

**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°C
b) Sugar mill needing thermal energy at 120°C
c) Blast furnace in Steel plant requiring heat at 1200°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
 - b) Sensible
 - c) Specific
 - d) Latent**
11. 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%**
12. The Chemical De-aeration or chemical oxygen scavenging is done by dosing _____ in condensate water.
- a) Phosphate
 - b) Limestone**
 - c) Alum
 - 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 NO_x 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 NO_x 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.
- 8.6 %
 - 8.0 %**
 - 10 %
 - None of the above
46. Heat to Power Ratio is defined as ratio of _____ to _____ required by energy consuming facility.
- thermal energy , electricity**
 - thermal energy , mechanical energy
 - electricity , thermal energy
 - chemical energy , mechanical energy
47. Which of the following characteristics of steam make it popular and useful in industries
- Highest specific heat and latent heat
 - Highest heat transfer coefficient
 - Inert
 - 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 ?
- Log Mean Temperature difference**
 - Long Mean Temperature Difference
 - Log Mean temperature Depth
 - 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:
- bend , vent
 - reducer , drain
 - slope , drain**
 - expander , vent
50. What are the three modes of heat transfer ?
- Radiation, Conduction, Convection**
 - Radiation, Distillation, Convection
 - Radiation, Conduction, Compression
 - Radiation, Condensation ,Compression

Section - II: SHORT DESCRIPTIVE QUESTIONS

Marks: 8 x 5 = 40

S1	<p>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.</p> <p>Solution:</p> $C_{\max} = m_{\text{cold}} \times C_{p,\text{cold}} = 2500 \text{ kg/hr} \times 4.18 \text{ kJ/kg}^\circ\text{C} = 10450 \text{ kJ/hr}^\circ\text{C}$ $C_{\min} = m_{\text{hot}} \times C_{p,\text{hot}} = 3000 \text{ kg/hr} \times 2.5 \text{ kJ/kg}^\circ\text{C} = 7500 \text{ kJ/hr}^\circ\text{C}$ <p>Effectiveness (ϵ) = Maximum possible heat transfer / Actual heat transfer</p> $Q_{\text{actual}} = m_{\text{cold}} \times C_{p,\text{cold}} \times (T_{\text{cold,out}} - T_{\text{cold,in}})$ $Q_{\text{actual}} = 2500 \text{ kg/hr} \times 4.18 \text{ kJ/kg}^\circ\text{C} \times (120 - 50)^\circ\text{C} = 2500 \times 4.18 \times 70 = 731,500 \text{ kJ/hr}$ $Q_{\max} = C_{\min} \times (T_{\text{hot,in}} - T_{\text{cold,in}})$ $Q_{\max} = 7500 \text{ kJ/hr}^\circ\text{C} \times (200 - 50)^\circ\text{C} = 7500 \times 150 = 1125000 \text{ kJ/hr}$ $\epsilon = 731,500 / 1125000 = 0.65$
S2	<p>An oil-fired furnace is operating at 1380 °C with ambient temperature of 30 °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/°C. Calculate the following:</p> <p>a) Efficiency of furnace by direct Method.</p> <p>b) Heat loss in furnace in terms of Fuel loss in lit/hr?</p> <p>Solution:</p> <p>Heat Input = $370 \times 0.93 \times 10000 = 3441000 \text{ kCal/hr}$</p> <p>Heat Output = $mC_p\Delta T$</p> $= 8000 \times 0.13 \times (1380 - 30) = 1404000 \text{ kCal/hr}$ <p>Efficiency = Heat Output / Heat Input</p> $= 1404000 / 3441000 = 40.8\%$ <p>Energy loss from furnace = $3441000 \times (1 - 0.408) \text{ kCal/hr} = 2,037,072 \text{ kCal/hr}$</p> <p>Fuel Loss / hour = $2,037,072 / 10000$</p> $= 203.7 \text{ kg/hr}$ $= 203.7 / 0.93 = 219 \text{ lit/h}$

