

Regn No: _____

Name: _____

(To be written by the candidates)

**7th NATIONAL CERTIFICATION EXAMINATION – Nov. 2008
FOR
ENERGY MANAGERS & ENERGY AUDITORS**

PAPER – 2: Energy Efficiency in Thermal Utilities

Date: 22.11.2008 Timings: 1400-1700 HRS Duration: 3 HRS Max. Marks: 150

Paper 2

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 Black HB Pencil, as per instructions

1	At which of the following pressure, the enthalpy of evaporation of steam will be highest ☒ a) 4 kg/cm ² b) 8 kg/cm ² c) 12 kg/cm ² d) 20 kg/cm ²
2	Ultimate analysis of fuel is determination of percentage of ☒ a) Higher calorific value b) Lower calorific value ☒ c) Carbon, Hydrogen, Nitrogen, Sulphur and Moisture d) Fixed carbon, ash, volatile matter and moisture
3	Which is the best suited pump for pumping furnace oil? a) Vertical turbine pump b) Centrifugal pump c) Diaphragm pump ☒ d) Gear pump
4	Steam generation in a boiler is 26 tonnes in 2 hours. Fuel consumption in the same period is 1 ton per hour. Continuous blow down is 10% of feed water input. The evaporation ratio is a) 11.7 b) 12 ☒ c) 13 d) 26
5	Mineral wool can be applied for temperature range application up to ☒ a) 500 °C b) 750 °C c) 950 °C d) 1200 °C

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Bureau of Energy Efficiency

Paper 2 – Set B Key

Paper 2

6	Typical Capacity of Super Critical thermal power plants is a) 210 MW b) 250 MW c) 500 MW ☒ d) 660 MW
7	The working media in a thermo compressor is a) Compressed Air b) Thermic fluid c) high temperature oil ☒ d) steam
8	The Gross Calorific Value of furnace oil, LSHS and LDO is of the order of a) 10 MJ /kg b) 32 MJ / kg ☒ c) 42MJ /kg d) 36 MJ / kg
9	The large difference between GCV and NCV of gaseous fuels is due to their a) large moisture content b) no moisture content c) low hydrogen content ☒ d) large hydrogen content
10	Fyrite apparatus is used for ☒ a) Analysis of unburnt in flue gas b) Calorific value of fuel c) Volumetric analysis of flue gas d) Measuring smoke density of flue gas
11	Heat loss through openings in furnaces is directly proportional to a) Absolute temperature b) Square of absolute temperature ☒ c) Fourth power of absolute temperature d) None of the above
12	Which of the following industry may not be ideal for adoption of co-generation system ? a) Fertilizer b) Pulp & Paper ☒ c) Foundry d) Textile
13	Which of the following equipment requires electricity for its operation ? a) Thermo compressor ☒ b) Heat pump c) Heat pipe d) Economizer
14	For coal fired system the flame length is dictated by: a) Moisture ☒ b) Volatile matter c) Ash content d) Fixed Carbon
15	Which type of Steam trap operates on the principle of difference in temperature between steam and condensate ? ☒ a) Thermodynamic trap b) Inverted Bucket c) Thermostatic trap d) All the above
16	Flash steam can be recovered from ☒ a) Superheated steam b) High pressure high temperature steam c) High pressure condensate d) Condensate at atmospheric pressure
17	Which type of the following steam trap is used in steam main lines ? a) Float b) Inverted Bucket ☒ c) Thermodynamic d) All the above
18	A power plant which uses first a gas turbine followed by a steam turbine for power generation is called a) Topping cycle ☒ b) Combined cycle c) Brayton cycle d) Bottoming cycle

