b) For fuels containing sulphur, low temperatures (below 160-170°C) of stack can lead to sulphur dew point corrosion. The main disadvantage of sulphur is the risk of corrosion by sulphuric acid formed during and after combustion, and condensing on cool parts of the chimney or stack, air preheater and economiser. ….(2.5 marks)
S-6	Calculate the electricity consumption in an induction melting furnace from the following melt cycle data Mild steel (MS) scrap charged : 1250 kg Specific heat of MS : 0.68 kJ/kg ^{0}C Latent heat of MS : 270 kJ/kg MS melting temperature : 1450 ^{0}C Inlet MS charge temperature : 35 ^{0}C Efficiency of furnace : 70%
	Ans: Theoretical energy required for melting = 1250 (0.68 x (1450 – 35) + 270)/3600 = 427.8 kWh …. (3 marks) Actual energy input to the furnace = 427.8 / 0.7 Electricity consumption = 611.2 kWh …. (2 marks)
S-7	Feed water is provided to a boiler from the feed water tank at 60°C, temperature of condensate water returning to the tank is 80°C, and temperature of makeup water is 27°C. What is the amount of condensate recovered?
	Solution: 

	27x + (1 – x) 80 =60 Therefore x = 0.37 (37 percent makeup water or only 63 per cent of condensate is recovered). ….(5 marks)
S-8	Milk is flowing in a pipe cooler at a rate of 0.95 kg/sec. Initial temperature of the milk is 55 °C and it is cooled to 18 °C using a stirred water bath with the constant temperature of 10°C around the pipe. Specific heat of milk is 3.86 KJ/kg°C. Calculate the heat transfer rate (kcal/hr) and also LMTD of the exchanger.
	Ans: Heat transfer in cooling milk = 0.95 * 3.86 * (55 – 18) = 135.7 KJ/sec =135.7 /4.18 = 32.46 kcal/sec =(32.46*3600)= 116856 kCal/hr …. (2.5 marks) LMTD: DT1 = 55 – 10 = 45 °C DT2 = 18 – 10 = 8 °C LMTD of the heat exchanger = (45 – 8) / ln (45 / 8) LMTD of the heat exchanger = 21.4 °C …. (2.5 marks)

-------- End of Section - II ---------

Section - III: LONG DESCRIPTIVE QUESTIONS Marks: 6 x 10 = 60

(i) Answer all SIX questions
(ii) Each question carries **Ten** marks

L-1	a) Find out the efficiency of the furnace oil fired boiler by the direct method in an agro product manufacturing plant given the following data: Type of boiler : Furnace oil fired Quantity of steam (dry) generated : 5 TPH Steam pressure / temp : 10 kg/cm^2(g)/ 180 ^{0}C

	Quantity of oil consumed : 0.350 TPH Feed water temperature : 75 ^{0}C GCV of Furnace oil : 10400 kCal/kg Enthalpy of saturated steam at 10 kg/cm^2 pressure : 665 kCal/kg Enthalpy of feed water : 75 kCal/kg Cost of furnace oil : Rs 32/kg Annual operating hours : 7200 hrs /year b) The oil fired boiler was converted to coconut shell firing maintaining the same steam and feed water parameters. i) Determine the fuel consumption per hour ii) Return on investment for the conversion scheme. Fuel fired in the boiler : coconut shell fuel GCV of coconut shell : 4200 kCal/kg Efficiency with coconut shell firing : 76% Cost of coconut shell : Rs 12/kg Annual interest on capital : Rs 6 lakhs /yr Annual operating hours : 7200 hrs /year Investment towards boiler conversion : Rs 50 lakhs
	Solution: a) Efficiency of furnace oil fired boiler (Direct method) Boiler Efficiency (η) = 5000 x (665-75) / (350 x 10400) = 81% (on GCV basis) …. (2.5 marks) b) i) Coconut shell fuel consumption after conversion: Fuel consumption = 5000 x (665-75) / (0.76 x 4200) = 924.2 kg/hr …. (2.5 marks) ii) ROI for the conversion scheme: Annual fuel cost of furnace oil fired boiler = 350 x 7200 x 32 = Rs 8,06,40,000 /year ….. (1 mark) Annual fuel cost of coconut shell fired boiler = 924.2 x 7200 x 12 = Rs 7,98,50,880/year ….. (1 mark) Annual net monetary savings after conversion $= \frac{[(8{,}06{,}40{,}000 - 7{,}98{,}50{,}880) - 6{,}00{,}000]}{50{,}00{,}000} \times 100$ = 3.8 % …. (3 marks)

L-2	A liquid waste stream has a flow rate of 3.5 kg/s and a temperature of 70^{o} C with a specific heat capacity of 4190 J/kgK. Heat recovered from the hot waste stream is used to pre-heat boiler make-up water. The flow rate of the make-up water is 2 kg/s, its temperature is 10^{o}C and its specific heat capacity is 4190 J/kg/K. The overall heat transfer coefficient of the heat exchanger is 800 W/m^{2}K. If a make-up water exit temperature of 50^{o}C is required, and assuming that there is no heat losses from the exchanger, determine 1) The heat transfer rate 2) The exit temperature of the effluent and 3) The area of the heat exchanger required

Solution :

i) Heat gained by makeup water = $Q_c = m_c\, c_c\, \Delta T = 2 \times 4190 \times (50-10)$
$= 335200$ W $= 335.2$ kW

…..(2 marks)

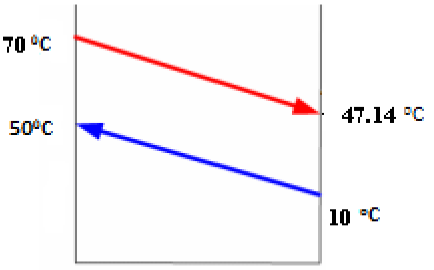
ii) $m_h\, c_h\, (t_{h1} - t_{h2}) = m_c\, c_c\, (t_{c1} - t_{c2})$

$3.5 \times 4190 \times (70 - t_{h2}) = 2 \times 4190 \times (50 - 10)$

$t_{h2} = 47.14\ ^{o}C$

…..(3 marks)

iii) Now because the water outlet temperature is above the outlet temperature of the effluent a counter-flow heat exchanger is required.



Counter Flow Arrangement

$$LMTD = \frac{\Delta t_1 - \Delta t_2}{\ln(\Delta t_1 / \Delta t_2)}$$

-

$$= \frac{((70-50)-(47.14-10)}{\ln (70-50)/(47.14-10)}$$

LMTD = 27.69^{o}C

…..(2.5 marks)

Q = UA (LMTD)

$$A = \frac{335200}{800 \times 27.69}$$

Area = 15.13 m^2

…..(2.5 marks)

L-3 Write short notes on any two of the following: (5 marks each)

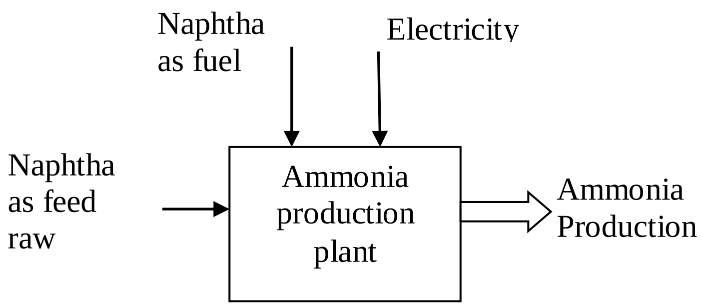
a) Plate heat exchanger (page 242 of book-2)

b) Multiple effect evaporator (page 247-248 of book-2)

c) Gas turbine cogeneration system (page 192 of book-2)

L-4

a) In a typical fertiliser manufacturing plant, the quantity of 133200 Ton of Ammonia is produced annually, using naphtha as fuel as well as raw material (feed) and electricity from captive power plant.



The quantity of annual raw material consumption and its heating values are given in table.

Raw material consumption	Quantity	Heating Value
1.Naphtha - feed	66800 Ton	10650 kCal / kg
2.Naphtha - fuel	31200 Ton	10650 kCal / kg
3.Electricity	1180 x Lakh kWh	2500 kCal/kWh

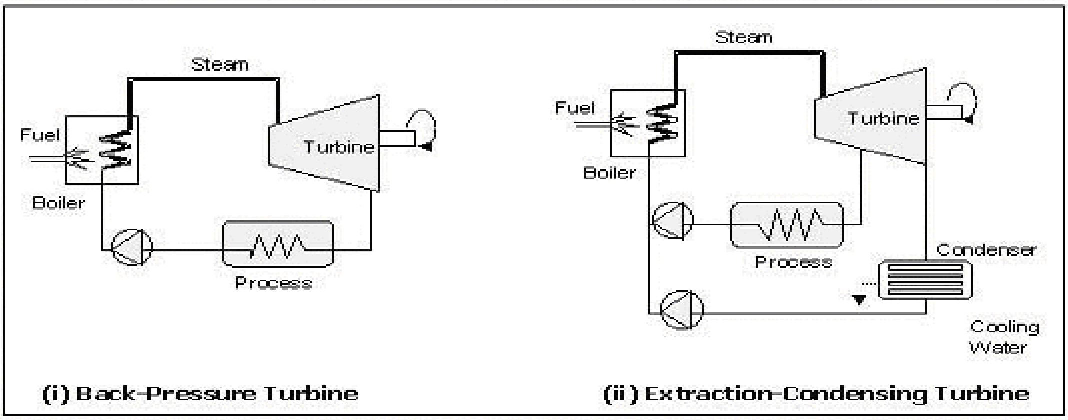
Calculate the specific energy consumption of ammonia production in Gcal / Ton.

b) Sketch the schematic diagram of "Back Pressure Turbine" and "Extraction Condensing Turbine" Cogeneration systems (Note: no explanation required).

Answer :

a) **Specific Energy Consumption(SEC) of Ammonia**

Raw material consumption	**Quantity**	**Heating Value**	**Gcal**	
1.Naphtha - feed	66800 Ton	10650 kCal / kg	711420	1 mark
2.Naphtha - fuel	31200 Ton	10650 kCal / kg	332280	1 mark
3.Electricity	1180 x Lakh kWh	2500 kCal/kWh	295000	1 mark
			1338700	
Ammonia production	133200 Ton			
Specific Energy Consumption(SEC) of Ammonia production =			**10.05 Gcal per Ton**	2marks

	b) Schematic diagram of (i) Back Pressure Turbine and (ii) Extraction Condensing Turbine Cogeneration systems  ……(2.5 marks for each schematic)
L-5	As a part of energy conservation measure, APH (Air Pre-heater) is installed in a fired heater. The APH is designed to pre-heat 240 m^3/min of combustion air to 250°C. Flue gas enters the APH at 375°C. Calculate the flue gas leaving the stack and also determine the improvement in furnace efficiency after the installation of APH with the following data Density of air : 1.15 kg/m^3 Specific heat of air : 0.23 Kcal/kg°C Specific heat of flue gas : 0.26 Kcal/kg°C Calorific value of fuel : 9850 Kcal/kg Air to fuel ratio : 18 Efficiency of furnace : 73 % Ambient temperature : 30°C
	Solution: Amount of Air flow = 240 * 60 * 1.15 = 16560 Kg/hr …. (1mark) Amount of fuel = 16560 / 18 = 920 Kg/hr …. (1mark) Amount of flue gas = 16560 + 920 = 17480 Kg/hr …. (1mark) Heat absorbed by combustion air = 16560 * 0.23 * (250 – 30) = 837936 Kcal/hr …. (1.5 marks)

	Temperature difference in flue gas = 837936 / (17480 * 0.26) = 184 °C …. (1.5 mark) Flue gas leaves the stack at temp = 375 – 184 = 191 °C …. (1 mark) Efficiency of APH = Heat absorbed by air / Heat input * 100 = 837936 * 100 / (920* 9850) = 9.2 % …..(2 marks) Overall efficiency after APH = 73 + 9.2 % = 82.2 % ….. (1 mark)
L-5	A process industry is equipped with a steam power plant generating 1,00,000 units/day and a separate low-pressure boiler generating at an average steam production of 8.3 Tons of steam/hour at enthalpy of 630 kcal/kg for process heating. The feed water temperature to the boiler is 70^{o}C. The efficiencies of the steam power plant and boiler are 29% and 75% respectively. Coal is used in both cases and calorific value of coal is 3800 kcal/kg. The management proposes to commission a cogeneration plant retaining the coal as fuel. The expected energy utilization factor of the cogeneration plant is 75%. Calculate coal savings with the new cogeneration plant.
	SOLUTION:

Heat input for separate production of power and useful heat	=	(100000 x 860) / (24 x 0.29) + (8.3 x (630-70) x 1000))/0.75
	=	12356321 + 6197333
	=	18553654 kcal/hr
		…..(4 marks)
Heat input with cogeneration plant	=	[(100000 x 860) /24 + (8.3 x (630-70) x 1000)] / 0.75
	=	(3583333 + 4648000) / 0.75
	=	10975111 kcal/hr
		…..(4 marks)
Coal savings	=	(18553654 – 10975111) / 3800
	=	1995 kg/h
		……(2 marks)

…………. End of Section – III ……….….

