Regn No: _____

Name: _____

(To be written by the candidates)

8th NATIONAL CERTIFICATION EXAMINATION FOR ENERGY AUDITORS – May, 2009

PAPER – 4:	**ENERGY PERFORMANCE ASSESSMENT FOR EQUIPMENT AND UTILITY SYSTEMS**
Date: 24.05.2009	**Timings: 1400-1600 HRS** **Duration: 2 HRS** **Max. Marks: 100**

General instructions:

- *Please check that this question paper contains **6** printed pages*
- *Please check that this question paper contains **16** 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: SHORT DESCRIPTIVE QUESTIONS **Marks: 10 x 1 = 10**

(i) Answer all **Ten** questions
(ii) Each question carries **One** mark
(iii) Answer should not exceed 50 words

S-1 Between a thermal power plant and a cogeneration plant with a back pressure turbine, which will have a higher heat rate?

Ans: A cogeneration plant will have a higher heat rate

S-2 Which loss is considered the most unreliable or complicated to measure in electric motor efficiency testing?

Ans. The stray load loss, because this loss is only estimated and not measured

S-3 How is the Overall Heat transfer Coefficient related to surface area?

Ans Inversely proportional.

S-4 The inclined manometer connected to a pitot tube is sensing which pressure in a gas stream?

Ans: The difference between total and static pressure (also called velocity pressure)

S-5 The more fouling fluid should be on which side of a shell & tube heat exchanger and why?

Ans. Tube side, because it is easier to clean

S-6 For which fuel the sulphur dew point of the flue gases is lower: Furnace oil or Natural gas.

Ans : Natural gas , because the sulphur content is less

S-7 What is the range of conversion efficiency of the gasification process using biomass?

Ans. 60 - 70 %

S-8 Calculate the annual power generated from a 100 kW wind turbine generator with a capacity factor of 20% ?

Ans : 100 x .20 x 8760 = 175200 kWhr

S-9 Define Profitability Index?

Ans. Profitability Index is defined as the Sum of the discounted net savings to the Capital Cost

S-10 In a power plant boiler if there is air ingress in the flue duct, which auxiliary system would be most affected?

Ans: Induced Draft Fan

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

Section - II: Long Questions

Marks: 2 x 5 = 10

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

L-1 The suction head of a pump is 5 m below the pump centerline. The discharge pressure is 4 kg/cm^2. The flow rate of water is 100 m^3 /hr. Find out the pump efficiency if the actual power input at the shaft is 15 kW.

Ans: Discharge Head = 4 kg/cm^2

= 40 metre head.

Suction Head = - 5 metre.

Total Head **= 40 – (-5) = 45 metre**

Hydraulic Power **= (100/3600) x 1000 x 9.81 x 45/1000**
= 12.26 kW

Pump Efficiency **= 100 x 12.26/15 = 81.7 %**

L-2. Calculate the blow down rate for a boiler with an evaporation rate of 3 tons/hr, if the maximum permissible TDS in boiler water is 3000 ppm. The make up water addition rate is 10 % and the feed water TDS is around 250 ppm.

Ans.

Blow down (%) **=** $$\frac{Feed\ water\ TDS\ x\ \%\ Makeup}{Permissible\ TDS\ in\ Boiler - Feed\ water\ TDS}$$

Percentage blow down **=** $$\frac{250\ X\ 10}{3000 - 250} = 0.91\%$$

If boiler evaporation rate is 3000 kg/hr then required blow down rate is:

= $$\frac{3000\ X\ 0.91}{100} = 27.3\ kg/hr$$

OR

Blow down (%) **=Feed water TDS x % Makeup/ Permissible TDS in Boiler**

Percentage blow down **= 250 x 10/ 3000 = 0.83%**

If boiler evaporation rate is 3000 kg/hr then required blow down rate is:

