12^{th} NATIONAL CERTIFICATION EXAMINATION FOR ENERGY AUDITORS – October, 2011

PAPER – 4: Energy Performance Assessment for Equipment and Utility Systems			
Date: 16.10.2011	Timings: 14:00-16:00 HRS	Duration: 2 HRS	Max. Marks: 100

General instructions:

- *Please check that this question paper contains **12** 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: BRIEF QUESTIONS **Marks: 10 x 1 = 10**

(i) Answer all **Ten** questions
(ii) Each question carries **One** mark

S-1	**The loading and unloading of a reciprocating compressor is carried out based on______**
Ans	Pressure (Also full marks may be given If a candidate writes 'Air Demand')
S-2	**In a power plant boiler, if there is air ingress in the flue gas duct, which auxiliary equipment would be most affected?**
Ans	Induced Draft Fan
S-3	**Calculate the boiler efficiency where the Turbine heat rate is 1930 kCal/ kWh and the generating unit heat rate is 2250 kCal/kWh**
Ans	Boiler Efficiency=(Turbine Heat Rate*100)/Unit Heat Rate= 85.7%
S-4	**Between back pressure turbine and condensing turbine which will have more power generation efficiency?**
Ans	Condensing turbine

S-5	**While reducing excess air in a boiler, what two parameters should be closely monitored in the exit flue gases?**
Ans	CO and O_2
S-6	**For the determination of which boiler losses by indirect method, the specific heat of superheated water vapour is used?**
Ans	Loss due to moisture in air, loss due to hydrogen in fuel and loss due to moisture in fuel (Full marks may be given for **any two** right answers)
S-7	**The EER of an air conditioner as indicated in BEE Star labeling scheme is represented in_________**
Ans	Watts/Watts
S-8	**What is the index used to express the harmonics level in an electrical system?**
Ans	Total Harmonic Distortion (THD)
S-9	**Which component of a cooling tower enhances heat transfer by maximizing water and air contact?**
Ans	Fill
S-10	**When you do a walk through energy audit of a cooling tower, which two parameters will you quickly spot check for indication of the cooling tower performance?**
Ans	Cold well temperature and wet bulb temperature (Range and approach may also be considered)

…………. End of Section - I ………….

Section - II: SHORT NUMERICAL QUESTIONS **Marks: 2 x 5 = 10**

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

L-1	**An open cycle gas turbine was running with naphtha as fuel. The following are the data collected during the gas turbine operation:** **Fuel (Naphtha) consumption : 180 kg/hr** **GCV of naphtha fuel : 11500 kCal/kg** **Overall Efficiency of gas turbine which includes air compressor and alternator : 28%** **Cost of naphtha fuel : Rs.40,000/Ton** **Find out the cost of fuel for generating one unit of electricity.**
Ans	Heat input to turbine = 11500 x 180 = 2070000 kCal/hr **1 Mark** Efficiency of gas turbine = 28% Gas turbine output = 2070000 x 0.28/ 860 = 674 kWh **2 Marks** Cost of generating 674 units of electricity = 180 kg x Rs.40 = Rs.7200/hr Cost of One unit of Electricity generation = 7200/674 = Rs.10.7 / kWh **2 Marks**
L-2	**In an air conditioning duct 0.5 m x 0.5 m, the average velocity of air measured by vane anemometer is 28 m/s. The static pressure at suction of the fan is -25 mmWC and at the discharge is 30 mmWC. The three phase induction motor draws 10.8 A at 415 V with a power factor of 0.9. Find out the efficiency of the fan if motor efficiency = 90% (Neglect air density correction).**
Ans	Volume flow rate of the fan, Q = Velocity x Area = 28 x (0.5 x 0.5) = 7 m^3/s **1 Mark** Power input to the fan shaft = Motor input power x motor efficiency = (Sqrt 3 x 0.415 x 10.8 x 0.9) x 0.9 = 6.3 kW **1 Mark** Fan efficiency = $\dfrac{\text{Volume in } m^3 / \text{Sec x total pressure in mmwc}}{102 \text{ x Power input to the shaft in (kW)}}$ **1 Mark for writing the formula** = $\dfrac{7 \times (30-(-25)) \times 100}{102 \times 6.3}$ Fan efficiency = 59.91% **2 Marks**