15^{th} NATIONAL CERTIFICATION EXAMINATION FOR ENERGY MANAGERS & ENERGY AUDITORS– August, 2014

PAPER – 2:	**Energy Efficiency in Thermal Utilities**		
Date:23-8-2014	Timings:14:00-17:00	Duration: 3 HRS	Max. Marks: 150

Section – I: OBJECTIVE TYPE — Marks: 50 x 1 = 50

(i) Answer all **50** questions
(ii) Each question carries **one** mark
(iii) Please hatch the appropriate oval in the OMR answer sheet with black pen or HB pencil.

1.	If the terminal temperature differences at the hot and cold end of a heat exchanger is same, then the LMTD is a) 100 ^{o}C <u>b) 0 ^{o}C</u> c) 50 ^{o}C d) none of the above
2.	Which of the following fuel fired steam boiler will have the least evaporation ratio? a) coconut shell b) natural gas c) oil <u>d) rice husk</u>
3.	Which of these is not true of 'critical point' of steam/water mixture? a) the temperature at critical point is 374.15^{o}C b) the pressure at critical point is 221.2 bar c) saturated liquid and saturated vapour lines meet at critical point <u>d) enthalpy of evaporation is maximum at critical point</u>
4.	Which of these fuels has the highest heating value? a) LPG b) methane <u>c) hydrogen</u> d) diesel
5.	The difference in temperature between steam and condensate is the principle of operation in a a) thermodynamic trap <u>b) thermostatic trap</u> c) orifice type trap d) none of the above
6.	Which of the following will be ideal for heat transfer in a heat exchanger? a) hot water b) super heated steam <u>c) saturated dry steam</u> d) wet steam
7.	What is the predominant mode of heat transfer in reheating furnaces? a) convection <u>b) radiation</u> c) conduction d) pulsation
8.	In a gas turbine, air compressor alone consumes about _____of the energy generated

	a) 5-10% b) 20-30% c) 30-40% d) 40-45%
9.	In an oil fired steam boiler the Air to fuel ratio by mass is 15:1 & evaporation ratio is 14:1. The flue gas to fuel ratio will be a) 29:1 b) 16:1 c) 1:1 d) 15:1
10.	The cogeneration system which has high overall system efficiency is one which uses a) back pressure steam turbine b) combined cycle c) extraction condensing steam turbine d) reciprocating engine
11.	Regenerator is used mainly along with a a) boiler b) high temperature furnace c) compressor d) gas turbine
12.	The device used to upgrade a lower pressure steam to a higher pressure steam is called a) heat pump b) thermo compressor c) heat pipe d) heat wheel
13.	Which of the following works on a refrigeration cycle? a) thermo compressor b) heat pipe c) heat wheel d) heat pump
14.	Which agro-residue has the lowest gross calorific value? a) deoiled bran b)paddy husk c)sawdust d) coconut shell
15.	The highest % of sulphur is present in a) LDO b) Furnace oil c) LSHS d) Kerosene
16.	Which of the following is not a property of ceramic fibre insulation? a) low thermal conductivity b) high heat capacity c) light weight d) thermal shock resistance
17.	For stoichiometric combustion of 1 kg of carbon, the required amount of air will be about a) 31 kg b) 21 kg c) 11.6 kg d) 2.67 kg
18.	For coal fired system, the flame length is influenced by a) moisture b) volatile matter c) ash content d) fixed carbon .
19.	Which of the following in fuel contributes to erosive effect on burner tips? a) ash b) water c) sulphur d) volatile matter

20.	The largest heat loss in the heat balance of a coal fired boiler is due to a) dry flue gas loss b) loss due to hydrogen in the fuel c) radiation losses d) moisture in the air
21.	Water treatment for steam boilers is generally required to a) remove hydrogen b) prevent scale formation c) help improve combustion efficiency d) reduce stack temperature
22.	The stoichiometric air to natural gas ratio by volume for complete combustion is a) 14-15 b) 7-8 c) 9.5-10.5 d) none of the above
23.	A rise in conductivity of boiler feed water indicates a) drop in the contamination of feed water b) greater purity of feed water c) rise in the TDS of feed water d) rise in oxygen level
24.	For transporting the steam to the long distance, the best quality of steam is a) dry saturated steam b) slightly superheated steam c) mildly wet steam d) very high pressure steam
25.	In a steam system, the purpose of air venting is because air a) is a good conductor b) acts as insulator c) is inert d) is diluent
26.	The inverted bucket trap operates on the principle of _______ difference between water and steam a) pressure b) density c) temperature d) velocity
27.	Furnace wall heat loss does not depend on ______ a) temperatures of external wall surfaces b) velocity of air around the furnace c) thermal conductivity of wall brick d) material of stock to be heated.
28.	The insulation material suitable for low temperature application to prevent heat gain is a) mineral fiber b) fiber glass c) silica d) polyurethane
29.	In FBC boiler, the combustion is carried out at a temperature a) closer to steam temperature. b) adiabatic combustion temperature c) below ash fusion temperature d) above ash fusion temperature
30.	The material used to control SOx in the FBC boiler is a) limestone b) alumina c) silica d) lime
31.	In an industry, exhaust gas from the furnace is used for power generation by installing waste heat recovery steam boiler and a steam turbine. This type of co-generation is termed as a) combined cycle b) Braton cycle c) topping cycle d) bottoming cycle
32.	F&A(from and at) rating of the boiler is the amount of steam generated from

	a) water at 0 ^oC to saturated steam at 100 ^oC b)water at feed water temperature to saturated steam at 100 ^oC <u>c)water at 100 ^oC to saturated steam at 100 ^oC</u> d)water at ambient temperature to saturated steam at 100 ^oC
33.	Pinch analysis of heat exchangers depicts plot of a) temperature vs entropy b) temperature vs area c) temperature vs specific heat <u>d) temperature vs enthalpy</u>
34.	The effectiveness of a heat exchanger does not depend on a) specific heat of hot fluid b) inlet temperature of hot fluid c) inlet temperature of cold fluid <u>d) LMTD</u>
35.	Parameter assumed to remain constant during LMTD calculation of a heat exchanger is a) temperature drop b) heat transfer area <u>c) specific heat of fluids</u> d) all the above
36.	How much kg of SO_2 is produced in complete combustion of 32 kg of sulphur? a) 16 b) 32 <u>c) 64</u> d) 128
37.	Micro turbine can be used to replace _______ for energy savings a)gas turbines b) diesel generator c) HRSG <u>d) PRV</u>
38.	When steam pressure reduces, which of the following increases ? a) sensible heat b) enthalpy of steam c) saturation temperature <u>d) specific volume</u>
39.	If excess air is 20% in a boiler, the excess oxygen in flue gas would be <u>a) 3.5%</u> b) 4% c) 2% d) 1.5%
40.	Which of the following requires the lowest stoichiometric oxygen demand (kg/kg of fuel)? a) hydrogen b) carbon <u>c) sulphur</u> d) methane
41.	Temperature control in fuel oil storage tank is intended to control <u>a) viscosity</u> b) density c) specific heat d) caloric value
42.	An increase in bulk density of a refractory increases its a) thermal conductivity b) heat capacity c) resistance to slag penetration <u>d) all of the above</u>
43.	In a CFBC boiler,the capture and recycling of bed material is accomplished by a) bag filter b) settling chamber <u>c) cyclone</u> d) scrubber system

44.	Bomb calorimeter is used to measure a) atmospheric pressure b) pour point of liquid Fuels c) calorific value of fuels d) viscosity of fuel
45.	Pick the wrong statement. The thermal efficiency of a furnace increases by a) preheating combustion air b) increasing the excess air flow rate c) reducing the surface heat loss d) minimizing the CO loss and un-burnt losses
46.	In a steam turbine power plant, vacuum is generated at a) turbine inlet b) condenser c) deaerator d) all of the above
47.	Heat wheels are mostly used in a situation of…. a) high temperature exhaust gases b) heat exchange between large masses of air having small temperature differences c) heat transfer between a liquid and gas d) corrosive gases
48.	In a condenser, which part of the heat of the steam is rejected? a) super heat b) latent heat c) sensible heat d) latent heat and super heat
49.	The highest energy loss occurs in which of the following thermal power plant equipment ? a) boiler b) steam turbine c) generator d) condenser
50.	Which of the following gives a rough estimate of calorific value of coal ? a) moisture content b) volatile matter c) fixed carbon d) ash content

-------- *End of Section - I* ---------

Section - II: SHORT DESCRIPTIVE QUESTIONS **Marks: 8 x 5 = 40**

(i) Answer all eight questions
(ii) Each question carries five marks

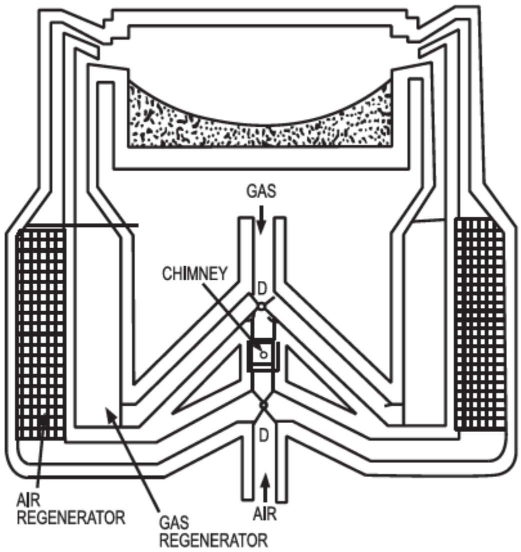
S1	An economizer was installed in the furnace-oil fired boiler. The following are the data monitored after commissioning the economiser. Air to fuel ratio = 20 Evaporation ratio of the boiler = 12 Specific heat of flue gas = 0.25 kcal/kg^{O}C. Condensate recovery in the plant = Nil. Calculate the rise in temperature of feedwater in an economizer, which brings down the flue gas temperature from 280 ^{O}C to 180 ^{O}C.

