NATIONAL CERTIFICATION EXAMINATION 2005
FOR
ENERGY AUDITORS
Question Papers & Model solutions to the Question Papers

PAPER – 4: ENERGY PERFORMANCE ASSESSMENT FOR EQUIPMENT AND UTILITY SYSTEMS

Date: 29.05.2005 Timings: 1400-1600 HRS Duration: 2 HRS Max. Marks: 100

General instructions:

- *Please check that this question paper contains **4** 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** marks

S-1 What have all boiler efficiency testing standards in common?

They do not include blowdown as a loss in the efficiency determination process.

S-2 For which fuel the difference between GCV and LCV will be smaller, Coal or Natural Gas?

Coal

S-3 The overall gas turbine efficiency is defined as η = ?
(Express the equation in units of kW and kWh)

$$\eta = \frac{\text{power output , kW}}{\text{fuel input to gas turbine in kg/h x GCV of fuel in kWh/kg}}$$

In case GCV is expressed in kCal/kg – give ½ mark.

S-4 The more fouling fluid should be on which side of a shell & tube heat exchanger?

Tube side (because it is easier to clean)

S-5 Which loss is considered the most unreliable or complicated to measure in electric motor efficiency testing?

The stray load loss, because this loss is either estimated or not measured, because the method to measure stray load loss is very complicated and rarely used on the shop floor.

S-6 Which pressure is sensed in a gas stream by an inclined manometer connected to a pitot tube?

The difference between total and static pressure also called velocity pressure.

S-7 What would you call, one lumen per square metre?

1 Lux.

S-8 What is the correction factor for actual free air discharge in a compressor capacity test if compressed air temperature is 10^0 C higher than ambient air? (Assume ambient air = 40^0 C)

Factor is (273 + 40) / (273 + 50) = 0.969

S-9 In the performance assessment of a refrigeration system, which performance ratio (energy efficiency) does not follow the trend "a higher ratio means a more efficient refrigeration system"?

The expression "power per ton" (in kW/ton) does not follow the trend. The higher the number the more inefficient the chiller.

S-10 Why does a wind generator produces less power in summer than in winter at the same wind speed?

The wind generator produces less power in summer because the air density in summer is lower due to warmer temperatures. (Or because the air density in winter is higher due to lower temperature)

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

Section - II: LONG DESCRIPTIVE 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 3 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.

Discharge Head	**:**	**3 kg/cm^2 equals 30 metre head.**
Suction Head	**:**	**- 5 metre.**
Total Head	**:**	**30 – (-5) = 35 metre.**
Hydraulic Power	**:**	**(100/3600) x 1000 x 9.81 x 35/1000 = 9.54 kW**

Pump Efficiency : 100 x 9.54/15 = 63.6%

L-2 (i) List any four common losses of boilers and furnaces.

(ii) Which loss is unique to boilers and does not occur in furnaces

(i)
a) radiation losses from the boiler hull
b) dry flue gas losses in the stack gas
c) losses due to moisture in the fuel
d) losses due to Hydrogen in the fuel that forms water by reacting with Oxygen of in the combustion air
e) losses due to incomplete combustion of Carbon to CO
f) losses due to remaining carbon in the residue (ash)
g) losses due to humidity in the air

(ii) Blow down losses occur only in boilers

-------- 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 An energy auditor or energy manager has the task to quickly assess within 20 minutes the technical/ financial performance of a newly installed paddy husk power plant.

The owner of the proposed plant provided the following information.

- Nominal capacity of power plant: 5 MW
- Plant load factor: 0.70
- Analysis of paddy husk, as given below

Fuel property	Weight %
Moisture	10.79
Ash	16.73
Carbon	33.95
Hydrogen	5.01
Nitrogen	1.00
Oxygen	32.52
GCV (kCal/kg)	3,568

What solutions will be provided by the energy auditor to the plant owners on the following.

(i) Tonnes of paddy husk fired per year if the power plant has an efficiency of 25% measured by the direct method.

(ii) The storage area required in square meters to store an inventory of paddy husks 30 cm high for 4 days of operation. Assume paddy husks bulk density of 100 kg/m^3.

(iii) Power plant capital cost is Rs. 20 crore and paddy husks cost as delivered is Rs. 1200/ tonne. Annual repair, maintenance and operation costs are 10% of capital cost. What is the simple pay back period if power is sold at Rs.3/kWh.

(i) Paddy husk energy needed per hour $= \frac{860 \text{ kCal} \times 5000 \times 0.70}{0.25}$

$=12{,}040{,}000$ kCal / hour

Tons of husk per hour $= \frac{12{,}040{,}000}{1000 \times 3568} = 3.3744$ **tons/hour**

Tons per year $3.3744 \times 8760 =$ 29,560 tons/year

(ii) Tons per day: 29,560/365 = 81 tons per day or

$4 \times 81 = 324$ tons for four days, or

$\frac{324 \text{ tons}}{0.1 \text{ ton}/ m^3} = 3240\ m^3 = a^2 \times 0.30$ m

Area = 10,800 m^2 or about one hectare land

(iii) Annual revenue cash flow $5{,}000 \times 8{,}760 \times 0.7 \times 3$ Rs./kWh = 91,980,000

