PAPER-2 COLOR C0DE : GREEN

24^{th} 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 = 50

1. 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

2. 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

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

4. 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

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

6. 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

7. 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

8. 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

9. 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%

10. 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

11. 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

12. 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

13. 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

14. 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

15. 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

16. 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

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

18. 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

19. 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

20. 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

21. 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**

22. 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

23. 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

24. 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

25. 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

26. 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

27. 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

28. 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

29. 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

30. 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

31. 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

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

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

34. 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**

35. 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

36. 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**

37. 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

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

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

40. 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

41. 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

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

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

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

45. 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

46. 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%

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

48. 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

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

50. 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

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

S1 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

S2 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.

S3 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:

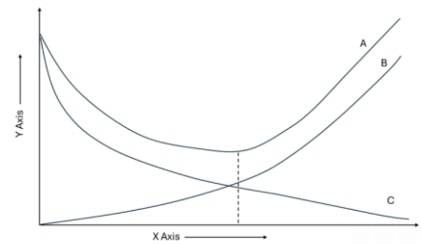
Flash steam available % = S1- S2/(L2)
% of Flash steam recoverable = (188 – 135)/518 = 10.2 %
a) Quantity of flash steam recovered from condensate = 1000 x 0.102 = 102 kg/hr

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

S4	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×4.18kJ/kg°C=10450kJ/hr°C $C_{min}=m_{hot}\times Cp_{,hot}$=3000kg/hr×2.5kJ/kg°C=7500kJ/hr°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×4.18kJ/kg°C×(120−50)°C=2500×4.18×70=731,500kJ/hr $Q_{max}=C_{min}\times(T_{hot,in}-T_{cold,in})$ Q_{max}=7500kJ/hr°C×(200−50)°C=7500×150=1125000 kJ/hr ϵ=731,500 /1125000 = 0.65
S5	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

S6 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

S7 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:

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S8 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:

$$\text{Fuel Consumption} = \frac{3050 \frac{kCal}{kWh} \times 3000\ kW}{9500\ kCal/sm^3}$$

$$= \frac{9150000\ kCal}{9500\ kCal/sm^3}$$

$$= 963.16\ sm^3$$

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

L1	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) = $\pi \times 0.2 \times 150$= 94.23 m^2

Total Heat Loss (Modified):
Total Heat Loss modified=281.25 kCal/hr/$m^2 \times$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
L2	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
L3	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
L4	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
L5	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.

L6

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: $h_1 - h_2$=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=$h_2 - h_f$=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