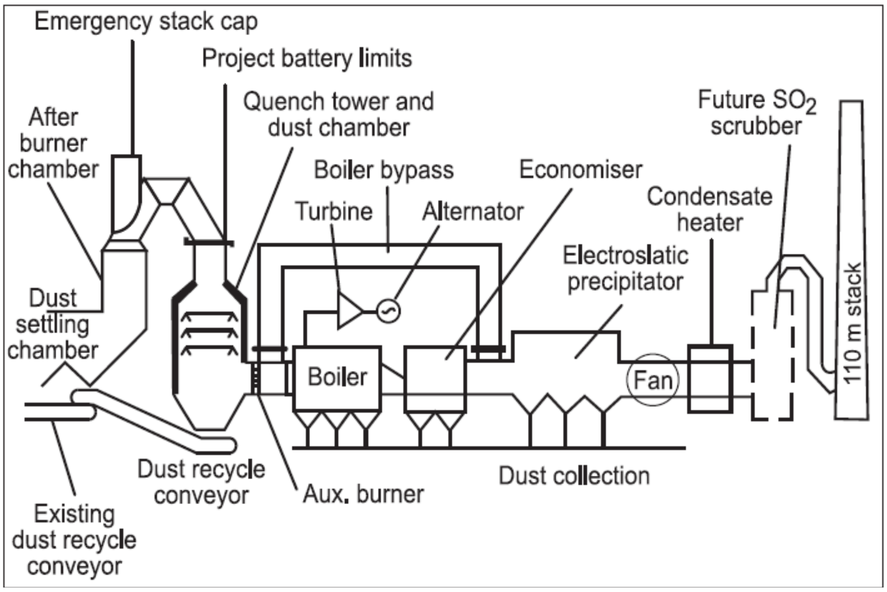
Ans	For 1 kg of fuel, steam generated = 12 kg For 1 kg of fuel, required combustion air = 20 kg For 1 kg of fuel, flue gas generated = 20 +1= 21 kg In economizer heat given by flue gas = heat received by water 21 x 0.25 x (280-180) = 12 x 1 x ΔT **Rise in temperature of water** ΔT = 43.75 **ºC**
S2	Hot condensate from a heat exchanger is coming out at 9 bar with a sensible heat of 176.4 kcal/kg. The condensate is flashed to 3 bar with a sensible heat of 133.4 kcal/kg and latent heat of 517 kcal/kg. The flash steam generated is 50 kg/hr. Find out the flow rate of hot condensate in kg/hr from the heat exchanger..
Ans	=S1- S2 / L2 % Flash steam available = (176.4-133.4) / 517 =8.3 % **Flow rate of hot condensate** = 50/.083 = **602 kg/hr**.
S3	The measured CO_2 in flue gas of oil fired boiler is 10 % against the theoretical CO_2 content of 14.5 %, Air to fuel ratio for combustion in the boiler is found to be 20. Calculate the theoretical air required for combustion.
Ans	% Excess air = (Theoretical CO_2 / Actual CO_2) – 1 = (14.5 / 10) – 1 **= 45 %** Theoretical air required for combustion = 20 / 1.45 **= 13.8 kg of air / kg of fuel**
S4	A gas turbine generator is operating with naphtha as a fuel. The following are the data collected during the gas turbine generator operation: Fuel (Naphtha) consumption = 350 kg/hr GCV of naphtha fuel = 10550 kcal/kg Overall efficiency of gas turbine generator = 35 % Cost of naphtha fuel = Rs 45000 / ton Find out the cost of generating one unit of electricity.
Ans	Heat input to the turbine = 10550 * 350 = 3692500 kcal/hr Efficiency of gas turbine = 35 % Gas Turbine Output = [(3692500x0.35) / 860] = 1503 kWh Cost of generating 1503 units of electricity = 350 kg/hr x Rs 45.0

	Cost of one unit of electricity generated	= Rs. 15750 = 15750 / 1503 **= Rs 10.5 per kWh**
S5	A paint drier requires 75.4 m^3/min of air at 93°C, which is heated in a steam-coil unit with 4 bar saturated steam. The density of air is 1.2 kg/m^3 and specific heat of air is 0.24 kcal/kg°C. Inlet air temperature to drier is 32°C. (see table below) How many kg of steam at 4 bar does this steam coil unit require per hour?	
Ans	Air flow rate (vol) = 75.4 m^3/min x 60 = 4524 m^3/hr Air flow rate (mass) = 4524 x 1.2 = **5428.8 kg/hr** Sensible heat of air = m x Cp x ΔT = 5428.8 x 0.24 x (93-32) = **79477 kcal/hr** Latent heat of Steam = 510 kcal/kg Steam required = 79477 / 510 Steam required **= 156 kg/hr**	
S6	List three functions of steam traps. What type of trap is generally used for main steam lines?	
Ans	i) Page no 80 & 81 To discharge condensate as soon as it is formed Not to allow steam to escape To be capable of discharging air and other incondensable gases ii) Thermodynamic steam trap is used in the main line	
S7	Explain with sketch the working principle of a regenerator used for high temperature furnace	
Ans	Ref page no 222	

Table for S5:

Steam pressure bar	Steam temperature °C	Enthalpy kcal/kg		
		Water	Evaporation	Steam
4.0	143	143	510	653

	Regenerator The Regeneration which is preferable for large capacities has been very widely used in glass and steel melting furnaces. Important relations exist between the size of the regenerator, time between reversals, thickness of brick, conductivity of brick and heat storage ratio of the brick. In a regenerator, the time between the reversals is an important aspect. Long periods would mean higher thermal storage and hence higher cost. Also long periods of reversal result in lower average temperature of preheat and consequently reduce fuel economy. (Refer Figure 8.5).  **Figure 8.5 Regenerator** Accumulation of dust and slagging on the surfaces reduce efficiency of the heat transfer as the furnace becomes old. Heat losses from the walls of the regenerator and air in leaks during the gas period and out-leaks during air period also reduces the heat transfer.
S8	Explain briefly the bottoming cycle cogeneration system and mention any two of its application in industry
Ans	i) Ref page no 191 **Bottoming Cycle** In a bottoming cycle, the primary fuel produces high temperature thermal energy and the heat rejected from the process is used to generate power through a recovery boiler and a turbine generator. Bottoming cycles are suitable for manufacturing processes that require heat at high temperature in furnaces and kilns, and reject heat at significantly high temperatures. Typical areas of application include cement, steel, ceramic, gas and petrochemical industries. Bottoming cycle plants are much less common than topping cycle plants. The Figure 7.6 illustrates the bottoming cycle where fuel is burnt in a furnace to produce synthetic rutile. The waste gases coming out of the furnace is utilized in a boiler to generate steam, which drives the turbine to produce electricity.



ii) steel, cement, ceramic, glass industry

-------- End of Section - II ---------

Section - III: LONG DESCRIPTIVE QUESTIONS **Marks: 6 x 10 = 60**

(i) Answer all SIX questions
(ii) Each question carries **Ten** marks

L 1	A counter-flow double pipe heat exchanger using hot process liquid is used to heat water, which flows at 10.5m^3/hr. The process liquid enters the heat exchanger at 180°C and leaves at 130°C. The inlet and exit temperature of water are 30°C and 90°C respectively. Specific heat of water is 4.18 kJ/kg°C. a) Calculate the heat transfer area, if overall heat transfer coefficient is 814 W/m^2°C.. b) What would be the percentage increase in area, if the fluid flows were parallel?
Ans	Water flow rate = 10.5 x 1000 = 10500 kg/hr Heat content in water = m x Cp x ΔT = 10500 x 4.18 x (90 – 30) = 2633400 KJ/hr = 2633400 / 3600 **= 731.5 kW** **For Counter current flow:** ΔT1 = 180 – 90 = 90°C ΔT2 = 130 – 30 = 100°C LMTD of counter flow = (100-90)/ ln(100/90) **= 95°C**

	Overall heat transfer coeff. = 814 W/m2°C Area of heat exchanger for counter flow = 731.5 x 1000 / (814x 95) **= 9.5 m^2** **For Parallel flow:** ΔT1 = 180 – 30 = 150°C ΔT2 = 130 – 90 = 40°C LMTD of parallel flow = (150-40)/ ln(150/40) = 83°C Overall heat transfer coeff. = 814 W/m2°C Area of heat exchanger for parallel flow = 731.5 x 1000 / (814 x 83) **= 10.8 m^2** Increase in the area for parallel flow = [(10.8 – 9.5) / 9.5] x 100 **= 14 %**
L 2	In a chlor-alkali plant, 100 TPD caustic solution at 30% concentration is dried to 55% concentration in a single effect evaporator, where the ratio of steam input to moisture removal is 1.0 kg/kg. It is proposed to be replaced by a triple effect evaporator at an investment cost of Rs. 5 crore, for which the ratio of steam input to moisture removal is 0.45 kg/kg. Steam for the evaporator is generated from an oil fired boiler at an evaporation ratio of 14 which operates for 300 days in a year. Calculate payback period if the cost of Fuel Oil is Rs.50,000 per ton.
Ans	% salt concentration at inlet = 30% % salt concentration at outlet = 55% Input quantity of caustic solution to drier = 100 TPD Amount of salt at drier inlet = 100x 0.3 = 30 TPD Flow rate of salt solution at drier outlet = 30 / 0.55 = 54.5 TPD Amount of water removed = 100 – 54.5 **= 45.5 TPD** Ratio of steam / moisture for single effect = 1.0 Amount of steam required for single effect = 45.5 TPD Ratio of steam / moisture for triple effect = 0.45 Amount of steam required for triple effect = 45.5 x 0.45 = 20.475 TPD Amount of steam saved by triple effect = 45.5 – 20.45 **= 25 TPD** Evaporation ratio = 14 Amount of fuel savings = 25 / 14 = **1.79 TPD**

	FO savings per year = 1.79 x 300 = 537 Tons/year Cost of FO saved = 537 x 50,000 = **Rs. 2.69 Crores per year** Investment on triple effect evaporator = Rs. 5 Crores Payback period = 5 / 2.69 = **1.86 years (or) 22 months**
L 3	a) List the advantages of CFBC boilers over AFBC boilers. b) What are the advantages of plate heat exchanger over shell and tube heat exchanger?
Ans	a) List the advantages of CFBC boilers over AFBC boilers. i. Higher processing temperature because of high gas velocity through the system. ii. Lower combustion temperature of about 870 oC can be achieved constantly, which results in minimal NOx formation. iii. The combustion air is supplied at 1.5 to 2 psig rather than 3 to 5 psig as required by bubbling bed combustors. iv. Higher combustion efficiency. v. Better turndown ratio. vi. Erosion of heat transfer surface in the combustion chamber is reduced, since the surface is parallel to the flow. In AFBC system, the surface is generally perpendicular to the flow. b) i. The heat recovery efficiency is higher for plate heat exchanger when compared with shell and tube heat exchanger ii. Plate heat exchanger is compact in size. iii. If the temperature difference is small between cold and hot stream, then plate heat exchanger is used more effectively when compared with shell and tube heat exchanger iv. Heat exchange surface is easily increased or decreased by addition or removal of plates.
L 4	List five energy saving measures **in each** of the following a) Oil fired industrial reheating furnace. b) Steam systems

	Typical energy efficiency measures for an industry with furnace are: 1) Complete combustion with minimum excess air 2) Correct heat distribution 3) Operating at the desired temperature 4) Reducing heat losses from furnace openings 5) Maintaining correct amount of furnace draught 6) Optimum capacity utilization 7) Waste heat recovery from the flue gases 8) Minimum refractory losses 9) Use of Ceramic Coatings b) Steam Systems 1) Avoiding Steam Leakages 2) Providing Dry Steam for Process 3) Utilising Steam at the Lowest Acceptable Pressure for the Process 4) Proper Utilization of Directly Injected Steam 5) Minimising Heat Transfer Barriers 6) Proper Air Venting 7) Condensate Recovery 8) Insulation of Steam Pipelines and Hot Process Equipments 9) Flash Steam Recovery 10) Pipe Redundancy 11) Reducing the Work to be done by Steam 12) Monitoring Steam Traps
L 5	A boiler utilizes Coconut shell as fuel and the ultimate analysis (by weight %) of the fuel is given below:

COMPONENT	Ultimate ANALYSIS %
Carbon	45
Hydrogen	5
Nitrogen	0.6
Oxygen	32
Sulfur	0.08
Mineral matter	4
Moisture	13.32

The CO_2 content of the exit flue gas measured is 10%.