………… End of Section - II …………

Section - III: LONG NUMERICAL QUESTIONS **Marks: 4 x 20 = 80**

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

N-1	Calculate the efficiency of the Atmospheric Fluidised Bed Combustion Boiler by indirect method using the following data: Analysis of blended coal (% by mass) Carbon : 53.9 % Hydrogen : 3.1 % Nitrogen : 1.1 % Sulphur : 0.3 % Ash : 23.8 % Oxygen : 10.5 % Moisture : 7.3 % GCV : 5060 kCal / kg The boiler operating parameters are given below. Steam pressure : 62.0 kg / cm^{2}g Steam temperature : 470 ^oC Actual air supplied : 8.91 kg/kg of coal Mass of dry flue gas : 9.31 kg/kg of coal Specific heat of flue gas : 0.23 kCal/kg ^oC Flue gas temperature : 160 ^oC CO_2 in flue gas : 14.7 % CO in flue gas : 325 ppm GCV of bottom ash : 800 kCal/kg GCV of fly ash : 452.5 kCal/kg Ratio of bottom ash to fly ash : 10 : 90 Ambient temperature : 32.4 ^oC Loss due to hydrogen in fuel : 3.54 % Loss due to moisture in fuel : 0.93 % Loss due to moisture in air : 0.2 % Surface heat losses : 2 % (as assessed)
Ans	To find all losses 1. % Heat loss in dry flue gas (L1) = L1 $= \frac{m \ x \ C_P \ x \ (T_f - T_a)}{GCV \ of \ fuel} \ x \ 100$ $= \frac{9.31 \ x \ 0.23 \ x \ (160 - 32.4)}{5060} \ x \ 100$

	= 5.40 % **4 Marks** 2. % Heat loss due to partial conversion of C to CO (L2) $= \frac{\%CO \ x \ C \ x \ 5654}{[\%CO + (\%CO_2)a] \ x \ GCV of \ fuel} \ x \ 100$ $= \frac{0.0325 \ x \ 0.539 \ x \ 5654}{[0.0325 + 14.7] \ x \ 5060} \ x \ 100$ =0.13 % **4 Marks** <u>3. % Heat loss due to unburnt in fly ash</u> % Ash in coal = 23.8 Ratio of bottom ash to fly ash = 10:90 GCV of fly ash = 452.5 Kcal/kg Amount of fly ash in 1 kg of coal = 0.9 x 0.238 = 0.2142 kg Heat loss in fly ash = 0.2142 x 452.5= 97 kCal / kg of coal % heat loss in fly ash L3 = 97 x 100 / 5060 = 1.92 % **4 Marks** <u>4. % Heat loss due to unburnt in bottom ash</u> GCV of bottom ash = 800 Kcal/kg Amount of bottom ash in 1 kg of coal = 0.10 x 0.238 = 0.0238 kg Heat loss in bottom ash = 0.0238 x 800 = 19.04 kCal/kg of coal % Heat loss in bottom ash L4 = 19.04 x 100 / 5060 = 0.38 % **4 Marks** 5. Loss due to hydrogen in fuel L5 = 3.54% (given) 6. Loss due to moisture in fuel L6 = 0.93% (given) 7. Loss due to moisture in air L7 = 0.2% (given) 8. Surface heat losses L8 = 2% (given) Boiler efficiency by indirect method = 100 – (L1+ L2+ L3+ L4+ L5+ L6+ L7+ L8) = 100-(5.40 + 0.13+ 1.92+ 0.38+ 3.54+0.93+0.2+2) = 100-14.57 = 85.5 % **4 Marks**
N-2	**a)** For a VFD retrofit in a compressed air system with an initial investment of Rs.2.55 lakhs the annual savings are Rs.58,000/- The NPV of the project over a six year period for 8% discount rate is Rs.13,134. The NPV of the project over a six year period for 10% discount rate is Rs.(-) 2468 Calculate the exact discount rate for NPV to be zero. **b)** A counter current Heat Exchanger with total heat transfer area of 52 m^2 is used to exchange heat between a hot effluent stream of specific heat 0.33 $kCal/kg^oC$ and cooling water stream.