Annual R&M cost, 0.1 x Rs.20 crores = - 20,000,000

Fuel costs 29,560 x 1200 = Rs. - 35,472,000

Annual return = Rs. 36,508,000

Pay back period $= \frac{200{,}000{,}000}{36{,}508{,}000}$ **= 5.478 years**

N-2 A 15 kW rated motor burns out. The financial manager of the firm wants to rewind the motor for Rs.3000 to save money. The Energy Manager wants to buy a new premium motor for Rs.20,000/- after selling motor for Rs. 5,000. He claims that he can save much more money in the next five years than the cost difference of the above two options. Other data is as under:

Operating hours/year	= 8000
Rewound motor efficiency	= 89%
New premium motor efficiency	= 93%
Motor loading	= 75%
Power cost	= Rs.4/kWh

(i) How much money does the energy manager actually save over 5 years and what is the simple pay back period ?

(ii) The financial manager claims the financial risk is still too high because operating hours may go down drastically in the next years. How many operating hours/year are required to recover the cost difference within 5 years.

(i) Electricity cost savings over 5 years:

$$15 \times 0.75 \left(\frac{100}{89} - \frac{100}{93}\right) \times 8{,}000 \times 4 \times 5 = \text{Rs.}86{,}988.$$

$$\text{Pay back period} = \frac{(20{,}000 - 5{,}000)}{(86988/5)}$$

$$= 0.86 \text{ years (or) } 10.3 \text{ months}$$

(ii) $15 \times 0.75 \left(\frac{100}{89} - \frac{100}{93}\right) \times \text{“Hours”} \times 4 \times 5 = \text{Rs.}15{,}000$

“Hours” = 1379 hours per year.

N-3 (i) What is the total weight of flue gas generated when 10 kg of Methane (CH_4) is burned with 10% excess air?

(ii) How much heat will be recovered from the flue gas by providing an additional water heater if the flue gas is cooled from 350^0 C to 210^0 C?

Additional Information:

Atomic weights C=12, H = 1, O = 16;
specific heat of flue gas = 0.24 kcal/kg°C).
Assume combustion air is 77% Nitrogen (N_2) and 23% Oxygen (O_2) by weight.

(a)

$$CH_4 + 2O_2 = 2H_2O + CO_2$$
$$(12+4) + 2(32) = 2(2+16) + (12+32)$$

16 kg of Methane require 64 kg of O_2

10 kg of Methane require $\frac{64}{16}$ = 40 kg of O_2

Therefore, Air (theoretical) required = $\frac{100}{23} \times 40$

= 173.91 kg.

Excess Air @ 10% = 17.39 kg

Therefore, 173.91 + 17.39 + 10 = 201.3 kg of stack gas

Or long calculation

CO_2 produced = $\frac{44}{16}$ x10 = 27.5 kg

H_2O produced = $\frac{36}{16}$ x 10 = 22.5 kg

Nitrogen (in theoretical air) = $\frac{173.91 \times 77}{100}$ = 133.91 kg.

Excess Air = 17.39 kg.

Total Flue Gas = CO_2 + H_2O + N_2 + Excess Air

= 27.5 + 22.5 + 133.91 + 17.39 = 201.30 kg of stack gas

(b) Heat recovered = m cp Δt = 201.30 x 0.24 x (350-210)
= 6763.7 kCal

N-4 A multi-storied shopping mall has installed 5 x 110 TR reciprocating compressors of which four compressors are in use and fully loaded for 16 hours per day. Specific power consumption of reciprocating compressor is 0.8 kW/TR. Due to higher energy cost shopping mall chief engineer has decided to replace reciprocating compressors with screw compressors having specific power consumption on 0.65 kW/Tk. Chief engineer need following input from energy consultant.

(i) Comparison of power and electricity consumption of both reciprocating and screw compressors?

(ii) Annual cost savings (for 350 days operation). Present unit cost is Rs 6.50 per kWh, investment for a 220 TR screw compressor is Rs 30 lakh.

(iii) What should be the size of cooling tower required for proposed screw compressors?

(i) **Operating reciprocating compressors capacity : 440 TR**

(If candidates have used 5 x 110 = 550 TR, then 70% of marks can be given)

Sp. Power consumption of compressor (reciprocating) : 0.8 kW/TR

Power consumption per hour : 0.8 x 440 = 352 kW

Required screw compressor capacity : 440 TR

Sp. Power consumption of compressor (screw) : 0.65 kW/TR

Power consumption per hour : 286 kW

By replacement of reciprocating compressors with screw compressors reduction in power is 66 kW per hour and in consumption 1056 kWh/day.

(ii) **Annual cost savings:**

Reduction in power consumption : 66 kW

Operating hours : 16 per day

Operating days : 350 days per year

Annual energy savings : 66 x 16 x 350

: 3.696 lakh kWh

Annual cost savings : Rs 24.024 lakh (@ Rs 6.50 per kWh)

(iii) Cooling tower capacity:

Operating refrigeration load : 440 TR

Vapour compression type refrigeration systems condenser load (TR) will be around 1.2 time of evaporator load (TR)

Cooling tower capacity : 1.2 x 440 TR

: 528 TR

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