For 100 kg of coconut shell fuel fired calculate the following

(a) Theoretical amount of air required for combustion

(b) Theoretical CO_2 content in flue gas.

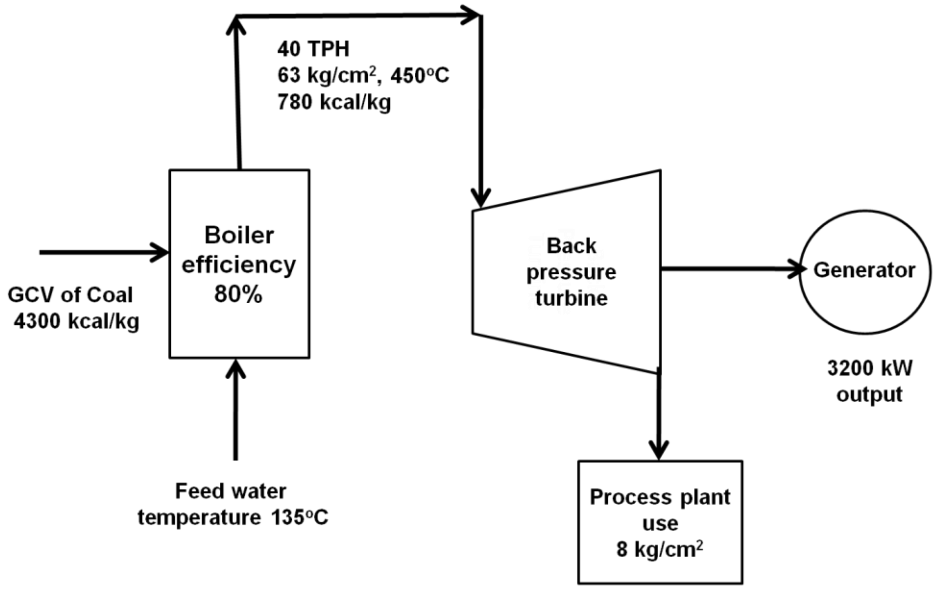
(c) % excess air supplied

Ans

a)

Total oxygen required =45x2.67+ 5 x 8+.08 x 1 = 160.23kg

Oxygen present in the fuel =32 kg

	Net oxygen required =160.23 - 32 = 128.23 kg Air required =128.23/0.23 = 557.52kg **Theoretical amount of air required for combustion =557.52 kg/100 kg of fuel.** b) Nitrogen in the air =557.52 - 128.23 = 429.29kg Nitrogen in the fuel =0.6kg Moles of Nitrogen = 429.89 / 28 = 15.35 Amount of carbon dioxide in flue gas = 45 x 44/12 = 165 kg Moles of Carbon dioxide =165 / 44 = 3.75 Moles of sulphur = 0.08 x 2/64 =0.0025 b)**Theoretical CO_2 content in flue gas = 3.75 / (3.75+15.35+.0025) =19.7%** **c) % Excess air supplied = 100x(19.7/10) -1 = 97%**
L-6	The schematic of a back pressure steam turbine cogeneration system of process plant operating round the clock with operating data is depicted below.  If the steam requirement of the process is to be increased to 44TPH which can be met by the existing boiler through the back pressure turbine, a) find out the reduction in cost of electrical energy drawn from the grid per day due to additional power generation ,assuming the same steam to power recovery as in the existing case and at a grid electricity cost of Rs.7/kWh, Aux power remains the same b) also find out the additional coal requirement per day?

Ans	Present steam to power recovery ratio =40,000 kg/hr / 3,200 kWh **= 12.5 kg/kWh** Additional steam generation = 4TPH Additional power generation potential = 4000 kg/hr /12.5 kg/kWh **=320 kW** **Daily saving** due to additional power generation =320 kW x24 hr x Rs.7 **= Rs 53,760** Additional coal requirement per hour = 4000 x(780-135) / (0.8 x 4300) **= 750 kg/hr** b)**Additional coal requirement** per day =750 kg/hr x 24 = 18,000 kg/day = **18 Ton/day**

-------- End of Section - III ---------

14th NATIONAL CERTIFICATION EXAMINATION FOR ENERGY MANAGERS & ENERGY AUDITORS – August, 2013

PAPER – 2: Energy Efficiency in Thermal Utilities

Date: 24.8.2013 Timings:14:00 -17:00 Hrs Duration:3 Hrs Max.Marks:150

Section – I: OBJECTIVE TYPE Marks: 50 x 1 = 50

(i) Answer all **50** questions
(ii) Each question carries **one** mark
(iii) Please hatch the appropriate oval in the **OMR** answer sheet with Black Pen or HB pencil

1.		In coal fired combustion, the flame length is influenced by a) moisture b) ash content c) <u>volatile matter</u> d) fixed carbon
2.		With increase in the percentage of excess air for combustion of coal, percentage of CO_2 in flue gas a) increases <u>b) decreases</u> c) remains same d) none of the above
3.		100 kg of a fuel contains 3% sulphur. For complete combustion of sulphur in the fuel it will require _________kg of oxygen <u>a) 3</u> b) 6 c) 30 d) 103
4.		Which property indicates the lowest temperature at which fuel oil is readily pumpable? a) flash point b) <u>pour point</u> c) specific heat d) specific volume
5.		Which of the following contributes to spluttering of flame at burner tip during combustion of fuel oil ? a) ash content b) <u>water content</u> c) sulphur content d) humidity of air
6.		In an oil fired steam boiler the air to fuel ratio is 15:1 & evaporation ratio is 14:1. The flue gas to fuel ratio will be

		a) 29:1 b) 16:1 c) 14:1 d) 15:1
7.		Which among the following fuels, on combustion ,has higher tendency towards acid corrosion in the flue gas path? a) a) LSHS b) furnace oil c) Diesel d) kerosene
8.		The balanced draft furnace is one that is operated with a) a) positive pressure b) induced and forced draft fan b) c) negative pressure d) Natural draft
9.		The factor that influences atomisation of fuel oil is a) viscosity b) density c) flash point d) pour point
10.		Which of the following is not measured in ultimate analysis ? a) carbon b) sulphur c) hydrogen d) moisture
11.		In flue gas, the oxygen measured is 4% by volume. The percentage excess air will be a) a) 23.5% b) 40% c) 21% d) 36%
12.		A boiler generates 5 TPH of steam at an efficiency of 78 %. The enthalpy added to steam in the boiler is 580 kcal/kg. The fuel consumption with a GCV of 4200 kcal/kg is a) 885 kg/hr b) 985 kg/hr c) 1038 kg/hr d) 1200 kg/hr
13.		Automatic blowdown controls for boilers work by sensing a) dissolved gases b) dissolved solids c) pH d) conductivity and pH
14.		Dissolved CO_2 in boiler feed water when left untreated would result in occurrence of _____in boiler tubes a) creep b) water side corrosion c) scale d) water hammer
15.		Recommended boiler feed water pH value at 25°C is --------- a) 8.0 - 9.0 b) 5.2 - 6.2 c) 9.8-10.2 d) 10-10.5
16.		Which of the following is not applicable in the preservation of boiler by dry method ? a) un-slacked lime b) activated alumina c) anhydrous calcium cloride d) hydrazine

17.		Which one of the following is true of a water softening process? a) It reduces hardness but not TDS b) It reduces both hardness and TDS c) It reduces TDS but not hardness d) None of the above
18.		Soot deposit in boiler tubes is predominantly due to a) poor water treatment b) low steam pressure c) incomplete combustion d) high excess air
19.		Which of the following will be the most suitable heating medium for heat transfer in indirect heating? a) dry saturated steam b) superheated steam c) wet steam d) hot water
20.		Ten meter lift of condensate in a distribution pipe will result in a back pressure of a) 0.1 bar b) 1 bar c) 10 bar d) 1.1 bar
21.		The difference in temperature between steam and condensate is the principle of operation of a) thermodynamic trap b) thermostatic trap c) orifice type trap d) float trap
22.		Water flows at a rate of 30 m^3/hr. at 15°C in a 150 mm bore pipe horizontally. What is the velocity of water flow in the pipe? a) 0.47 m/s b) 0.94 m/s c) 1.88 m/s d) 3.7 m/s
23.		To drain condensate from tracer steam lines , the most common trap used is__________ a) thermodynamic b) bimetallic c) inverted bucket d) float trap
24.		The velocity of steam in steam pipe is directly proportional to a) number of bends in pipe b) specific volume of steam c) length of pipe d) fifth power of pipe diameter
25.		Condensate, at 3 bar pressure & 160°C, when exposed to atmosphere will a) fully convert to flash steam b) partly convert to flash steam c) remain as condensate d) convert to superheated steam
26.		Steam at 4 bar has sensible heat of 144 kcal/kg and latent heat of 510 kcal/kg. If the steam is 90% dry than the total enthalpy of steam in kcal/kg is a) 588 b) 654 c) 603 d) 459
27.		For transporting steam to a long distance, the most suitable among the following will be a) slightly superheated steam b) dry saturated steam

		c) mildly wet steam d) high pressure steam
28.		Heat transfer in a reheating furnace is achieved by a) conduction b) convection c) radiation d) <u>all of the above</u>
29.		Which of the following is not a property of ceramic fibre ? a) low thermal conductivity b) light weight c<u>) high heat capacity</u> d) thermal shock resistant
30.		The unit of overall heat transfer coefficient is a) kcal/m-hr-°C b) <u>kcal/ m²-hr-°C</u> c) kcal/m²-°C d) kcal/ m-°C
31.		Which property of ceramic coating influences energy savings in furnaces? a) <u>emissivity</u> b) coating thickness c) conductivity d) convective heat transfer coefficient
32.		In a CFBC boiler the capture and recycling of bed materials is accomplished by a) elecrostatic precipitator b) bag filter <u>c) cyclone</u> d) scrubber
33.		What is the most effective way to avoid ambient air infiltration into a continuous furnace? a) close all openings b) increase the chimney height c) operate at about 90% capacity d) <u>maintain slightly positive pressure inside the furnace</u>
34.		The storage heat losses in a batch type furnace can be best reduced by use of a) hot face insulating bricks b) <u>hot face ceramic fibre</u> c) cold face insulating bricks d) cold face ceramic fibre
35.		Tuyeres is a terminology associated with a) forging furnace b) <u>cupola</u> c) open hearth furnace d) heat treatment furnace
36.		Which of the following is a synthetic refractory? a) MgO b) Al_2O_3 <u>c) SiC</u> d) SiO_2
37.		Alumina is a ___________________ type of refractory a) basic b) acidic **c)** <u>neutral</u> d) none of the above
38.		An increase in bulk density of a refractory increases its a) volume stability b) heat capacity c) resistance to slag penetration d) <u>all of the above</u>

39.		Which of these is used in a fluidised bed boiler to control sulphur dioxide emissions? a) charcoal b) limestone c) sand d) silica
40.		In FBC boiler the combustion is carried out at a temperature a) closer to steam temperature b) at adiabatic combustion temperature c) at and above ash fusion temperature d) below ash fusion temperature of fuel used
41.		Low combustion temperature minimises___ in FBC boilers **a) NOx** b) SOx c) CO d) Suspended particulate matter
42.		A chemical plant needs steam at 3 bar and 10 bar in addition to electric power. The most suitable co-generation choice among the following will be a) extraction cum condensing b) condensing turbine c) back pressure turbine d) extraction cum back pressure turbine
43.		Power is to be generated from a cement kiln exhaust gas. The applicable type of cogeneration is called a) topping cycle b) Carnot cycle c) bottoming cycle d) Brayton cycle
44.		Which of the following works on a refrigeration cycle? a) heat pipe b) heat wheel c) heat pump d) thermo compressor
45.		Which of these devices can be used for recovering waste heat from the textile drier exhaust? a) heat wheel b) recuperator c) economizer d) regenerator
46.		Wick in heat pipe is provided to facilitate a) forward movement of hot vapors b) forward movement of hot liquid c) return of condensed liquid d) return of hot vapors
47.		Which of the following requires electrical energy for equipment operation? a) thermo compressor b) heat pump c) heat pipe d) economizer
48.		The exhaust from which of the following is not suitable for waste heat boiler application? a) gas turbine b) hot air dryer c) diesel engine d) furnace
49.		Pinch analysis of process streams depicts the plot of a) temperature vs entropy b) temperature vs area c) temperature vs specific heat d) temperature vs enthalpy

50.		Correction factor for LMTD calculation is applicable for a) parallel flow b) counter current flow c) <u>cross flow</u> d) both (a) & (b)

……. End of Section – I …….

