

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
- (iii) Answer should not exceed 50 words

S-1 If the power consumed by a refrigeration compressor is 2 kW per ton of refrigeration, what is the energy efficiency ratio?

$$\text{EER} = \frac{12000 \text{ Btu}}{2000 \text{ W}} = 6$$

S-2 When using a chemical cell oxygen measuring device for stack gas analysis, state the equation to find out the excess air in %?

$$\text{EA} = \frac{\text{O}_2\%}{21 - \text{O}_2 \%} \times 100 \%$$

S-3 Which has more energy content, 1 kg of Hydrogen or 1 kg of gasoline?

1 kg of Hydrogen

S-4 Write the overall heat transfer coefficient U, as a function of sensible heat (q_s) and latent heat (q_L).

$$U = (q_s + q_L) / (A \times \text{LMTD})$$

Paper 4 – Energy Auditor – Set A

- 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 only estimated and not measured, the method to measure is very complicated and rarely used on the shop floor.

- S-6 The inclined manometer connected to a pitot tube is sensing which pressure in a gas stream?

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

- S-7 When using an ultrasonic flow meter for flow measurements in a water pipe which major additional parameter must be guessed or known to calculate the flow in cubic meter per second.

The actual inner diameter to calculate the free cross-sectional area of the pipe.

- S-8 What is the correction factor for actual free air discharge in a compressor capacity test if compressed air discharge temperature is 15° C higher than ambient air? Assume ambient air = 40° C.

Factor is $(273 + 40) / (273 + 55) = 0.954$

- S-9 Which expression to state the energy efficiency of a chiller does not follow the trend “a higher number means a more efficient 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 What have all boiler efficiency testing standards in common?

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

----- 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 (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
 - b) dry flue gas losses
 - c) losses due to moisture in the fuel

- d) losses due to Hydrogen in the fuel that forms water with Oxygen in the combustion air
- e) losses due to partial 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

L-2 The suction head of a pump is 5 m below the pump centerline. The discharge pressure is 3 kg/cm². The flow rate of water is 100 m³ /hr. Find out the pump efficiency if the actual power input at the shaft is 12 kW.

Discharge Head : 3 kg/cm² equals 30 metre head.
Suction Head : - 5 metre.
Total Head : 30 – (-5) = 35 metre.
Hydraulic Power : $(100/3600) \times 1000 \times 9.81 \times 35/1000 = 9.54 \text{ kW}$
Pump Efficiency : $100 \times 9.54/12 = \underline{79.5\%}$

----- 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 You as an energy auditor have the task to quickly assess within 20 minutes the technical/ financial performance of a paddy husk fired power plant to be installed.

The plant owner provided you the following information.

- Nominal capacity : 7 MW
- Assumed plant load factor : 0.75
- Number of hours of operation : 8760/ year
- Analysis of paddy husk

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

Paper 4 – Energy Auditor – Set A

Provide solutions to the following to the plant owner.

- (i) Tonnes of paddy husk to be fired per year if the power plant has an overall efficiency of 25%.
- (ii) The area required in square meters to store an inventory of paddy husk 30 cm high for 4 days of operation. Assume paddy husk bulk density of 100 kg/m³.
- (iii) Power plant capital cost is Rs. 28 crores and rice husk cost as delivered is Rs. 1500/ tonne. Annual repair, maintenance and operation costs are 10% of capital costs. What is the simple pay back period if electricity is sold at Rs.3/kWh.

$$(i) \quad \text{Paddy husk energy needed per hour} = \frac{860 \text{ kCal} \times 7000 \times 0.75}{0.25} = 18,060,000 \text{ kCal / hour}$$

$$\text{Tons of husk per hour} = \frac{18,060,000}{1000 \times 3568} = 5.06 \text{ tons/hour}$$

$$\text{Tons per year } 5.06 \times 8760 = 44,340 \text{ tons/year}$$

$$(ii) \quad \text{Tons per day: } 44,340/365 = 121.48 \text{ tons per day or}$$

$$4 \times 121.48 = 486 \text{ tons for four days, or}$$

$$\frac{486 \text{ tons}}{0.1 \text{ ton/ m}^3} = 4859 \text{ m}^3 = a^2 \times 0.30 \text{ m}$$

$$\text{Area} = 16,197 \text{ m}^2$$

$$(iii) \quad \text{Annual revenue cash flow } 7,000 \times 8,760 \times 0.75 \times 3 \text{ Rs./kWh} = \text{Rs. } 137,970,000$$

$$\text{Annual R\&M cost, } 0.1 \times \text{Rs.28 crores} = \text{Rs. - } 28,000,000$$

$$\text{Fuel costs } 44,340 \times 1500 = \text{Rs. - } 66,510,000$$

$$\text{Annual return} = \text{Rs. } 43,460,000$$

$$\text{Pay back period} = \frac{280,000,000}{43,460,000} = 6.44 \text{ years}$$

N -2 A performance evaluation of a large air fan resulted in the following data.

