Regn No: _________________

Name: ___________________

(To be written by the candidates)

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

PAPER – 3:	**Energy Efficiency in Electrical Utilities**		
Date: 16.10.2011	Timings: 0930-1230 HRS	Duration: 3 HRS	Max. Marks: 150

Section – II: SHORT DESCRIPTIVE QUESTIONS **Marks: 8 x 5 = 40**

(i) Answer all <u>Eight</u> questions
(ii) Each question carries <u>Five</u> marks

S-1	**An energy audit of a fan was carried out. It was observed that the fan was delivering 16,000 Nm^3/hr of air with static pressure rise of 55 mm WC. The power measurement of the 3-phase induction motor coupled with the fan recorded 1.9 kW/ phase on an average. The motor operating efficiency was assessed as 86% from the motor performance curves. What would be the fan static efficiency?.**
Ans	Q = 16,000 Nm^3 / hr.= 4.444 m^3/sec , SP = 55 mmWC, η_{St} = ?, Power input to motor= 1.9x3=5.7 kW Power input to fan shaft=5.7 x0.86=4.902 kW $$\text{Fan static } \eta = \frac{\text{Volume in } m^3/\text{sec} \times \Delta P_{st} \text{ in mmWc}}{102 \times \text{Power input to shaft}}$$ $$= \frac{4.444 \times 55}{102 \times 4.902}$$ = 0.4888 = 48.88%
S-2	**A 15 kW, 3 phase, 415 V induction motor draws 25 A and 12 kW input power at 400 V. Calculate the Apparent and Reactive Power drawn by the motor at the operating load?**
Ans	Apparent power = 1.7321 x 0.400 x 25 = 17.32 Kva Reactive power = squrt (apparent power ^{2}- active power^2) Active power = 12 kW Therefore reactive power = sqrt (300.0 -144) = sqrt (171.2) = 12.48 kVAr
S-3	**List any five energy conservation opportunities in a fan system.**
Ans	Minimizing demands on the fan. 1. Minimising excess air level in combustion systems to reduce FD fan and ID fan load. 2. Minimising air in-leaks in hot flue gas path to reduce ID fan load, especially in case of kilns, boiler plants,

	furnaces, etc. Cold air in-leaks increase ID fan load tremendously, due to density increase of flue gases and in-fact choke up the capacity of fan, resulting as a bottleneck for boiler / furnace itself. 3. In-leaks / out-leaks in air conditioning systems also have a major impact on energy efficiency and fan power consumption and need to be minimized. The findings of performance assessment trials will automatically indicate potential areas for improvement, which could be one or a more of the following: 1. Change of impeller by a high efficiency impeller along with cone. 2. Change of fan assembly as a whole, by a higher efficiency fan 3. Impeller derating (by a smaller dia impeller) 4. Change of metallic / Glass reinforced Plastic (GRP) impeller by the more energy efficient hollow FRP impeller with aerofoil design, in case of axial flow fans, where significant savings have been reported 5. Fan speed reduction by pulley dia modifications for derating 6. Option of two speed motors or variable speed drives for variable duty conditions 7. Option of energy efficient flat belts, or, cogged raw edged V belts, in place of conventional V belt systems, for reducing transmission losses. 8. Adopting inlet guide vanes in place of discharge damper control 9. Minimizing system resistance and pressure drops by improvements in duct system
S-4	**A water pump of a process plant is analysed for efficiency and following data is collected:** **Flow - 50 m^3/hr, Suction head -3 meters, Discharge head - 27 meter, meters, Power drawn by motor – 7.5 kW, Motor efficiency – 92%** **Determine the pump efficiency**

Hydraulic power	Q (m^3/s) x total head (m) x 1000 x 9.81 /1000
	(50/3600) x 24 x 1000 x 9.81/1000
Hydraulic power	3.27 kW
Power input to pump	7.5x 0.92
	6.9 kW
Pump efficiency	3.27/6.9
	47.39%