Section - II: SHORT DESCRIPTIVE QUESTIONS Marks: 8 x 5 = 40

(i) Answer all **Eight** questions
(ii) Each question carries **Five** marks

S-1	**The following are the parameters obtained from a steam audit of a cylindrical dryer used for drying cloth.** **Cloth Throughput = 20 m/minute** **Cloth Density = 9.8 m/kg** **Measured Condensate Rate = 135 kg/hour** **Calculate the specific steam consumption per kg of cloth.**
	Cloth throughput per hour = 20 x 60 = 1200 m/hr Weight of cloth = 1200 / 9.8 = 122.45 kg/hr Steam consumption = condensate collected Specific steam consumption = 135/122.45 =1.1 kg of steam per kg of cloth
S-2	**In a crude distillation unit of a refinery, furnace is operated to heat 300 kilo Litres/hr of crude oil at an inlet temperature of 255°C by firing 2.5 kilolitres/hr of furnace oil having GCV of 9880 kcal/kg. If the efficiency of the furnace is 82% ,calculate the outlet temperature of the crude oil from the furnace. Consider the following data:** **Specific heat of Crude Oil = 0.65 kcal/kg°C** **Specific gravity of Crude Oil = 0.86** **Specific gravity of furnace Oil = 0.98**
	Solution: Furnace oil consumption = 2.5 X 0.98 = 2.45 TPH Heat input to the furnace = 2.45 x 1000 x 9880 = 24.2 x 10^6 Kcal/hr Heat absorbed by the crude = 24.2 x 10^6 x 0.82 = 19.85x 10^6 Kcal/hr Q = m * Cp * Del T 19.85 * 10^6 = 300 * 0.86 * 1000 * 0.65 * ΔT ΔT = 118 °C T out = 255 + 118 = 373 °C

	Temperature of crude at furnace outlet is 373 °C
S-3	**In a process plant, 20 TPH of steam after pressure reduction with pressure reducing valve to 20 kg/cm^2 gets superheated. The temperature of steam is 280°C. The management wants to install a de-superheater to convert superheated steam into saturated steam at 20 kg/cm^2 for process use, and its saturation temperature is 210°C.** **Calculate quantity of water at 30°C to be injected in de-superheater to get the desired saturated steam using the following data.** **Specific heat of superheated steam = 0.45 kcal/Kg°C** **Latent heat of steam at 20kg/cm^2 = 450 kcal/kg**
	Answer Quantity of heat available above saturation = 20,000 x 0.45 x (280-210) = 6,30,000 kCal Quantity of water required in de-superheater = Q x{1x (210-30) + 450}= 630000 = 1000 Kg/hr
S-4	**A 5 TPH capacity boiler is generating saturated steam at 8 kg/ cm^{2}g .The following operating parameters was measured during the survey.** **Furnace oil consumption - 200 kg/hr.** **GCV of furnace oil - 10,500 kcal/kg** **Qty of steam generation - 3000 kg/hr** **Feed water temperature - 60 °C** **Enthalpy of dry saturated steam - 660 kcal/kg** **Dryness fraction - 0.9** **Saturation temperature of steam - 170 °C** **Calculate the boiler efficiency by direct method.**
	Boiler Efficiency = $\frac{2700 \text{ kg x } (660-60) \text{ kcal/kg } + 300 \text{ x } (170-60) \text{ x } 100}{200 \text{ kg x } 10500 \text{ kcal/kg}}$ = 78.7%
S-5	**In a pharma industry, a chemical process requires 5000 kg/hr of dry saturated steam at 7 kg/cm^2 (g). Specific volume of steam at 7 kg/cm^{2}g is 0.24 m^3/kg . Determine the pipe diameter size for a steam flow velocity of 25 m/s.**
	The velocity of steam = 25 m/s Specific volume at 7 kg/cm^2 g = 0.24 m^3/kg Mass flow rate of steam = 5000 kg/hr

	= 5000/3600 = 1.389 kg/sec Volumetric flow of steam = 1.389 x 0.24 =0.333 m^3/sec Therefore, using formula:
S-6	**Distinguish between plate heat exchanger and shell and tube heat exchanger ?**
Ans	**Shell and Tube heat Exchangers** Shell-and-tube heat exchangers consist of a bundle of parallel tubes that provide the heat-transfer surface separating the two fluid streams. The tube-side fluid passes axially through the inside of the tubes; the shell-side fluid passes over the outside of the tubes. Baffles external and perpendicular to the tubes direct the flow across the tubes and provide tube support. Tube sheets seal the ends of the tubes, ensuring separation of the two streams. The process fluid is usually placed inside the tubes for ease of cleaning or to take advantage of the higher pressure capability inside the tubes. The thermal performance of such an exchanger usually surpasses a coil type but is less than a plate type. Pressure capability of shell-and-tube exchangers is generally higher than a plate type but lower than a coil type. **Plate Heat Exchangers** Plate heat exchangers consist of a stack of parallel thin plates that lie between heavy end plates. Each fluid stream passes alternately between adjoining plates in the stack, exchanging heat through the plates. The plates are corrugated for strength and to enhance heat transfer by directing the flow and increasing turbulence. These exchangers have high heat-transfer coefficients and area, the pressure drop is also typically low, and they often provide very high effectiveness. However, they have relatively low pressure capability. The biggest advantage of the plate and frame heat exchanger, and a situation where it is most often used, is when the heat transfer application calls for the cold side fluid to exit the exchanger at a temperature significantly higher than the hot side fluid exit temperature i.e. "temperature cross". This would require several shell and tube exchangers in series due to the lack of purely counter-current flow. The overall heat transfer coefficient of plate heat exchangers under favorable circumstances can be as high as 8,000 W/m^2 ^oC. With traditional shell and tube heat exchangers, the U-value will be below 2,500 W/m^2 ^oC.
S-7	**Give reasons for the following** a) **Explain why natural gas requires less amount of excess air compared to solid/liquid fuels** b) **Why steam is to be used at the lowest practicable pressure for indirect process heating ?**
Ans	**a) Natural gas requires less amount of excess air compared to solid/liquid fuels** Natural gas is in the gaseous form and lighter than air, it mixes with air readily (intimate mixing of air (oxygen) and fuel takes place) and aids to complete combustion with less amount of excess air. It does not produce smoke or soot. It has no sulphur content. It is lighter than air and disperses into air easily in case of leak. Natural gas is also free of ash. Solid or liquid fuels must be changed to a gaseous form before they will burn. Hence it requires more excess air compared to natural gas for complete combustion. Solid fuels need to be pulverized properly to get uniform sizes and liquid fuels need to be preheated and atomized

	properly for intimate mixing with air to ensure complete combustion. Hence more excess air is provided for solid and liquid fuels. **b) Steam is to be used at the lowest practicable pressure for indirect process heating** A study of the steam tables would indicate that the latent heat in steam reduces as the steam pressure increases. It is only the latent heat of steam, which takes part in the heating process when applied to an indirect heating system. Thus, it is important that its value be kept as high as possible. This can only be achieved if we go in for lower steam pressures. As a guide, the steam should always be generated and distributed at the highest possible pressure, but utilized at as low a pressure as possible since it then has higher latent heat. However, it may also be seen from the steam tables that the lower the steam pressure, the lower will be its temperature. Since temperature is the driving force for the transfer of heat at lower steam pressures, the rate of heat transfer will be slower and the processing time greater. In equipment where fixed losses are high (e.g. big drying cylinders), there may even be an increase in steam consumption at lower pressures due to increased processing time. There are, however, several equipment in certain industries where one can profitably go in for lower pressures and realize economy in steam consumption without materially affecting production time. Therefore, there is a limit to the reduction of steam pressure. Depending on the equipment design, the lowest possible steam pressure with which the equipment can work should be selected without sacrificing either on production time or on steam consumption.
S-8	**List down five major advantages of waste heat recovery in rolling mill furnace**
	1. Fuel economy 2. Improved combustion/less excess air/reduction in stack losses 3. Increased output 4. Reduction in scale losses 5. Uniform temperature across the material 6. Reduced pollution 7. Less auxiliary energy consumption 8. Reduction in equipment sizes

------- End of Section - II ---------

Section - III: LONG DESCRIPTIVE QUESTIONS Marks: 6 x 10 = 60

(i) Answer all **Six** questions
(ii) Each question carries **Ten** marks

L-1	**An oil fired reheating furnace has an operating temperature of around 1000°C. Average furnace oil consumption is 440 litres/hour. The flue gas exit temperature after the air preheater is 300°C. Combustion air is preheated from ambient temperature of 35°C to 200°C through the air preheater. The other data are as given below.** **Specific gravity of oil = 0.92** **Calorific value of oil = 10,200 kcal/kg** **Average O_2 percentage in flue gas = 14%** **Theoretical air required = 14 kg of air per kg of oil**

	Specific heat of air = 0.24 kcal/kg°C **Specific heat of flue gas = 0.23 kcal/kg°C** **Find out the sensible heat carried away by the exhaust gases and heat recovered by the combustion air in kcal/hr as a percentage of the energy input.**
Ans	Energy input = 440 litres/hr = 440 x 0.92 kg/hr = 404.80 kg/hr = 404.80 x 10,200 = 41,28,960 kCal/hr : Excess air $= \frac{\%O_2}{(21-O_{2\%})} \times 100$ $= \frac{14 \times 100}{(21-14)}$ = 200% Theoretical air required = 14 kg of air to burn 1 kg of oil Actual mass of air required = 14 x (1 + 200/100) kg/kg of oil = 42 kg/kg of oil Sensible heat loss in the flue gas = m x C_p x ΔT m = mass of flue gas = 42 + 1 = 43 kg/kg of oil C_p = Specific heat of flue gas = 0.23 ΔT = Temperature of flue gas – Ambient Temperature = 300°C – 35°C = 265 °C Heat loss = 43 x 0.23 x (300-35) = 43 x 0.23 x 265 = 2620.85 kCal/kg of oil = 2620.85 x 404.80 Kcal/hr = 10,60,920 Kcal/hr Sensible heat loss in the flue gas as % heat loss to input energy $= \frac{10{,}60{,}920 \times 100}{41{,}28{,}960}$ = 25.7 % Heat gained by combustion air = 42 x 0.24 x (200-35) = 1663.2 kCal/kg of oil = 1663.2 x 404.80 Kcal/hr = 673263.36 Kcal/hr

Heat gained by combustion air as % of input energy $= \frac{673263.36 \times 100}{41{,}28{,}960}$

$= 16.3\ \%$

L-2 **Describe briefly any two of the following**

a) **Mechanical de-aeration and chemical de-aeration**

b) **Functions of a steam trap**

c) **Describe the operation of regenerator for high temperature furnace**

Ans

a) Mechanical de-aeration and chemical de-aeration

In de-aeration, dissolved gases, such as oxygen and carbon dioxide, are expelled by preheating the feed water before it enters the boiler.