	The monitored parameters are given below: <table><tr><th>Parameters</th><th>Unit</th><th>Inlet</th><th>Outlet</th></tr><tr><td>Hot fluid flow</td><td>kg/hr</td><td>86532</td><td>86532</td></tr><tr><td>Hot fluid temperature</td><td>^oC</td><td>84</td><td>57</td></tr><tr><td>Cold fluid temperature</td><td>^oC</td><td>45</td><td>54</td></tr></table> Assuming LMTD correction factor of 0.91 for plate heat exchanger, calculate i) The corrected LMTD ii) Overall heat transfer coefficient, U (kCal/hr.m^2.^{o}C)
Ans	**a)** The positive and negative NPV's which are closest to zero discount rates are Rs (+)13,134 corresponding to 8% discount rate and Rs (-) 2,468 corresponding to10% discount rate . Hence the exact discount rate = (0.08+(0.1-0.08)*(13134)/(13134-(-2468))*100 = 9.68 % **6 Marks** **b)** i) LMTD, Counter flow = {(84-54) – (57-45)}/ {ln (84-54) / (57-45)} = 19.64 ^{0} C **8 Marks** Correction Factor, F = 0.91 (given) Corrected LMTD = F x LMTD = 0.91 x 19.64 = 17.9 ^{0} C **2 Marks** ii) Overall heat transfer coefficient, U = Q / (A x Corrected LMTD) U = 771000 / (52 x 17.9) = 828 kCal/hr.m^2.^{0}C **4 Marks**
N-3	a) A centrifugal water pump operates at 30 m^3/hr and at 1440 RPM. The pump operating efficiency is 65% and motor efficiency is 89%. The discharge pressure gauge shows 3.4 kg/cm^2. The suction is 3 m below the pump centerline. If the speed of the pump is reduced by 20 %, estimate the following: i) pump flow, ii) pump head and iii) motor power. Assume motor and pump efficiency remains same at the reduced speed. **b)** In a 75 kW four pole induction motor operating at 49.8 Hz and rated for 415 V and 1440 RPM, the actual measured speed is 1470 RPM. Find out the percentage loading of the motor if the voltage applied is 410 V.

Ans	**a)** Flow = 30 m^3/hr Head developed by the pump = 34 – (-3) = 37 m Power drawn by the pump = (30/3600) x 37 x 1000 x 9.81/(1000 x 0.65) = 4.65 kW i) Flow at 80 % speed = 30 / Q2 = 1440/1152 = 24 m3/hr ii) Head at 80% speed = 37 / H2 = $(1440/1152)^2$ = 23.68 m iii) Shaft Power at 80% speed = 4.65/kW2 = $(1440)^3$ / $(1152)^3$ = 2.38 kW Power drawn by motor = 2.38 / 0.89 = 2.67 kW **b)** $\% \text{ Loading} = \dfrac{\text{Slip}}{(Ss - Sr) \times (Vr / V)^2} \times 100\%$ **1 Mark** Synchronous speed = 120 x 49.8 / 4 = 1494 rpm Slip = Synchronous Speed – Measured speed in rpm. = 1494 – 1470 = 24 rpm. **2 Marks** $\% \text{ Loading} = \dfrac{24}{(1494 - 1440) \times (415/410)^2} \times 100\% = 43.37\%$ **2 Marks**
N-4	Answer **ANY ONE OF THE FOLLOWING** among A, B, C and D
A)	A cement kiln exhaust gas has the following composition on dry basis : CO_2 – 24.7%, O_2 – 5.1%, CO - 0.1%, N_2 – 70.1%. The static pressure and temperature measured in the duct are -710 mmWC and 300^0C respectively. The velocity pressure measured with a pitot tube is 20.5 mmWC. The atmospheric pressure at the site is 10350 mmWC. Determine the volumetric flow rate of exhaust gas flowing through a duct of 3200 mm diameter (Pitot tube constant = 0.89)
Ans	Molecular weight exhaust gas (dry basis) M = $\%CO_2 x M_{CO2} + \%O_2 x M_{O2} + \%CO x M_{CO} + \%N_2 \times MN_2$ = {(24.7 x 44) + (5.1 x 32) + (0.1 x 28) + (70.1 x 28)}/100 = 32.16 kg/kg mole **5 Marks** Exhaust Gas density at operating temperature= γ = [PM / RT] = [(10350 – 710) x 32.16) / { 847.84 x (273+300) } = 0.638 kg/m^3 **5 Marks** Duct Area= 3.14 x(3.2/2) ^{2}= 8.05 m^2