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19	Which of the following influences energy savings when ceramic coating is applied on furnace hot side ? a) Conductivity ☒ c) Emissivity b) Convective heat transfer coefficient d) Factor for total radiation
20	The Chemical used for dozing boiler drum to reduce dissolved gases is ☒ a) hydrazine b) Chlorine c) Alum d) None of these
21	Among the following which one is the desired pressure for a forging furnace ? a) - 10 mm WC b) - 5 mm WC c) 0 mm WC ☒ d) Positive
22	The total dissolved solids after water treatment through a softener plant : a) Reduces ☒ b) Remains the same c) Increases d) Reduces by 50%
23	Pre-heating of combustion air by 100°C will save about -----% of fuel. a) 0.5 ☒ b) 5 c) 2.5 d) None of the above
24	The insulation thickness for which the total cost is minimum is called a) Minimum insulation thickness ☒ c) Economic thickness b) Cheapest insulation thickness d) None of the above
25	Which of the following does not contribute to efficient use of steam ? ☒ a) Superheated steam for indirect process heating b) Insulation of steam pipe lines c) Reducing the work to be done by steam d) Providing dry steam for process
26	Which of the following releases the maximum energy per kg on complete combustion ? a) Carbon ☒ b) Hydrogen c) Sulphur d) Magnesium
27	The coefficient of thermal expansion of refractory material should be a) Very high b) High c) Medium ☒ d) Low
28	High emissivity coatings are most effective on : a) Outer surface of furnace ☒ b) Inner surface of furnace c) Furnace charge d) None of the above
29	Reduction of specific fuel consumption using ceramic fibre is ideally suited for: a) Tunnel Kiln b) Pusher type reheating furnace c) Glass furnace ☒ d) Heat Treatment furnace
30	Which among the following steam turbines has the highest efficiency ? ☒ a) Condensing turbine b) Back pressure turbine c) Extraction condensing d) Double extraction condensing

Paper 2

31	"Turndown ratio" for burners is the ratio of a) air to fuel b) maximum fuel input to actual fuel input ✓ c) maximum fuel input over minimum fuel input for minimum excess air d) maximum air input over minimum air input
32	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
33	The equipment having the highest efficiency in case of conventional power plant is a) Boiler ✓ b) Electric generator c) Cooling tower d) gas turbine
34	The equipment used to remove dirt from steam lines before steam trap is a) Vent b) Drain ✓ c) Strainer d) By pass line
35	Fluidized bed combustion ----- generation of SO_x and NO_x emissions. a) increases ✓ b) decreases c) has no effect on d) none of the them
36	Removal of dissolved gases from boiler feed water is called a) Degasification ✓ b) Deaeration c) De-oxidation d) None of the above
37	The most common form of refractory material extensively used in the construction of small furnaces is----- a) silica bricks ✓ b) Fire brick c) chrome magnesite d) Calcium silicate blocks
38	FBC boiler has an advantage of: ✓ a) Burning high quality coal b) Burning variety liquid fuels c) Burning wide variety of coal d) None of the above
39	On a stationary grate coal firing system the clinker formation is due to a) More fines in coal b) Undisturbed coal bed c) Low ash fusion temperature ✓ d) All of the above
40	An oil fired boiler is operating at 5% O₂ in the flue gas. The percentage excess air supplied to the boiler is approximately a) 15 % b) 25 % ✓ c) 31 % d) 42 %
41	A rise in the conductivity of boiler feed water indicates ✓ a) Decrease in level of dissolved solids b) Greater purity of feed water c) Increase in level of dissolved solids d) None of the above

Paper 2

42	Which type of steam will be ideal for indirect heat transfer in a heat exchanger? a) Super heated steam ☒ b) Dry saturated steam c) Wet steam d) None of the above
43	Recovery of heat from dryer exhaust air is a typical application of: a) waste heat recovery boiler b) heat pump ☒ c) heat wheels d) economizer
44	Which of the following cogeneration system has maximum heat to power ratio? a) Gas turbine b) Combined cycle ☒ c) Back pressure steam turbine d) Reciprocating engine
45	Heat exchanger will be more efficient if the flow path of hot and cold fluids is in: a) co-current mode ☒ b) counter current mode c) cross current mode d) none of the above
46	Which is the best location for measuring CO ₂ and O ₂ % in flue gases for combustion efficiency a) Bottom of the chimney b) After economizer c) Before economizer ☒ d) Outlet of the boiler
47	If an equipment's steam consumption is 2 T/hr what should be the steam trap capacity? a) 1.5 T/hr b) 2.0 T/hr ☒ c) 3.0 T/hr d) 5.0 T/hr
48	In flue gas, the theoretical CO ₂ is 15.0% and the measured CO ₂ is 12% by volume. The % excess air is: a) 50% b) 150% ☒ c) 25% d) 20%
49	The device used to upgrade a lower pressure steam to a higher pressure steam is called a) Heat pipe b) Heat pump c) Heat wheel ☒ d) Thermo compressor
50	CFBC is a good choice if a) capacity of boiler is medium to large b) sulphur emission and NO _x control is important c) the boiler required to fire low grade fuel or fuel with highly fluctuating fuel quality ☒ d) all of the above