Mechanical de-aeration

Mechanical de-aeration for the removal of these dissolved gases is typically utilized prior to the addition of chemical oxygen scavengers. Mechanical de-aeration is based on Charles' and Henry's laws of physics. Simplified, these laws state that removal of oxygen and carbon dioxide can be accomplished by heating the boiler feed water, which reduces the concentration of oxygen and carbon dioxide in the atmosphere surrounding the feed water. Mechanical de-aeration can be the most economical. They operate at the boiling point of water at the pressure in the de-aerator. They can be of vacuum or pressure type.

Chemical de-aeration

While the most efficient mechanical deaerators reduce oxygen to very low levels (0.005 mg/litre), even trace amounts of oxygen may cause corrosion damage to a system. Consequently, good operating practice requires removal of that trace oxygen with a chemical oxygen scavenger such as sodium sulfite or hydrazine. Sodium sulphite reacts with oxygen to form sodium sulphate, which is removed through blow down. Hydrazine reacts with oxygen to form nitrogen and water. It is invariably used in high pressures boilers when low boiler water solids are necessary, as it does not increase the TDS of the boiler water.

b) Functions of a steam trap

The three important functions of steam traps are:

1 • To discharge condensate as soon as it is formed in the steam line / pipes.

2

3 • Not to allow steam to escape.

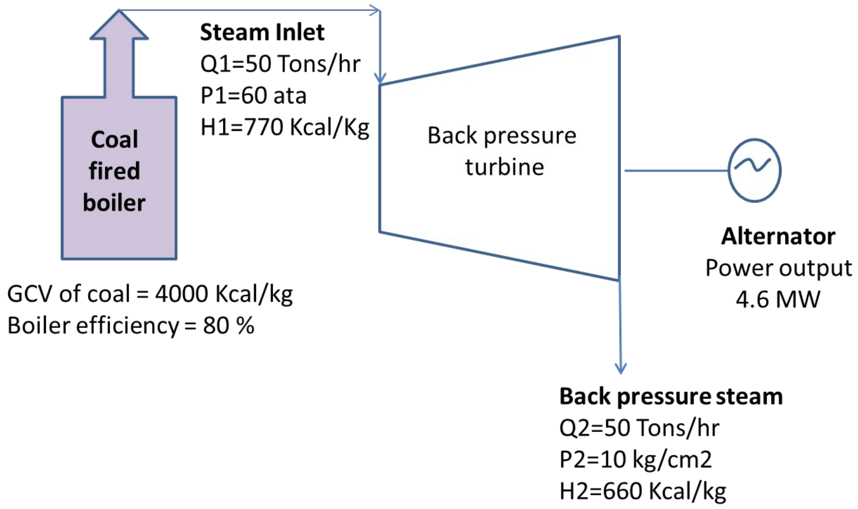
• To be capable of discharging air and other incondensable gases from the steam pipe.

c) Operation of regenerator for high temperature furnace

There are two sets of regenerators consisting of refractory bricks. In one path, the flue gases flow heating up the chequered refractory bricks on one side, while through the

	other path, air for combustion flows which picks up the heat from heated chequered refractory bricks on the other side. The cycle reverses with the time interval.
L-3	**A heat exchanger is to be designed to condense the hydrocarbon vapor mixture from a distillation column at the rate of 11.0 kg/sec which is available at its saturation temperature of 120°C. The latent heat of condensation of the hydrocarbon vapor mixture is 450 kJ/kg. The cooling water at 32°C is used in counter-current direction at the rate of 58 kg/sec to condense the vapor mixture. The specific heat of cooling water is 4.18 kJ/kg °C. Determine LMTD and area of the heat exchanger surface if the overall heat transfer co-efficient is 550 J/m²s°C.**
Ans	Heat loss in hydrocarbon vapour mixture = heat gain in cooling water 11 * 450 = 58 * 4.18 * (T – 32) T = 52.4 °C Water leaves the exchanger at 52.4°C LMTD = (120-32)-(120-52.4)/ln(120-32)/(120-52.4) LMTD of counter flow pattern = 77.4 °C Q = m*Cp* ΔT = U * A * LMTD 58 * 4.18 * (52.4 – 32) * 1000 = 550 * A * 77.4 A = 116.3 m^2 Area of the heat exchanger surface is 116.3 m^2
L-4	**A steam pipeline of 250 mm outer diameter & 100 meters long is insulated with 150 mm Mineral wool insulation. As an energy conservation measure, the management has upgraded the existing Mineral wool insulation with efficient calcium silicate insulation.** **Calculate the economics in terms of payback if the insulation is upgraded at a cost of 20 lakhs.** **Given:** **Operating hours : 8000** **Boiler efficiency : 87 %** **Fuel Oil Cost : Rs. 45,000 per ton** **GCV of the fuel : 10,200 kcal/kg** **Thickness of Mineral wool insulation : 150 mm** **Thickness of Calcium Silicate insulation : 100 mm** **Surface temperature with Mineral wool insulation : 70 °C** **Surface temperature with Calcium silicate insulation : 55 °C** **Ambient temperature : 30 °C**

Ans	Heat loss with Mineral wool insulation = {10 + (Ts –Ta)/20} x (Ts – Ta) = (10 + (70 – 30)/20 } x (70 – 30) = 480 kCal/hr per Square meter Heat loss with Calcium silicate insulation = (10 + (55 – 30)/20 } x (55 – 30) = 281.25 kCal/hr – Sq. m Surface Area with Mineral wool = 3.14 D L = 3.14 x 0.550 x 100 = 172.7 Square meter Surface Area with Calcium Silicate= 3.14 x 0.450 x 100 = 141.3 Square meter Heat loss with Mineral wool = 480 x 172.7 = 82896 kCal/hr Heat loss with Calcium silicate = 281.25 x 141.3 = 39741 kCal/hr Annual savings = (82,896 - 39,741) x 8,000 x 45,000 / 10,200 x 1000 x 0.87 = Rs. 17.5 Lakhs / year Payback period = 20 / 17.5 = 1.14 years = 13.7 months
L-5	**The energy flow diagram in a cogeneration plant in paper industry is given below.**



Calculate the following

i) **Input coal consumption per hour if feed water temperature is 50°C**

ii) **Heat to power ratio of cogeneration plant**

iii) **% turbine and generator losses**

Ans

Input coal consumption = Q=50,000 x(770-50) / (0.8 x 4000) =11.25 Tons/ hr

Heat to power ratio = (50,000 x 660) / (4600 x 860) = 8.34

Turbine and generator loss = 50000 x 770 –(4600 x 860 +50,000 x 660)/10^6 = 1.544 Million kCal

% loss = 1.544 x 10^6 x 100 / (50,000 x 770) =4%

L-6 **List down any ten points that need attention while selecting biomass fluidised bed combustion boiler**

The following areas need attention with biomass fed boilers:

- Uneven spreading of biomass fuel on boiler grate can lead to secondary combustion in the super-heater zone, resulting in overheating of super heater tubes and fluctuations in steam pressure.
- Frequent erosion of super-heater and economizer coils can occur, due to high silica content in the biomass, especially in rice husk.
- High extraneous matter in biomass (sand and mud) causes tube fouling and fluidized bed to be drained more frequently, with resultant heat loss.
- Carbon and dust coating of boiler tubes results in lowering of steam temperatures, especially during soot blowing.
- Presence of Pesticides (used during farming) adds to tube failure frequencies; mainly due to potassium constituents.
- Corrosive constituents in biomass adversely affect boiler internals, especially the super-heater tubes. Chloride content in certain types of biomass (like cotton stalk, 8–9%) can combine

		with sodium and potassium in high temperature regime to aggravate the corrosion process. 🕐 Some boilers which use Red Gram husk/twigs as fuel pose corrosion problems at the cold end (i.e., secondary super-heater and economizer tubes), due to the sulfur content. 🕐 The biomass fuel mix fed to the boiler, in quite a few cases, contains a combination of 6 to 7 biomass types. Each biomass has a separate air-to fuel ratio, and it is difficult to set a workable air–fuel ratio. 🕐 High moisture content in the biomass causes frequent jamming of the fuel in feeders, leading to fluctuations in steam pressure and temperature. 🕐 High moisture content in the biomass also leads to plugging and choking of closely spaced heating surfaces. This situation is further aggravated by the super-heater tube coil with very close spacing, often the result of a desire to achieve a compact design. 🕐 Due to biomass fuel size variation, occurance of unburnts in flue gases and bottom ash is high, resulting in lower efficiency and also variation in steam pressure and temperature. 🕐 Absence of biomass feed rate measurement mechanism leaves little room for accurate assessment of heat rate/efficiency. Providing a weighing mechanism is difficult on account of different biomass fuel combinations being used, with different (and low) bulk densities. 🕐 Degradation of biomass during storage in exposed ambient wet atmosphere leads to loss of heat value. Loss of material due to windage and carpet loss, coupled with loss of heat value on account of decay (inherent biomass characteristics), can cause an error in assessment of input fuel energy (as the input heat is customarily evaluated based on received biomass quantities and GCV).

------- End of Section - III ---------

13th NATIONAL CERTIFICATION EXAMINATION FOR ENERGY MANAGERS & ENERGY AUDITORS - September 2012

PAPER – 2:	**Energy Efficiency in Thermal Utilities**		
Date: 15.9.2012	Timings:14:00-17:00Hrs	Duration:3 Hrs	Max.Marks:150

Section – I: OBJECTIVE TYPE — Marks: 50 x 1 = 50

(i) Answer all **50** questions
(ii) Each question carries **one** mark

1.	Steam mains are run with a slope primarily to a) avoid water hammer b) increase the velocity of steam c) avoid condensation of steam d) reduce radiation and convection losses
2.	Which of the following is not true of condensate recovery? a) reduces water charges b) reduces fuel costs c) increases boiler output d) increases boiler blow down
3.	If 10% air is entrained in a steam system at 3 kg/cm^2 g then the saturation temperature of steam will be a) less than the saturation temperature at 3 kg/cm^2 g b) more than the saturation temperature at 3 kg/cm^2 g c) equal to the saturation temperature at 3 kg/cm^2 g d) equal to the saturation temperature at 3.3 kg/cm^2 g
4.	The mineral matter in coal after combustion mostly becomes a) carbon dioxide b) carbon monoxide c) nitrous oxide d) ash
5.	Conditioning of coal with water in certain boilers is done to a) increase unburnt losses b) increase GCV c) minimize losses of fine coal particles d) increase convection heat transfer
6.	Which of the following is false? a) LPG vapour is twice as light as air b) LPG is a mixture of propane and butane c) LPG is a gas at normal atmospheric pressure d) LPG is required to be odorized
7.	Of the following fuels, which will have the highest carbon content? a) furnace oil b) coal c) natural gas d) paddy husk