S3	<p>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.</p> <div data-bbox="636 247 1042 487" data-label="Figure"> </div> <p>Solution:</p> <p>A – Combined Costs B – Depreciation cost of insulation C – Fuel cost due to loss X Axis – Insulation thickness Y axis – Annual cost</p>
S4	<p>How do multiple effect evaporators save energy?</p> <p>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.</p> <p>Solution:</p> <p>Page-247</p>
S5	<p>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.</p> <p>Solution:</p> <p>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:</p> $ \begin{aligned} \text{Fuel Consumption} &= \frac{3050 \frac{\text{kCal}}{\text{kWh}} \times 3000 \text{ kW}}{9500 \text{ kCal/sm}^3} \\ &= \frac{9150000 \text{ kCal}}{9500 \text{ kCal/sm}^3} \\ &= 963.16 \text{ sm}^3 \end{aligned} $

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 $80 \text{ m}^3/\text{min}$ of air at 92°C , which is heated by wood fired thermic fluid heater. The density of air is $1.2 \text{ kg}/\text{m}^3$ and the specific heat of air is $0.24 \text{ kCal}/\text{kg } ^\circ\text{C}$. The inlet air temperature to the drier is 32°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 $2000 \text{ kCal}/\text{kg}$ 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) = $80 \text{ m}^3/\text{min} \times 60 = 4800 \text{ m}^3/\text{hr}$

Air flow rate (mass) = $4800 \times 1.2 = 5760 \text{ kg}/\text{hr}$

Sensible heat of air = $m \times C_p \times T = 5760 \times 0.24 \times (92-32) = 82944 \text{ kcal}/\text{hr}$

Efficiency of wood fired heater = 50%

Wood consumption = $82944 / (2000 \times 0.5) \text{ per hr} = 83 \text{ kg per hr}$

Cost of wood per day = $83 \times \text{Rs } 5 \times 8 \text{ hour} = \text{Rs } 3320 \text{ per day}$

Cost of Auxiliary electricity = $10 \text{ kW} \times 8 \text{ hrs} \times 7 = \text{Rs.}560 \text{ per day}$

Total cost of operation = Rs.3880 per day

Cost of Infra-red heater operation:

Electric heater power consumption= $82944/0.9/860 = 107.2 \text{ kw}$

Electricity consumption per day= $107.2 \text{ kW} \times 8 \text{ hr} = 857.3 \text{ kwh per day}$

	<p>Cost of operation per Day= 857.3 x Rs 7= Rs 6001.00 per day</p> <p>Since the per day expenses are higher in case of electric heater, it is not economical.</p>
S8	<p>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:</p> <p>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 °C Make up water temperature 35 °C</p> <p>Calculate the quantity of flash steam which can be recovered, and the annual fuel oil savings on account of the flas recovery.</p> <p>Solution:</p> <p>Flash steam available % = $S1- S2/(L2)$ % of Flash steam recoverable = $(188 - 135)/518 = 10.2 \%$ a) Quantity of flash steam recovered from condensate = $1000 \times 0.102 = 102 \text{ kg/hr}$</p> <p>Balance Condensate available for recovery after flash steam = $1000 - 102 = 898 \text{ kg/hr}$</p> <p>Heat recovered = Latent Heat of Flash Steam + Sensible Heat of Condensate = $(102 \times 518) + (898 \times (95 - 35)) = 106716 \text{ kCal/hr}$ b) Oil saved = $106716 \times 6000 / (0.80 \times 10200) = 78.5 \text{ tons/yr}$</p>

L1	<p>Briefly explain the following waste heat recovery devices.</p> <ul style="list-style-type: none">• 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
L2	<p>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.</p> <p>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?</p> <p>Solution:</p> <ul style="list-style-type: none">• 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 <p>Calculations:</p> <p>1.Total Heat Content of Superheated Steam (h_{superheat}):</p> <p>H_{superheat} = h + Cp x ΔT = 663kcal/kg+0.45kcal/kg°Cx70°C = 663kcal/kg+31.5kcal/kg = 694.5kcal/kg</p> <p>2.Why Superheated Steam Should Not Be Used for Process Heating:</p> <ul style="list-style-type: none">• 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.