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

Section - II: SHORT DESCRIPTIVE QUESTIONS

Marks: 8 x 5 = 50

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

S-1 What are the advantages & disadvantages of calculating Boiler efficiency by direct method? Calculate the boiler efficiency if the evaporation ratio is 6 for a coal fired boiler? Steam enthalpy – 650 kcal/kg & GCV of coal – 5000 kcal/kg, feed water temperature 40°C

Answer:

- a) Advantages of Direct Method - Simple & Easy to calculate
Disadvantages - It does not indicate which loss is predominant

b) Evaporation Ratio = 6
Boiler Efficiency =
$$\frac{\text{Evap. Ratio} (\text{Steam Enthalpy} - \text{F.Water enthalpy}) \times 100}{\text{GCV of fuel}}$$
$$= 6 ((650 - 40)/(5000)) \times 100$$
$$= 73.2\%$$

S-2 Match the following:

Cogeneration system	Typical range of heat to power ratio
a) Back pressure steam turbine	1) 2.0 – 10.0
b) Extraction-condensing steam turbine	2) 1.3 – 2.0
c) Gas turbine	3) 1.1 – 2.5
d) Combined cycle	4) 1.0 – 1.7
e) Reciprocating engine	5) 4.0-14.3

Answer:

a – 5, b – 1, c – 2, d – 4, e - 3

S-3 In a re-rolling mill furnace the outlet flue gas temperature is 550°C. The industry has installed a recuperator to preheat combustion air upto 300°C and reduces fuel consumption by 15%. List down other three more advantages other than reduction in fuel consumption which would accrue to the industry.

Answer:

- Reduction in scale losses
- Yield Improvement
- Higher throughput from the furnace
- Any other relevant point !!!!

S-4 List five disadvantages if the steam pipe line is not insulated:

Answer:

Heat Loss from bare surfaces
Steam condensation in pipes
Water Hammering
Poor quality of steam to process
Leakage through the flanges and valves due to vibration caused by water hammering effect
Any other relevant point !!!!

S-5 The data of gas turbine of gas based power plant is given below. Calculate the efficiency of gas turbine.

Capacity of gas turbine	= 0.220 GW
Plant operating hours per Annum	= 8000 hrs
Plant load factor	= 90 %
Gas Consumption per Annum	= 526 MMSCM
Calorific value of gas	= 8400 Kcal/SCM

Answer:

Efficiency of Gas Turbine =

= $\frac{\text{Power Generation in KWh} \times 860 \text{ Kcal/KWh} \times 100}{\text{Avg. Gas Consumption/month in SCM} \times \text{NCV in Kcal/SCM}}$

Annual power generation = $0.220 \times 10^6 \times 8000 \times 0.9$
= $1584 \times 10^6 \text{ KWh}$

Efficiency = $\frac{(1584 \times 10^6 \times 860) \times 100}{(526 \times 10^6 \times 8400)} = 30.83\%$

S-6 List three methods by which steam trap performance is assessed

Answer:

- Visual testing
- Sound Testing
- Temperature Testing

S-7 Calculate the savings in heat loss due to reduction in blow down by using auto blow-down controller, from 2.5% to 1% for 10T/hr boiler, which operates 8000 hrs/year. The temperature of boiler blow down water is 180°C, boiler efficiency is 80% and GCV of F.oil is 10,000 kCal/kg. Feed water temp.= 30°C

Answer:

Present blow –down quantity = $10 \times (2.5/100) = 0.25$ Ton/hr

Blow down quantity with controller = $10(1/100) = 0.1$ Ton/hr

Reduction in Blow down = $0.25 - 0.1 = 0.15$ ton/hr

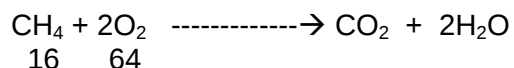
Heat savings = $0.15 \times 1000 \times (180-30) = 22500$ Kcal/hr

Equivalent F.oil savings = $22500/(10000 \times 0.8) = 2.81$ Kg/hr

Annual F.oil Savings = $2.81 \times 8000 = 22500$ kg or 22.5 T/yr

S-8 For combustion of $125 \text{ m}^3/\text{hr}$ Methane gas, estimate quantity of air required with 10% excess air. Density of methane gas is 0.6 kg/m^3

Answer:



For 16 kg of Methane require 64 kg of Oxygen or $(64/0.23)$ 278 kg of air

$125 \text{ m}^3/\text{hr}$ methane = $125 \times 0.6 = 75$ kg of Methane

So, 75 kg of methane require = $(75/16) \times 278 = 1303.125$ kg/hr of Stoichiometric air .

With 10% excess air the Actual air required = $(1+(10/100)) \times 1303.125$
= 1433.43 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

L-1 An oil fired boiler has the following operating parameters

Steam Generation	= 5 T/hr
Steam Pressure	= 8 kg/cm ²
Feed water temperature	= 60 °C
Steam Enthalpy	= 660 kcal/kg
Saturation temperature	= 170 °C
Boiler efficiency	= 80%
GCV of Oil	= 10,000kCal/kg
Steam Quality	= Dry Saturated

- a) Calculate fuel oil consumption per hour
- b) If the dryness fraction becomes 0.7, calculate fuel oil consumption per hour assuming same boiler efficiency

Answer:

a)

$$\text{Boiler efficiency} = Q \times (h_s - h_f) \times 100 / q \times \text{GCV of oil}$$

$$80 = 5000 \times (660 - 60) \times 100 / q \times 10,000$$

$$q = 375 \text{ kg/hr}$$

b)

$$80 = [3500 \times (660 - 60) + 1500 (170 - 60)] \times 100 / q \times 10,000$$

$$q = 283.12 \text{ kg/hr}$$

L-2 Explain the significance of heat to power ratio. Under what circumstances is cogeneration attractive?

Answer:

Heat to power ratio is one of the most technical parameters influencing the selection of the type of cogeneration system. The heat to power ratio of the facility should match with the characteristics of the cogeneration system to be installed. It is defined as the ratio of thermal energy to the electricity required and expressed as kW_{th}/kW_e. The plant may therefore be setup to supply part or all of the site heat and electricity loads or an excess of either may be exported if a suitable customer is available.

Cogeneration is most attractive under following conditions:

- Demand for steam and power is balanced.
- Peaks and troughs in demand can be managed.

The ratio of heat to power required by a site may vary during different times of the day and seasons of the year. Importing power from grid can make up shortfall in electrical output from cogeneration plant and firing standby boilers can satisfy additional heat demand. Many large cogeneration units utilize supplementary firing of exhaust gases in order to modify the heat to power ratio of the system to match site loads.

L-3 An uninsulated 100 mm pipe of 200m length carries steam at 10 kg/cm². The surface temperature measured is 165°C. Find out the annual cost saving achieved by insulating it with 50 mm. insulating material, which will bring the surface temperature down to 60°C. The boiler efficiency is 85%, the fuel oil (with GCV of 10000 Kcal/kg) cost is Rs.20,000 / tonne and ambient air temperature is 30°C and annual operating hour is 8000 hours.