= 3000 x .83/100 = 24.9 kg/hr

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

Section - III: Numerical Questions

Marks: 4 x 20 = 80

(i) Answer all **Four** questions
(ii) Each question carries **Twenty** marks

N-1 Government of India has undertaken various schemes to promote energy efficiency in the country. In the last one year implementation of these schemes have resulted in savings as given below:

S. No.	Name of the scheme	Energy Source	Units	Quantity Saved
1	Energy Efficiency in Buildings	Electricity from grid	Million kWh	62

2	Energy Efficiency in Industries	Electricity from Grid	Million kWh	1216
		Electricity from Captive Diesel Generation	Million kWh	1000
		Fuel Oil	Lakh kilo liter	1.85
		Coal	Lakh tons	3.5
		Natural Gas	Lakh Sm^3	15728
3	Domestic Appliance Labelling Scheme	Electricity from grid	Million kWh	1374
4	Various other schemes as reported by different States exclusive of GOI schemes	Electricity from grid	Million kWh	635
		Thermal Energy Saved	MTOE	80702

Given that:

1 kWhr = 860 kCal
GCV of Coal = 4000 kCal/ kg
GCV of Natural Gas = 8500 k Cal/Sm^3
Assuming GCV of fuel Oil & Diesel = 10000 kCal/kg
Specific gravity of fuel Oil = 0.94, & for diesel 0.85
Assume average Transmission and Distribution Losses in India = 20%
Average Plant Load Factor = 78%
Specific diesel consumption = 3.5 kWh/ltr

Calculate : i) Total Energy Saved in MTOE (metric ton oil equivalent)
ii) Total Generation Capacity Avoided (in MW) in the country because of energy savings due to grid connected power.

Ans: Total Electricity Saved from grid = 62 + 1216 + 1374 + 635 = 3287 million kWh

MTOE due to electrical savings = (3287 x 10^6 x 860) / 10^7
= 282682 MTOE

MTOE due to coal savings= (3.5 x 10^5 x 1000 x 4000) / 10^7

= 140000 MTOE

MTOE due to natural gas savings= (15728 x 10^5 x 8500) / 10^7

= 1336880 MTOE

MTOE due to Fuel oil savings = (1.85 x 10^5 x 0.94 x 1000 x 10000) / 10^7

= 173900 MTOE

MTOE due to captive diesel generation = 1000 x 10^6 x 0.85 x 10000 / 3.5 x 10^7

= 242857 MTOE

Total MTOE = 282682 + 140000 + 1336880 + 173900 + 80702 + 242857 = 2257021 MTOE

ii) Grid Electricity Saved = (62 +1216 + 1374 + 635) million k Wh =

= 3287 x 10^6 kWh

Therefore Avoided Capacity = 3287 x 10^6 /(0.78 x .80 x 365 x 24 x 1000)

= 601.3 MW

N-2 A pharma unit had installed a centralized refrigeration system of 120 TR Capacity several years ago. The refrigeration system operators 24 hours a day, 200 days per annum and the average electricity cost is Rs. 4.5/ kWh. The following are the key operational parameters.

- Compressor operating current and power factor : 153 amps. 0.9 pf
- Condenser pump operating current and power factor: 43 amps, 0.88 pf
- Chiller pump operating current and power factor : 25 amps, 0.9 pf
- CT fan operating current and power factor : 20 amps. 0.65 pf
- ΔT across the chiller (evaporator) : $3.5^{O}C$
- Chilled water flow : 23 Lit / Sec
- Total head developed by chiller pump : 35 mtrs.
- Condenser water flow : 41 Lit / Sec
- Total head developed by condenser pump : 30 mtrs.

PS: *all the motors operate at 415 Volts:*

Calculate:

- The power consumed by the compressor, condenser pump, chiller pump and CT fan.
- TR developed by the system
- Specific power consumption i.e. overall kW/TR and COP and Energy Efficiency ratio (EER)
- Combined efficiency (motor and pump) of condenser and chiller pumps

The unit proposes to replace the existing condenser and chilled water pumps with efficient pumps having a combined efficiency of 65%. Also the unit goes in for condenser cleaning by which the power consumption of compressor has reduced by 10%.