	2 Marks Volume flow rate $= A\ Cp\ (2 \times g \times \Delta P / \gamma)^{1/2} = 8.05 \times 0.89\ (2 \times 9.81 \times 20.5/0.638)^{1/2}$ $= 179.89\ m^3/s$ Volume flow rate $= 6\ 47\ 596\ m^3/h$ **8 Marks**
	or
B)	Determine the cooling load of a commercial building for the following given data**:** **Outdoor conditions :** DBT = 35°C, WBT = 25°C, Humidity = 18 g of water / kg of dry air **Desired indoor conditions :** DBT = 25.6°C, RH = 50 %, Humidity = 10 g of water / kg of dry air Total area of wall = 40 m^2, Total area of window = 20 m^2 U – Factor (Wall) = 0.33 W / m^2K U – Factor (Roof) = 0.323 W / m^2K U – factor [fixed windows with aluminium frames and a thermal break] = 3.56 W / m^2K Other data: • 15 m x 25 m roof constructed of 100 mm concrete with 90 mm insulation & steel decking. • CLTD at 17:00 hr : Details : Wall = 12°C; Roof = 44°C; Glass Window = 7°C • SCL at 17 : 00 hr : Details : Glass Window = 605 W/ m^2 • Shading coefficient of Window = 0.74 • Space is occupied from 8:00 to 17:00 hr by 25 people doing moderately active work. • Sensible heat gain / person = 75 W ; Latent heat gain / person = 55 W ; CLF for people = 0.9 • Fluorescent light in space = 21.5 W/m^2 ; CLF for lighting = 0.9 • Ballast factor details = 1.2 for fluorescent lights & 1.0 for incandescent lights • Computers and office equipment in space produces 5.4 W/m^2 of sensible heat • One coffee maker produces 1050 W of sensible heat and 450 W of latent heat. • Air changes / hr of infiltration = 0.3 • Height of building = 3.6 m

Ans	**I External Heat Gain** (i) Conduction heat gain through the wall = U – factor x net area of wall x CLTD = 0.33 x (40-20) x 12] = 79.2 W **2 Marks** (ii) Conduction heat gain through the roof = U – factor x net area of roof x CLTD = 0.323 x (15 x 25) x 44 = 5 329.5 W **2 Marks** (iii) Conduction heat gain through the windows = U – factor x net area of windows x CLTD = (3.56 x 20 x 7) = 498.4 W **2 Marks** (iv) Solar radiation through glass = Surface area x Shading coefficient x SCL = (20 x 0.74 x 605) = 8954 W **2 Marks** **II Internal Heat Gain** (i) Heat gain from people = Sensible heat gain + Latent heat gain Sensible heat gain = (No. of people x Sensible heat gain / person x CLF) = (25 x 75 x 0.9) = 1687.5 W Latent heat gain = No. of people x Latent heat gain / person = (25 x 55) = 1375 W Therefore, Heat gain from people = (1687.5 + 1375) = 3062.5 W (ii) Heat gain from lighting = (Energy input x Ballast factor x CLF) Energy input = (Amount of lighting in space / unit area) x Floor area = 21.5 x (15 x 25) = 8062.5 W Therefore, heat gain from lighting = (8062.5 x 1.2 x 0.9) = 8707.5 W **3 Marks** (iii) Heat generated by equipment : Sensible heat generated by coffee maker = 1050 W Latent heat generated by coffee maker = 450 W Sensible heat gain by computers and office equipment = 5.4 x 375 = 2025 W Therefore, Heat generated by equipment = 3525 W **2 Marks** (iv)Heat gain through air infiltration = (Sensible heat gain + Latent heat gain) Sensible heat gain = (1210 x airflow x ΔT) Airflow =(Volume of space x air change rate) / 3600 = { (15 x 25 x 3.6) x 0.3 } / 3600