8.	100 kg of a fuel contains 2% sulphur. For complete combustion of sulphur it will require _________kg of oxygen a) 2 b) 4 c) 50 d) 200
9.	In the direct method of efficiency evaluation of boilers which of the following is not required? a) enthalpy of steam b) calorific value of fuel c) O_2 in flue gas d) mass flow rate of steam
10.	Select the incorrect statement with respect to steam a) evaporation is a constant temperature process b) higher the pressure higher is the steam saturation temperature c) higher the pressure higher is the latent heat d) latent heat at critical point is zero
11.	The amount of flash steam generated from the condensate mainly depends on _____ a) sensible heat of high pressure condensate b) sensible heat of flash steam c) latent heat of flash steam d) all of the above
12.	Tuyeres is a terminology associated with a) induction furnace b) pusher type furnace c) arc furnace d) cupola
13.	In determining the economic thickness of steam pipe insulation which of the following is not required? a) cost of fuel b) boiler efficiency c) steam pressure d) heat content of fuel
14.	The softening temperature of a refractory is indicated by a) Pyrometric cone equivalent (PCE) b) refractoriness under load (RUL) c) creep d) cold crushing strength
15.	Which of the following is not a property of ceramic fibre ? a) low thermal conductivity b) light weight c) high heat capacity d) thermal shock resistant
16.	Low combustion temperature in FBC boilers results in the reduced formation of a) NOx b) SOx c) CO d) CO_2
17.	An axial compressor is used in conjunction with which of the following a) gas turbine b) back pressure steam turbine c) condensing steam turbine d) all of the above
18.	Power is to be generated from a cement kiln exhaust gas. The applicable type of cogeneration is called a) topping cycle b) trigeneration c) bottoming cycle d) none of the above
19.	The effectiveness of a heat exchanger does not depend on

	a) specific heat of hot fluid b) specific heat of cold fluid c) inlet temperature of hot fluid d) LMTD
20.	An element in fuel oil responsible for corrosion in exhaust system of a boiler is a) carbon b) hydrogen c) sulphur d) chlorine
21.	The presence of calcium and magnesium bicarbonates in feedwater to a boiler would form: a) acidic solution b) alkaline solution c) neutral solution d) none of the above
22.	Turn down ratio of a burner is the ratio of a) maximum to minimum fuel input without affecting optimum excess air levels b) minimum to maximum fuel input without affecting optimum excess air levels c) maximum to average fuel input d) average to minimum fuel input
23.	Comparatively, lowest excess air is required in a a) coal burner b) low pressure oil burner c) high pressure gas burner d) high pressure oil burner
24.	The velocity of steam in steam pipe is directly proportional to a) number of bends in pipe b) specific volume of steam c) length of pipe d) diameter of the pipe
25.	The emissivity of ceramic coatings used in furnace a) decreases with increase in furnace temperature b) Increases with increase in furnace temperature c) remains constant d) decreases with increase in furnace pressure
26.	Scale losses in reheating furnaces will a) increase with excess air b) decrease with excess air c) have no relation with excess air d) increase with CO in combustion gases
27.	Instrument used for measuring billet temperature in a reheating furnace is ___. a) thermograph b) infrared pyrometer c) Pt/Pt-Rh thermocouple with indicator d) chrome alumel thermocouple with indicator
28.	Glass mineral wool can be applied for temperature range application upto a) 950 ^oC b) 500 ^oC c) 1200 ^oC d) 750 ^oC
29.	Heat transfer in a reheating furnace is achieved by a) Conduction b) Convection c) Radiation d) All of the above
30.	The storage heat losses in a batch type furnace can be best reduced by a) insulating brick b) ceramic fibre c) cold face insulation d) fire brick
31.	The cogeneration system which has high overall system efficiency is a) back pressure steam turbine b) combined cycle

	c) extraction condensing steam turbine d) reciprocating engine
32.	The Brayton cycle is a characteristic of a) steam turbine b) petrol engine c) <u>gas turbine</u> d) none of the above
33.	Recuperator as a waste heat recovery system is used mainly in a a) boiler b) <u>reheating furnace</u> c) compressor d) gas turbine
34.	The device used for recovering waste heat from the textile drier exhaust a) <u>heat wheel</u> b) recuperator c) economizer d) regenerator
35.	Density of liquid fuels are measured at a reference temperature of a) 0°C b) <u>15°C</u> c) 25°C d) 30°C
36.	Which of the following contributes to erosive effect on burner tips during combustion? a) <u>ash content</u> b) water content c) sulphur content d) volatile matter
37.	In the context of cogeneration turbine, the thermodynamic process taking place is a) <u>expansion</u> b) condensation c) contraction d) both (a) & (c)
38.	Reduction of steam pressure will increase a) sensible heat b) enthalpy of steam c) saturation temperature d) <u>specific volume</u>
39.	Ten meter lift of condensate in a distribution pipe work will result in a) 0.1 bar back pressure b) <u>1 bar back pressure</u> c) 10 bar back pressure d) none of the above
40.	_____________ is predominantly used as a medium for soot blowing in boilers . a) compressed air b) <u>steam</u> c) high pressure water d) all of the above
41.	The recommended TDS level for package fire tube boilers is a) 10,000 ppm b) 5,000 ppm c) 2,000 ppm d) <u>3,000 ppm</u>
42.	Ideal furnace for melting & alloying is a) <u>induction furnace</u> b) cupola furnace c) rotary hearth d) recirculating bogie furnace
43.	Commonly used flux medium in a cupola furnace a) calcium carbide b) fluorspar c) <u>calcium carbonate</u> d) sodium carbonate

44.	Dolomite is a ________ type of refractory a) acidic b) basic c) neutral d) none of the above
45.	The unit of specific gravity in SI system is a) kg/ m^3 b) m^3/kg c) gm/cc d) none of the above
46.	Insulation used for temperatures more than 350°C is a) polyurethane b) polystyrene c) calcium silicate d) wood
47.	Time dependent property that determines the deformation of a refractory is a) creep b) refractoriness under load c) porosity d) crushing strength
48.	Capillary wick is a part of a) heat pump b) heat wheel c) heat pipe d) heat recovery steam generator
49.	The working fluid for thermo compressor is a) low pressure steam b) high pressure steam c) compressed air d) waste heat from chimney
50.	Fly ash in a FBC boiler is in the range of a) 20% b) 30% c) 40% d) none of the above

Section - II: SHORT DESCRIPTIVE QUESTIONS **Marks: 8 x 5 = 40**

(i) Answer all **8** questions
(ii) Each question carries 5 marks

S-1 In a paper industry, 35,000 kg/hr of soda liquor with specific heat of 0.38 kCal/kg°C is heated using saturated steam at 8 bar in a heat exchanger from 65°C to 115°C. Calculate the LMTD of the exchanger & the amount of steam required for heating using the following data:

Steam Pressure (bar)	Steam Temperature °C	Enthalpy kcal/kg		
		Water	Evaporation	Steam
8.0	170	170	490	660

Ans	a) Heat gain by soda liquor = 35000 x 0.38 x (115-65) = 665000 Kcal/hr Heat lost by saturated steam = 665000 Kcal/hr Steam required for heating = 665000 / 490 = 1357 Kg/hr Amount of steam required for heating is 1.36 Ton/hr b)LMTD calculation = $\dfrac{(170-115)-(170-65)}{\text{Ln}\dfrac{(170-115)}{(170-65)}}$ = (55-105)/ln(55/105) = 77.3°C
S-2	A process requires 5.5 tonnes/hr of dry saturated steam at 7 kg/cm^2g having specific volume of 0.28 m^3/kg. For the flow velocity not to exceed 25 m/s, determine the pipe diameter.
Ans	Volumetric flow rate = 5500 x 0.28 = 1540 m^3/hr = 1540/3600 = 0.43 m^3/s Cross sectional area = volumetic flow rate / velocity = 0.43 / 25 3.14 x D^2/4 = 0.017 D^2 = 0.0217 Diameter, D = 0.149 m (or) 150 mm
S-3	a) 230 kg/hr of hot condensate from a heat exchanger is coming out at 6 bar(g) with a sensible heat of 166 kCal/kg. Using a flash vessel, the condensate is flashed to 1 bar(g) with a sensible heat of 120 kCal/kg and latent heat of 526 kCal/kg. Find out the flash steam generation in kg/hr. b) The flash steam produced above is used to heat water from 30°C to 80°C by direct injection. Calculate the quantity of hot water in that can be obtained per hour.
Ans	a) Flash steam available % =(S1 - S2) / L2 S1 = is the sensible heat of higher pressure steam S2 = is the sensible heat of the steam at lower pressure L2 = is the latent heat of flash steam (at lower pressure) Flash Steam generated = $\dfrac{(166 - 120) \times 230}{526}$ = 20.11 Kg/hr. b) Quantity of hot water generated

	m x cp x (80-30) = 20.11 x (120+526) m = 260 kg/hr
S-4	The evaporation ratio of a coal fired boiler is 4.50. A quantity of 600 kCal/kg of heat is added to the feed water in the boiler to produce the steam. a) If the GCV of coal is 3800 kCal/kg, find out the efficiency. b) Find out the total enthalpy of the steam as per the details of the data given below Saturation temperature = 143^{o}C Sensible heat = 143.7 kCal/kg Latent heat = 509.96 kCal/kg Specific volume = 0.47 m^3/kg Dryness fraction of steam = 96%
Ans	a) Boiler efficiency (%) = $\frac{\text{Evaporation ratio x enthalpy added x 100}}{\text{GCV of coal}}$ Boiler efficiency = 4.5 x 600/3800 = 71 % b) Total enthalpy of steam = 143.7 + (0.96 x 509.96) = 633.26 kCal/kg
S-5	a. 'Steam should be used in the process at the lowest acceptable pressure ' . Explain the significance of the terms 'lowest' and 'acceptable' b. Explain briefly about 'turbine heat rate'. How is it related to turbine efficiency ?
Ans	**a.** 'lowest' : Lower the pressure higher is the latent heat which is primarily used in the process. Hence the lowest pressure would be desirable. 'acceptable': However the lower the steam pressure lower will be the steam temperature. Since the temperature is the driving force for heat transfer, rate of heat transfer reduces and increases process time. Therefore there is a limit to the reduction in steam pressure. **b.** Heat rate is the heat input to turbine, needed to produce 1 kWh of electricity Turbine efficiency is the ratio useful heat and power output, to the heat input to the turbine in Kcal or KJ, expressed as a percentage. Performance of steam turbine is also expressed as heat rate, which is the quantity of heat in kCal or KJ required to generate 1 kWh of electrical power output. Turbine heat rate is expressed in kJ/kWh. The inverse relation between heat rate and efficiency is applicable only to a power plant, since all the input energy is deployed for power generation alone.

S-6	Write short notes on factors affecting wall losses in batch type reheating furnaces?
Ans	a) Emissivity of walls : Emissivity of fire brick refractory should be high Emissivity of most of the refractory bricks decreases with increase in temperature. High emissivity coatings whose emissivity increases with temperature can be used to increase emissivity and decrease wall losses. b) Conductivity of refractories: The refractory and insulating bricks should have low thermal conductivity. Chosing low thermal conductivity bricks will reduce wall losses. Conductivity raises with rise in temperature. Batch type furnaces can use ceramic fibre to reduce storage losses. c) Wall thickness of batch furnaces: Heat losses can be reduced by increasing the **wall thickness**, or through the application of insulating bricks. Outside wall temperature and heat losses for a composite wall of a certain thickness of firebrick and insulation brick are much lower due to lesser conductivity of may be worked out to reduce the heat storage.
S-7	Explain any two proven methods of testing steam traps**?**
ANS	There are two proven methods of testing of steam traps: - Sound method and Temperature method. **1.Sound Method :** Mechanisms within steam traps and the flow of steam and condensate through steam traps generate sonic (audible to the human ear) and supersonic sounds. Proper listening equipment, coupled with the knowledge of normal and abnormal sounds, can yield reliable assessments of steam trap working condition. Listening devices range from a screwdriver or simple mechanic's stethoscope that allow listening to sonic sounds. **2.Temperature Method:** Saturated steam and condensate exist at the same temperature. So it's not possible to distinguish between the two based on temperature. Still, temperature measurement provides important information for evaluation purposes. A cold trap (i.e., one that is significantly cooler than the expected saturated steam temperature) indicates that the trap is flooded with condensate, assuming the trap is in service. On the other hand, the temperature downstream of the trap will be nearly constant if significant steam is getting past the trap. At the low-end, spitting on the trap and watching the sizzle provides a general indication of temperature.