L3	<p>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:</p> <p>Main Steam Parameters: Steam Parameters at Turbine inlet: High-pressure steam at 9 MPa, 400°C and enthalpy of 3118.8 kJ/kg</p> <p>Exhaust Steam Parameters: Exhaust of steam of turbine being sent for process heating has an enthalpy of 2815.8 kJ/kg</p> <p>The return Condensate from the process is saturated liquid at 10 kPa having enthalpy of 191.81 kJ/kg.</p> <p>Calculate the following:</p> <ol style="list-style-type: none"> Energy Utilization Factor , Heat to Power Ratio, <p>Solution:</p> <p>Net enthalpies drop per kg of Steam: Work done by the turbine per kg of steam: $h_1 - h_2 = 3118.8 \text{ kJ/kg} - 2815.8 \text{ kJ/kg} = 303 \text{ kJ/kg}$</p> <p>Total Mass Flow Rate of Steam: To achieve a net power output of 25 MW Turbine input = $25 / (0.98 \times 0.97 \times 0.98) = 26.84 \text{ MW}$ Steam Required = $26.84 \times 1000 \times 860 \times 4.18 / 303 / 1000 = 318.4 \text{ TPH}$</p> <p>Total Thermal Energy Output: Thermal energy output to the process heater (enthalpy difference): $\text{process} = h_2 - h_f = 2815.8 \text{ kJ/kg} - 191.81 \text{ kJ/kg} = 2624 \text{ kJ/kg}$ Total thermal energy output = $318.4 \text{ TPH} \times 1000 \times 2624 \text{ kJ/kg} / 4.18 / 860 / 1000 = 232.4 \text{ MW}$</p> <p>Energy Utilization Factor (EUF): Total fuel energy input = $m_{\text{fuel}} \times \text{GCV} = 80000 \text{ kg/hr} \times 18800 \text{ kJ/kg} / 4.18 / 860 / 1000 = 418 \text{ MW}$ Total useful energy output = $25 \text{ MW} + 232.4 \text{ MW} = 257.4 \text{ MW}$ Energy Utilization Factor = $257 \text{ MW} / 418 \text{ MW} = 61\%$</p> <p>Heat to Power Ratio: $232.4 / 25 = 9.29$</p>
L4	<p>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:</p> <ul style="list-style-type: none"> 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:

$$S=[10+20(T_s-T_a)]\times(T_s-T_a)$$

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

$$S=13.25\times 65=861.25 \text{ kCal/hr/m}^2$$

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:

$$S=[10+20(T_s-T_a)]\times(T_s-T_a)$$

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

$$S=11.25\times 25=281.25 \text{ kCal/hr/m}^2$$

3. Calculate Total Heat Loss

Existing Insulation:

- Length of pipe = 150 m
- Diameter of pipe = 100 mm
- Outer diameter after existing insulation = $0.1 \text{ m} + (0.03\times 2) \text{ m} = 0.16 \text{ m}$

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

Total Heat Loss (Existing):

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

Modified Insulation:

- New thickness of insulation = 50 mm (0.05 m)
- New diameter = $0.1 + (0.05\times 2) = 0.2 \text{ m}$

$$\text{Surface area (Amodified)} = \pi \times 0.2 \times 150 = 94.23 \text{ m}^2$$

Total Heat Loss (Modified):