Calculate:

- The envisaged power consumption of the compressor, condenser and chiller pump
- Hourly energy savings (compressor, condenser and chilled water pump)
- Annual energy and equivalent monetary savings (compressor, condenser and chilled water pump)
- Specific power consumption i.e. overall kW/ TR and COP and Energy Efficiency ratio (EER)

<u>Answer</u>

Present Condition:

Compressor Power	**:**	**99 kW**
Condenser Pump Power	**:**	**27.2 kW**
Chiller Pump Power	**:**	**16.2 kW**
CT Fan	**:**	**9.4 kW**
Total Power	**:**	**151.8 kW**
TR Devp	**:**	**(23 * 3600 * 3.5 / 3024) = 95.83**
Sp. Power	**:**	**1.58 kW/ TR**
Compressor kW/TR	**:**	**99/95.83**
	:	**1.03 kW/tR**
COP	**:**	**3.516/kW/TR = 3.41**
EER	**:**	**12/kW/TR**
	:	**11.65**
Condenser pump efficiency	**:**	**44.4%**
Chiller pump efficiency	**:**	**48.8%**

Proposed condition:

Compressor Power	**:**	**89 kW**
Condenser Pump Power	**:**	**18.6 KW**
Chiller Pump Power	**:**	**12.2 kW**
CT Fan	**:**	**9.4 kW**
Total Power	**:**	**129.2 kW**
TR Devp	**:**	**95.83 TR i.e. (23 LPS * 3600 Sec * 3.5 / 3024)**
Sp. Power	**:**	**1.35 kW/ TR**
Compressor kW/TR	**:**	**89/95.83 = 0.93 kW/TR**
COP	**:**	**3.516 / 0.93 = 3.78**
EER	**:**	**12 / 0.93 = 12.90**

	Compressor	**Condenser Pump**	**Chiller Pump**
Hourly energy savings – kWh	**(99-89) = 10**	**(27.2-18.6) = 8.6**	**(16.2–12.2) = 4.0**
Annual energy savings – kWh (4800 hrs)	**48000**	**41280**	**19200**
Annual monetary savings (Rs) @ Rs. 4.5/ kWh	**216000**	**185760**	**86400**

N-3 A fertilizer plant consuming 100TPH of saturated steam at 45 kg/sq.cm pressure has been using Indian coal as fuel to the boiler and is now switching over to Imported coal.

Typical ultimate analysis of the two types of coals:

Parameters	Indian coal %	Imported coal %
Carbon	41.11	58.96
Hydrogen	2.76	4.16
Nitrogen	1.22	1.02
Oxygen	9.89	11.88

Sulphur	0.41	0.56
Moisture	5.98	9.43
Ash	38.63	13.99
GCV (kCal/kg)	4,000	5,900

Determine:

(i) Coal requirement in each case

(ii) Calculate % dry flue gas losses in both cases

Assume: in both cases

Flue gas temperature = 200^{o}C

Ambient temperature = 30^{o}C

Enthalpy of steam = 668 kCal/kg

Feed water temperature = 80^{o}C

Specific heat of flue gases = 0.23

Boiler efficiency with Indian coal = 75%

Boiler efficiency with Imported coal = 82%

Oxygen content in flue gases with Indian coal = 10%

Oxygen content in flue gases with Imported coal = 4%

Answer

Coal requirement

$$\mathbf{Q = \frac{Steam\ (q) \times (hg - hf)}{Efficiency \times GCV}}$$

Indian coal

$$\mathbf{Q = \frac{100{,}000 \times (668 - 80)}{0.75 \times 4000}}$$

19.6 T/hr

Imported coal

$$\mathbf{Q = \frac{100{,}000 \times (668 - 80)}{0.82 \times 5900}}$$

12.1 T/hr

Find theoretical air requirement

Indian coal

$$\mathbf{= \frac{[(11.6 \times C) + \{34.8 \times (H_2 - O2/8)\} + (4.35 \times S)]}{100}}\ \mathbf{kg / kg\ of\ coal}$$