	= 0.1125 m^3 / s Therefore, sensible heat gain= 1210 x 0.1125 x (35 – 25.6) =1279.58 W Latent heat gain = 3010 x 0.1125 x (18 – 10) = 2709 W **3 Marks**
	(table below)
	or
C)	(i) If the heat rate of a power plant is 2900 kCal/kWh, what is its efficiency? (ii) What is the condenser vacuum in millibar, if the condenser back pressure is 0.89 kg/cm²? (iii) Explain how Terminal Temperature Difference (TTD) can also be negative (iv) Calculate the % auxiliary power consumption for a Thermal power station if Gross Heat Rate is 3200 kCal/kWh and Net Heat rate is 3500 kCal/kWh.
Ans	(i) The efficiency of a power plant is inverse of heat rate Efficiency = ((1*860)/2900)*100 = 29.7% **5 Marks** (ii) Condenser vaccum, kg/cm² (a) = Atmospheric pressure – Condenser back pressure **5 Marks** Condenser Vacuum = 1 – 0.89 Calculated condenser vacuum = 0.11 kg/cm² (a) = 110 millibar (iii) In some of the cases, because of the de-superheating zone in the feed water heater, the feed water temperature leaving the heater may be higher than the saturation temperature of the condensing zone. Therefore, the heater may have a negative TTD **5 Marks** (iv) Auxiliary Power(%)= (1-(Gross Heat Rate/Net Heat rate))*100 = (1-(3200/3500))*100 = 8.5% **5 Marks**
	or

No	Space Load Components	Sensible Heat Load (W)	Latent Heat Load (W)
1	Conduction through exterior wall	158.4	------
2	Conduction through roof	5 329.5	------
3	Conduction through windows	498.4	------
4	Solar radiation through windows	8954	------
5	Heat gained from people	1 687.5	1 375
6	Heat gained from lighting	8 707.5	------
7	Heat gained from equipment	3 075	450
8	Heat gained by air infiltration	1 279.58	2 709
	Total space cooling load	**29 689.88**	**4 534**

Total Cooling Load = **34,223.88 W**

4 Marks

D)	In an oil fired furnace following are the operating parameters: Capacity of furnace - 10 T/hr Daily production operating at 10 hours a day - 100 T/day Specific fuel consumption - 65 litres /T of finished product Flue gas temperature at the exit of furnace - 600 ^oC Ambient temperature - 30 ^oC G.C.V of oil - 10,000 kCal/kg Theoretical air required for combustion - 14 kg of air/ kg of fuel Specific heat of flue gas - 0.26 kCal/kg^oC Specific heat of air - 0.24 kCal/kg^oC Oxygen in flue gas - 8 % The management is planning to install a recuperator to preheat the combustion air upto 200^oC Yield without the recuperator - 90% Yield after installing the recuperator - 95% Calculate (i) the percentage heat reduction in flue gas after installation of recuperator (ii) the increase in daily production due to yield improvement (iii) specific fuel consumption after installing the heat recovery recuperator (assuming 1 % fuel saving for every 20^oC rise in combustion air temperature)
Ans	**i)** % excess air supplied = 8/ (21-8) = 61.5 % **2 Marks** Actual mass of air supplied = [1 + (EA/100)] x theoretical air = [1 + (61.5/100)] x 14 =22.61 kg of air/kg of fuel **2 Marks** Daily fuel consumption =65 x 100 = 6500 kg/day **<u>(In the question the Sp. Gravity of fuel is not given. If the candidate has calculated as above ie 65 litres full marks may be give.</u>** **<u>If a candidate assumes a sp.gravity and multiplies 65 x assumed sp.gravity again full marks may be given.)</u>** Heat in flue gas = {6500 + (6500 x 22.61)} x 0.26 x (600-30) = 22743513 kCal/day Heat in preheated combustion air = 6500 x 22.61 x 0.24 x (200 - 30) = 5996172 kCal/day Percentage heat reduction in flue gas =(5996172 / 22743513) = 26.4 % **5 Marks**

	(ii) Daily additional production due to yield improvement = 100 x 95/90 = 105.5 Tonnes/day Additional production = 105.5 – 100 = 5.5 T/day **5 Marks** **(iii)** Reduction in fuel consumption = (200 - 30)/20 = 8.5 % Fuel consumption after waste heat recovery = 6500 – (6500 x 0.085) = 5947.5 Specific fuel consumption Daily oil consumption = 5947.5 kg/day Production = 105.5 T/day Specific fuel consumption = 5947.5/ 105.5 = 56.37 kg/tone **6 Marks**

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