	<p>Total Heat Loss modified=$281.25 \text{ kCal/hr/m}^2 \times 94.23 \text{ m}^2 = 26502.2 \text{ kCal/hr}$</p> <p>Reduction in Heat Loss: Reduction=Total Heat Loss existing–Total Heat Loss modified= $64938.25 - 26502.2 = 38436 \text{ kCal/hr}$</p> <p>Annual Heat Savings: Annual Heat Savings=$38436 \text{ kCal/hr} \times 6,500 \text{ hr/year} = 24,98,34,325 \text{ kCal/year}$</p> <p>Fuel Savings:</p> <p>Fuel Oil Data:</p> <ul style="list-style-type: none"> • Net Calorific Value (NCV) = $9,500 \text{ kCal/kg}$ • Boiler Efficiency = 82% <p>Convert heat savings to fuel required: Fuel Required=NCV× Efficiency/Annual Heat Savings</p> <p>Substitute the values:</p> <p>Fuel Required=$(249834325/9,500/0.82)/1000$ = 32 tonnes</p> <p>Monetary Savings: Monetary Savings=Fuel Required×Cost per Tonne= $32 \text{ tonnes} \times 50,000 \text{ Rs/tonne} = \text{Rs } 16 \text{ lakhs}$</p> <p>4. Calculate Simple Payback Period</p> <p>Cost of Insulation:</p> <ul style="list-style-type: none"> • Cost = $\text{Rs. } 2000 \times 150 = \text{Rs. } 3,00,000/-$ <p>Simple Payback Period:</p> <p>Payback Period= Cost of Insulation / Monetary Savings = $3,00,000 / 16,00,000 = 0.1875 \text{ Year or } 2.25 \text{ Months}$</p>
L4	<p>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:</p> <ul style="list-style-type: none"> • 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 $\text{Rs. } 50,000$ per tonne. • Net Calorific Value of fuel is $9,500 \text{ kCal/kg}$. • The cost of insulation is $\text{Rs. } 2000/\text{meter}$.

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:

$$S=[10+20(T_s-T_a)]\times(T_s-T_a)$$

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

$$S=13.25\times 65=861.25 \text{ kCal/hr/m}^2$$

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:

$$S=[10+20(T_s-T_a)]\times(T_s-T_a)$$

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

$$S=11.25\times 25=281.25 \text{ kCal/hr/m}^2$$

3. Calculate Total Heat Loss

Existing Insulation:

- Length of pipe = 150 m
- Diameter of pipe = 100 mm
- Outer diameter after existing insulation = $0.1 \text{ m} + (0.03 \times 2) \text{ m} = 0.16 \text{ m}$

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

Total Heat Loss (Existing):

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

Modified Insulation:

- New thickness of insulation = 50 mm (0.05 m)
- New diameter = $0.1 + (0.05 \times 2) = 0.2 \text{ m}$

$$\text{Surface area (A}_{\text{modified}}) = \pi \times 0.2 \times 150 = 94.23 \text{ m}^2$$

Total Heat Loss (Modified):

Total Heat Loss modified = $281.25 \text{ kCal/hr/m}^2 \times 94.23 \text{ m}^2 = 26502.2 \text{ kCal/hr}$

Reduction in Heat Loss:

Reduction = Total Heat Loss existing - Total Heat Loss modified = $64938.25 - 26502.2 = 38436 \text{ kCal/hr}$

Annual Heat Savings:

Annual Heat Savings = $38436 \text{ kCal/hr} \times 6,500 \text{ hr/year} = 24,98,34,325 \text{ kCal/year}$

Fuel Savings:**Fuel Oil Data:**

- Net Calorific Value (NCV) = $9,500 \text{ kCal/kg}$
- Boiler Efficiency = 82%

Convert heat savings to fuel required:

Fuel Required = $\text{NCV} \times \text{Efficiency} / \text{Annual Heat Savings}$

Substitute the values:

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

Monetary Savings:

Monetary Savings = Fuel Required \times Cost per Tonne = $32 \text{ tonnes} \times 50,000 \text{ Rs/tonne} = \text{Rs } 16 \text{ lakhs}$

4. Calculate Simple Payback Period**Cost of Insulation:**

- Cost = $\text{Rs. } 2000 \times 150 = \text{Rs. } 3,00,000/-$

Simple Payback Period:

Payback Period = $16/3$
= 5.33 years

L5

- Explain the significance of bulk density in refractory materials.
- Explain the benefits of using monolithic refractories.
- 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:

- 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.
- 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= $(0.84 \times 32/12) = 2.24$ kg of O₂

Oxygen requirement for Hydrogen= $(0.12 \times 16/2) = 0.96$ 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 = $500 \times 0.95 = 475$ kg per hr

Quantity of Air required with excess air = $475 \times 14 \times 1.2 = 7980$ 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 stoichiometric 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

- | | |
|--|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| | <ol style="list-style-type: none">5. 348 kg6. 400 kg/hr7. 12 kCal/kg8. De-aerator9. Blowdown10. latent heat of vaporization |
|--|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|