Answer:

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

$$T_s = 165^\circ\text{C}$$

$$T_a = 30^\circ\text{C}$$

$$\text{Existing heat loss (By formulae)} = 2261.25 \text{ kCal/hr.m}^2$$

$$\text{Heat loss in modified system (S2) (By formulae)} = 345 \text{ kCal/hr.m}^2$$

Existing pipe dimension = Ø 100 mm & 200 m length

$$\text{Existing surface area (A1)} = 3.14 \times 0.1 \times 200 = 62.8 \text{ m}^2$$

$$\text{Surface area after insulation} = 3.14 \times 0.2 \times 200 = 125.6 \text{ m}^2$$

$$\text{Total heat loss in existing system} = 62.8 \times 2261.25 = 142006.5 \text{ Kcal/hr.}$$

$$\text{Total heat loss in modified system} = 125.6 \times 345 = 43332 \text{ Kcal/hr}$$

$$\text{Reduction in heat loss} = 142006.5 - 43332 = 98674.5 \text{ Kcal/hr.}$$

$$\text{Total annual heat loss} = 98674.5 \times 8000$$

$$= 7893.96 \times 10^5 \text{ Kcal}$$

$$\text{Calorific value of fuel} = 10000 \text{ Kcal/kg}$$

$$\text{Boiler Efficiency} = 85\%$$

$$\text{Annual fuel oil saving} = 7893.9 \times 10^5 / 1000 \times 0.8$$

$$= 92869 \text{ kg/year}$$

$$\text{Annual cost saving} = 92869 \times 20000 / 1000$$

Annual cost saving = Rs.18,57,380/-

- L-4 (a) Explain the important properties of ceramic fibre.
(b) Name five general requirements of refractory material.

Answer:

- Lower Thermal Conductivity: This allows construction of thinner linings.
- Lower Heat Storage : Less heat absorption due to lower density.
- Good thermal shock resistance: Allows faster heating and cooling.
- Mechanical Resilience: This allows prefabrication.
- Low installation Cost.
- Simple Maintenance.
- Higher Thermal Efficiency: Allows more accurate and uniform temperature.

The general requirements of a refractory material can be summed up as :

- Ability to withstand high temperatures.
- Ability to withstand sudden changes of temperatures.
- Ability to withstand action of molten metal slag, glass, hot gases, etc.
- Ability to withstand load at service conditions.
- Ability to withstand load and abrasive forces.
- Low coefficient of thermal expansion.
- Should be able to conserve heat.
- Should not contaminate the material with which it comes into contact.

L-5 (a) Calculate the blow down rate for a boiler with an evaporation rate of 4 tons/hr, if the maximum permissible TDS in boiler water is 3500 ppm and with 20 % make up water addition. The feed water TDS is around 350 ppm.

(b) Steam at a pressure of 15 kg/cm²g is flashed to a lower pressure of 2 kg/cm²g. If the steam flow rate is 2000 kg/hr. Calculate the % of flash steam and flow rate of flash steam?

Given are the data from steam tables :

Sensible heat of steam at 15 kg/cm ² g	: 200 kCal/kg
Sensible heat of steam at 2 kg/cm ² g	: 120 kCal/kg
Latent heat of steam at 2 kg/cm ² g	: 526 kCal/kg

Answer:

a) Blow down (%) = $\frac{\text{Feed water TDS} \times \% \text{ Makeup}}{\text{Permissible TDS in Boiler}}$

Percentage blow down = $350 \times 20/3500 = 1.99 \%$

If boiler evaporation rate is 4000 kg/hr then required blow down rate is:

= $4000 \times 1.99 / 100 = 79.6 \text{ kg /hr}$

b) The flash steam quantity can be calculated from the following formula:

% Flash steam = $(S1 - S2) / L2$

Where S1 is the sensible heat of high pressure condensate.

S2 is the sensible heat of steam at lower pressure

L2 is the latent heat of flash steam at the lower pressure.

Substituting values = $(200-120)/526 = 80/526 = 15.2\%$

Flow rate of high-pressure steam: 2000 kg/hr.

Flash steam quantity: $2000 \times (15.2/100) = 304 \text{ kg/hr.}$

L-6 List ten energy conservation opportunities available in a boiler system

Answer :

Stack Temperature

Feed water preheating using economizer

Excess air control

Combustion air pre heating

Automatic Blowdown

Reduction of scaling and soot losses

Radiation and convection heat loss

Variable speed control for blowers and pumps

Proper boiler loading

Incomplete combustion and unburnt losses

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