Pitot tube measurement average velocity pressure	: 75 mm water column
Suction pressure	: - 20 mm water column
Outlet pressure	: 480 mm water column
Area of duct	: 8 square meter
Pitot tube constant	: 0.85
Corrected gas density	: 1.15 kg/ m ³

- (i) Calculate flow in m³/sec.

Paper 4 – Energy Auditor – Set A

- (ii) Calculate the static fan efficiency based on the following 3 phase motor data.

Line current : 100 Amps
 Line voltage : 11,000 volts
 Power factor of electric motor : 0.9
 Efficiency of motor at the operating load is 95%.

$$(i) \quad \text{Flow (v)} = C_p \times A \times \frac{\text{SQRT}(2 \times 9.81 \times \Delta P \times \gamma)}{\gamma}$$

C_p = Pitot tube constant

A = Area of duct

ΔP = Pitot tube measurement average velocity pressure

γ = Corrected gas density

$$\text{Flow (v)} = 0.85 \times 8 \times \frac{\text{SQRT}(2 \times 9.81 \times 75 \times 1.15)}{1.15}$$

$$\text{Flow (v)} = 0.85 \times 8 \times \frac{\text{SQRT}(1692)}{1.15} = 243.2 \text{ m}^3/\text{sec}$$

- (ii) Power input to fan = $1.732 \times V \times I \times \text{Power factor} / 1000$
 = $1.732 \times 11000 \times 100 \times 0.95 / 1000 = 1628.946 \text{ kW}$
 Static fan efficiency = $(243.2 \times 500) / (102 \times 1628.946) = 73.2\%$

- N-3 A multi-storied shopping mall has installed 5 x 110 TR reciprocating compressors of which four compressors are in use and fully loaded for 14 hours per day. The specific power consumption of reciprocating compressor is 0.8 kW/TR. Due to higher energy cost the shopping mall chief engineer has decided to replace reciprocating compressors with screw compressors having specific power consumption of 0.65 kW/TR. The chief engineer needs following input from energy consultant:

- (i) Comparison of power and electricity consumption of both reciprocating and screw compressors?
- (ii) Annual energy bill savings (for 320 days operation). Present unit cost is Rs 6.00 per kWh
- (iii) What should be the size of cooling tower required for proposed screw compressors?

- (i) Operating reciprocating compressors capacity : 440 TR
 Sp. Power consumption of compressor (reciprocating) : 0.8 kW/TR
 Power consumption per hour : $0.8 \times 440 = 352 \text{ kW}$
 Required screw compressor capacity : 440 TR
 Sp. Power consumption of compressor (screw) : 0.65 kW/TR
 Power consumption per hour : $0.65 \times 440 = 286 \text{ kW}$

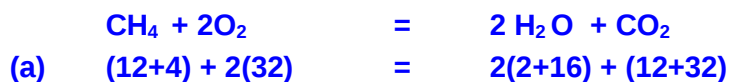
Paper 4 – Energy Auditor – Set A

By replacement of reciprocating compressors with screw compressors reduction in power is 66 kW and in consumption 924 kWh/day.

- (ii) Reduction in power consumption : 66 kW
Operating hours : 14 per day
Operating days : 320 days per year
Annual energy savings : 66 x 14 x 320
: 2.957 lakh kWh
Annual cost savings : Rs 2.957 x 6 = Rs. 17.742 lakh
- (iii) 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
- N-4 (i) What is the total weight of flue gas generated when 20 kg of Methane (CH₄) 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 300⁰ C to 140⁰ 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 (N₂) and 23% Oxygen (O₂) by weight.



16 kg of Methane require 64 kg of O₂

20 kg of Methane require $\frac{64}{16}$ = 80 kg of O₂

Therefore, Air (theoretical) required = $\frac{100}{23} \times 80$
= 347.8 kg

Excess Air @ 10% = 34.78 kg

Therefore, 347.8 + 34.78 + 20 = 402.6 kg of stack gas

Or long calculation

CO₂ produced = $\frac{44}{16} \times 20 = 55$ kg

Paper 4 – Energy Auditor – Set A

$$\text{H}_2\text{O produced} = \frac{36}{16} \times 20 = 45 \text{ kg}$$

$$\text{Nitrogen (in theoretical air)} = \frac{347.8 \times 77}{100} = 267.81 \text{ kg.}$$

Total Flue Gas = $\text{CO}_2 + \text{H}_2\text{O} + \text{N}_2 + \text{Excess Air}$

$$= 55 + 45 + 267.81 + 34.78 = 402.6 \text{ kg of stack gas}$$

$$\begin{aligned} \text{(b) Heat recovered} &= m c_p \Delta t = 402.6 \times 0.24 \times (300 - 140) \\ &= \underline{15,459.8 \text{ kCal}} \end{aligned}$$

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