	Finally, non-contact (i.e., infrared) temperature measuring devices provide the precision of thermometers and thermocouples without requiring physical contact. Non-contact temperature measurement makes it easier to evaluate traps that are relatively difficult or dangerous to access closely.
S-8	A vessel has to be cooled from 90°C to 55°C. The mass of the vessel is 2 tonnes. The specific heat of vessel material is 0.18 kCal/kg °C. The vessel is cooled with water which is available at 28°C. The maximum allowed increase in water temperature is 5°C. Calculate the quantity of water required for vessel cooling.
Ans	Mass of vessel (m) = 2000 kg Specific heat (Cp) = 0.18 kCal/kg °C Initial vessel temperature (T1) = 90°C Desired vessel temperature (T2) = 55°C Total heat that has to be removed from the vessel = m x Cp x (T1 - T2) = 2000 x 0.18 x (90-55) = 12600 kCal Quantity of water required = M kg Specific heat of water = 1 kCal/kg °C Inlet cooling water temperature (T3) = 28°C Maximum cooling water outlet temperature (T4) = 33°C Heat removed by water, 12600 = M x 1 x (33 - 28) Quantity of water required , M = 12600/5 = 2520 kg

------- End of Section - II ---------

Section - III: LONG DESCRIPTIVE QUESTIONS **Marks: 6 x 10 = 60**

(i) Answer all **6** questions
(ii) Each question carries **10** marks

L-1	Paddy husk is being used as a fuel in a water tube boiler. The ultimate analysis of fuel is given below. Calculate the theoretical quantity of air required for complete

combustion and also compute the quantity of CO_2, H_2O and SO_2 generated per 100 kg of fuel. The ultimate analysis of paddy husk is given below.

Ultimate analysis of paddy husk	%
Moisture	10.8
Mineral Matter	16.7
Carbon	34.0
Hydrogen	5.0
Nitrogen	0.9
Sulphur	0.1
Oxygen	32.5
GCV (kCal/kg)	3570

ANS

Considering a sample of 100 kg of paddy husk. The chemical reactions are:

Oxygen required for complete combustion of carbon:

C + O2 à CO2
(34.0) C + (34 x 2.67) O2 à **124.78** CO2
90.78

Oxygen required for complete combustion of hydrogen:

H2 + O2 à H2O

(5) H2 + (5 x 8) O2 à **45** H2O
40

Oxygen required for complete combustion of sulphur:

S + O_2 à SO_2

(0.1) S + (0.1 x 1) O_2 à **0.2** SO_2
0.1

Total Oxygen required = 90.78 + 40 + 0.1 = 130.88

Oxygen already present in 100 kg fuel (given) = 32.5 kg
Additional Oxygen Required = 130.88 -32.5 = 98.38
Therefore quantity of dry air reqd. = (98.38) / 0.23 = 427 kg

CO_2 generated per 100 kg of fuel = 124.78 kg
H_2O generated per 100 kg of fuel = 45 kg

SO_2 generated per 100 kg of fuel = 0.2 kg

L-2

In a crude distillation unit of a refinery, furnace is operated to heat 500 m^3/hr of crude oil from 255°C to 360°C by firing 3.4 tons/hr of fuel oil having GCV of 9850 kcal/kg. As an energy conservation measure, the management has installed an air preheater

	(APH) to reduce the flue gas heat loss. The APH is designed to pre-heat 57 tonnes/hr of combustion air to 195°C. Calculate the efficiency of the furnace before & after the installation of APH. Consider the following data: • Specific heat of crude oil = 0.6 kcal/kg°C • Specific heat of air = 0.24 kcal/kg°C • Specific gravity of Crude oil = 0.85 • Ambient temperature = 28°C.
ANS	<u>Before the installation of APH</u> Heat gain by the crude = 500 x 1000 x 0.85 x 0.6 x (360-255) = 26775000 Kcal/hr Heat input to the furnace = 3.4 x1000x 9850 = 33490000 kcal/hr Efficiency of the furnace = 26775000 / 33490000 = 80 % <u>After the installation of APH</u> Heat gain by the crude = 500 x 1000 x 0.85 x 0.6 x (360-255) = 26775000 Kcal/hr Heat gain by Air-preheater = 57 x 1000 x 0.24 x (195-28) = 2284560 Kcal/hr Heat reduction in input to the furnace = Heat gain by Air-preheater New Heat input to the furnace= 33490000 – 2284560 = 31,205,440 Efficiency of furnace after installation of APH = 26775000 / 31,205,440 = 85.8 %
L3	The management of a foundry is considering retrofitting the existing heat treatment furnace with hot face insulation of 75 mm ceramic fibre. (Note: Hot face insulation is known as veneering: ie over the existing refractory lining, ceramic fibre modules are applied to reduce the heat loss during operation and heat storage loss in refractory structure). <u>Furnace Operating data</u>**:** Heat Treatment furnace : (Bogey Type) Batch Operation Furnace Capacity : 5 Ton (per batch) Fuel type : Furnace Oil <u>Surface Area of</u> Side walls : (1.4 x 4.5) x 2 = 12.6 m^2 Back Wall : 0.95 x 1.4 = 1.33 m^2

	Roof : $0.95 \times 4.5 = 4.3\ m^2$ Refractory Type : Fire Bricks Wall Thickness Side walls : 18 inches Arch : 13.5 inches Number of cold starts per month: 5 Nos. Number of batches per month: 15 Nos. Fuel Cost : Rs 48/ kg GCV of furnace oil : 10200 kCal/kg

Heat Storage (kCal /m^2) for batch operation and cold start from walls and roof area are given below.

	For batch operation		Cold Start	
	Existing(with only fire bricks)	75 mm Veneering+ fire bricks	Existing(with only fire bricks)	75 mm Veneering+ fire bricks
Wall	79480	45350	116697	23,964
Roof	74770	31,401	97,236	16,438

For batch operation furnace **is** heated from 300°C to 850°C
For cold start up furnace is heated from ambient 30 °C to 850°C

Calculate the following due to veneering
a) Total heat loss reduction per month from wall and roof during batch operation.
b) Total heat loss reduction per month from wall and roof during cold starts.

Ans

Heat loss calculation for batch operation

Heat reduction from Wall per m^2 = 79480-45350 =34130 Kcal

Heat reduction from total side wall & back wall = 34130 x13.93 =475430.90 Kcal

Heat reduction from roof per m^2 = 74770- 31401 =43369 Kcal

Heat reduction from total roof area = 43369 x 4.3 = 186486.7 Kcal

Total heat reduction per batch from wall& roof = 475430. 90 + 186486.7
= 661917.60

Number of batches per month = 15 Nos

Total heat reduction per month from wall& roof = 661917.6 x15
= **9928764** Kcals/month

Heat loss calculation for Cold Start

Heat reduction from Wall per m^2 = 116697.5- 23,964.50 = 92733 Kcal

	Heat reduction from total side wall & back wall = 92733 x13.93 = 1291770.69 Kcal Heat reduction from roof per m^2 = 97,236 - 16,438.00 = 80798 Kcal Heat reduction from total roof area = 80798 x 4.3 = 347431.4 Kcal Total heat reduction per batch from wall& roof =1291770.69 + 347431.4 =1639202 Number of cold starts per month =5 Nos. Total heat reduction per month from wall& roof = **8196010** Total heat reduction per month from operation and cold start =**1,81,24,774**kCal/month
L-4	a) Find out the efficiency of the furnace oil fired boiler by direct method in a agro product manufacturing plant with the data given below: Type of boiler : Furnace oil fired Quantity of steam (dry) generated : 5 Ton per hour (TPH) Steam pressure / temp : 10 kg/cm^2(g)/ 180 ^oC Quantity of oil consumed : 0.350 TPH Feed water temperature : 75 ^oC GCV of Furnace oil : 10400 kCal/kg Enthalpy of saturated steam at 10 kg/cm^2 : 665 kCal/kg Enthalpy of feed water : 75 kCal/kg b) The above furnace oil fired boiler was converted to coconut shell firing. Determine the boiler efficiency by direct method after conversion. GCV of coconut shell fuel : 4565 kCal/kg Quantity of coconut shell consumed for the same steam demand and pressure. : 850 kg/hr c) The cost of fuel and operating hour of boiler are given below. • Operating hour/ year = 5000 hr • Cost of furnace oil per ton = Rs 40000/ton • Cost of coconut per ton = Rs 5000/ton Find out the annual cost saving due to the fuel substitution fuel in the above boiler?
ANS	**a)Boiler efficiency with furnace oil firing :** Boiler Efficiency (η) = 5000 x (665-75) x 100 / (350 x 10400) Boiler efficiency = 81% (on GCV basis) **b)Boiler efficiency with coconut shell fuel firing** : Boiler Efficiency (η) = 5000 x (665-75) x 100/ (850 x 4565) Boiler efficiency = 76% (on GCV basis) **c) Annual cost saving** Annual furnace oil cost = 5000Hr x 0.35 x Rs 40000

= Rs.7.0 crore

Annual coconut shell Cost = 5000 hrs x 0.85x Rs.5000
= Rs. 2.125 crore

Annual cost saving = 7.0- 2.125= Rs 4.875 Crore

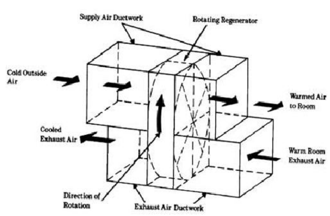
L5

Explain briefly <u>any two</u> of the following

a) Heat Wheel
b) Topping and bottoming cycles for cogeneration with examples
c) Economic thickness of insulation

Ans

a) Heat wheel



Widely used in low to medium temperature waste heat recovery systems.

A disk rotates between two side-by-side ducts: one a cold gas duct, the other a hot gas duct.

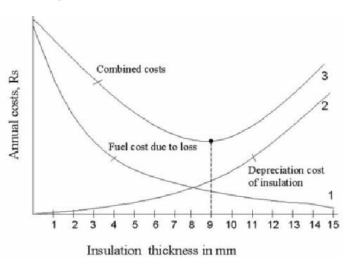
As the disk slowly rotates, sensible heat (moisture that contains latent heat) is transferred to the disk by the hot air and, as the disk rotates, from the disk to the cold air.

b) Topping and bottoming cycles for cogeneration with examples

In a topping cycle, the fuel supplied is used to first produce power and then thermal energy, which is the by-product of the cycle and is used to satisfy process heat or other thermal requirements ex. steam turbine, Diesel engine, Gas turbine etc.

In a bottoming cycle, the primary fuel produces high temperature thermal energy and the heat rejected from the process is used to generate power through a recovery boiler and a turbine generator Power production from waste heat of cement plant, sponge iron plant etc

c) Economic thickness of insulation



As the insulation thickness increases heat loss cost reduces, At the same time insulation cost increases. Hence there is an optimum limit to thickness. The economic thickness of insulation is the thickness at which the combined cost is least.

L6	List five energy conservation measures in ANY TWO of the following: a) Furnaces b) Steam distribution systems c) Boilers
Ans	a) Furnaces 1) Complete combustion with minimum excess air 2) Correct heat distribution 3) Operating at the desired temperature 4) Reducing heat losses from furnace openings 5) Maintaining correct amount of furnace draught 6) Optimum capacity utilization 7) Waste heat recovery from the flue gases 8) Minimum refractory losses 9) Use of Ceramic Coatings b) Steam Distribution systems 1. Monitoring Steam Traps 2. Avoiding Steam Leakages 3. Providing Dry Steam for Process 4. Utilising Steam at the Lowest Acceptable Pressure for the Process 5. Minimising Heat Transfer Barriers 6. Proper Air Venting 7. Condensate Recovery 8. Insulation of Steam Pipelines and Hot Process Equipments 9. Flash Steam Recovery 10. Reducing the Work to be done by Steam c) Boilers 1. Reduce Stack Temperature 2. Feed Water Preheating using Economiser 3. Combustion Air Preheating 4. Ensure complete Combustion 5. Control excess air 6. Radiation and Convection Heat Loss 7. Automatic Blowdown Control 8. Reduction of Boiler Steam Pressure 9. Variable Speed Control for Fans, Blowers and Pumps 10. Ensure boiler Loading for Efficiency 11. Boiler Replacement for efficiency