For Indian coal

$$= \frac{[(11.6 \times 41.11) + \{34.8 \times (2.76 - 9.89/8)\} + (4.35 \times 0.41)]}{100} = 5.3 \text{ kg / kg of coal}$$

For Imported Coal

$$= \frac{[(11.6 \times 58.96) + \{34.8 \times (4.16 - 11.88/8)\} + (4.35 \times .56)]}{100} = 7.79 \text{ kg / kg of coal}$$

Excess air percentage in Indian coal = 10 x 100/ 21 - 10 = 90.9%

Excess air percentage in Imported coal = 4 x 100/ 21 – 4 = 23.5%

Actual mass of air (AAS)

Kg/ kg of coal = 5.3 x 1.9 = 10.07 kg (Indian coal)

= 7.79 x 1.235= 9.62 kg (Imported coal)

Heat loss in dry flue gas $= \frac{M \times C_P (T_f - T_a) \times 100}{GCV}$

- **Indian coal** $= \frac{(10.07+1) \times 0.23 \times (200 - 30) \times 100}{4000}$

$= 10.8\%$

- **Imported coal** $= \frac{(9.62+1) \times 0.23 \times (200 - 30) \times 100}{5900}$

$= 7.04\%$

Alternatively:

Indian Coal : Mass of dry flue gas = Mass of (CO_2 + SO_2 + N_2 + O_2) in flue gas + N_2 in air we supply

$$= \frac{0.4111 \times 44}{12} + \frac{0.0041 \times 64}{32} + 0.0122 + \frac{10.07 \times 77}{100} + \{(10.07-5.3) \times 23/100\}$$

= 10.38 kg/kg of fuel.

Imported Coal:

$$= \frac{0.5896 \times 44}{12} + \frac{0.0056 \times 64}{32} + 0.0102 + \frac{9.62 \times 77}{100} + \{(9.62- 7.79) \times 23/100\}$$

= 10.01 kg/kg of fuel.

Heat loss dry flue gas:

Indian Coal: $= \frac{10.38 \times 0.23 \times (200 - 30) \times 100}{4000} = 10.1\%$

Imported Coal: = 10.01 x 0.23 x (200 – 30) x 100 = 6.63%
5900

N-4 The cost and estimated savings data for an energy saving retrofit project is given in table below.

Retrofit cost	Energy & demand savings	Maintenance cost savings
Rs. 1,00,000	6000 kWh/year & Rs.3800/year as demand charges	Annual maintenance cost savings will be Rs. 2000/-.

- The key data is given below:
- Energy savings are based on Rs 3.00/kWh
- No changes in energy rates for 10 years
- The project has a 10 year life period

Calculate NPV for the upgrade option against 12% discount rate.

Ans

Cost of Energy & demand savings per year = 6000 x 3 + 3800 = Rs 21,800

The cash flow detail for ten year duration is given below:

Year	Retrofit cost	Cost of Energy & demand savings	Maintenance cost savings	Cash flow	Discount Factor for 12%	Present Value
0	100000	0	0	-100000	1.000	-100000
1	0	21800	+2000	23800	0.893	21253.4
2	0	21800	+2000	23800	0.797	18968.6
3	0	21800	+2000	23800	0.712	16945.6
4	0	21800	+2000	23800	0.636	15136.8
5	0	21800	+2000	23800	0.567	13494.6
6	0	21800	+2000	23800	0.507	12066.6
7	0	21800	+2000	23800	0.452	10757.6
8	0	21800	+2000	23800	0.404	9615.2
9	0	21800	+2000	23800	0.361	8591.8
10	0	21800	+2000	23800	0.322	7663.6

	Total		**20,000**	**1,38,000**		**34,493.8**

The NPV for the upgrade option against 12% interest rate = Rs 34,494/-

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