S-5	**Distinguish between NPSH available and NPSH required in case of a centrifugal pump?**
Ans	NPSH Required (NPSHR): The minimum pressure required at the suction port of the pump to keep **the pump from cavitating.** NPSHA is a function of pumping system and must be calculated, whereas NPSHR is a function of the pump and must be provided by the pump manufacturer. **NPSHA must be greater than NPSHR for the pump system** to operate without cavitating. Put another way, you must have more suction side pressure available than the pump requires.
S-6	**A DG set is operating at 600 kW load with 450^{o}C exhaust gas temperature. The DG set generates 8 kg of exhaust gas/ kWh generated. The specific heat of gas at 450^{o}C is 0.25 kCal/ kg^{O}C. A heat recovery boiler is installed after which the exhaust temperature drops to 230^{O}C. How much steam will be generated at 3 kg/ cm^2 with enthalpy of 650.57 kCal/ kg. Assume boiler feed water temperature as 30^{o}C.**
Ans	= 600 kWh x 8 kg gas generated/ kWh output x 0.25 kCal/ kg ^{o}C x (450^{o}C-230^{o}C) =2,64,000 kCal/hr Steam generation = 2,64,000 kCal/hr / (650.57 – 30) = 425.41 kg/ hr.

S-7	**Briefly explain transformer losses and how the total transformer losses at any load level can be computed.**
Ans	Transformer losses consist of two parts: No-load loss and Load loss 1. No-load loss (also called core loss) is the power consumed to sustain the magnetic field in the transformer's steel core. Core loss occurs whenever the transformer is energized; core loss does not vary with load. Core losses are caused by two factors: hysteresis and eddy current losses. Hysteresis loss is that energy lost by reversing the magnetic field in the core as the magnetizing AC rises and falls and reverses direction. Eddy current loss is a result of induced currents circulating in the core. 2. Load loss (also called copper loss) is associated with full-load current flow in the transformer windings. Copper loss is power lost in the primary and secondary windings of a transformer due to the ohmic resistance of the windings. Copper loss varies with the square of the load current. ($P=I^2R$). For a given transformer, the manufacturer can supply values for no-load loss, $P_{NO\text{-}LOAD}$, and load loss, P_{LOAD}. The total transformer loss, P_{TOTAL}, at any load level can then be calculated from: $P_{TOTAL} = P_{NO\text{-}LOAD} + (\%\ Load/100)^2 \times P_{LOAD}$ Where transformer loading is known, the actual transformers loss at given load can be computed as: $= \text{No load loss} + \left(\frac{\text{kVA Load}}{\text{Rated kVA}}\right)^2 \text{full load loss}$
S-8	**Discuss in brief any three methods by which energy can be saved in a building air conditioning system**
Ans	a) Cold Insulation Insulate all cold lines / vessels using economic insulation thickness to minimize heat gains; and choose appropriate (correct) insulation. b) Building Envelop Optimise air conditioning volumes by measures such as use of false ceiling and segregation of critical areas for air conditioning by air curtains. c) Building Heat Loads Minimisation Minimise the air conditioning loads by measures such as roof cooling, roof painting, efficient lighting, pre-cooling of fresh air by air- to-air heat exchangers, variable volume air system, otpimal thermo-static setting of temperature of air conditioned spaces, sun film applications, etc.

-------- *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	**Write short notes on any three of the following** **(i) Effect of supply voltage on capacitor KVAR rating** **(ii) Pump impeller trimming** **(iii) Affinity laws for centrifugal machines** **(iv) Trigeneration** **(v) Building fenestration**
Ans	i) Ideally capacitor voltage rating is to match the supply voltage. If the supply voltage is lower, the reactive kVAr produced will be the ratio V_1^2/V_2^2 where V_1 is the actual supply voltage, V_2 is the rated voltage. ii) Impeller trimming refers to the process of machining the diameter of an impeller to reduce the energy added to the system fluid. Impeller trimming offers a useful correction to pumps that, through overly conservative design practices or changes in system loads are oversized for their application. The laws with respect to impeller trimming will be **Flow,** $Q \propto D$ **Head,** $H \propto D^2$ **Power,** $P \propto D^3$ iii) The equations relating centrifugal machine performance parameters of flow, head and power absorbed, to speed are known as the *Affinity Laws*: **Flow,** $Q \propto N$ **Head,** $H \propto N^2$ **Power,** $P \propto N^3$ Where, *Q* = Flow rate *H* = Head or resistance *P* = Power absorbed *N* = Rotating speed iv) Trigeneration refers to simultaneous generation of steam (heat), power and refrigeration through integrated systems. For example in a DG set besides power is generated, Steam is produced with waste exhaust gases and Chilled water is generated using jacket cooling water. Three different utilities are created using a single fuel as energy source. v) Fenestration systems include windows, skylights, ventilators, and doors that are more than one-half glazed. All openings (including the frames) in the building envelope that let in light. Total area of the fenestration measured using the rough opening (including glazing, sash and frame). For glass doors where glazed vision area is less than 50% of the door area, the fenestration area is the glazed vision area; otherwise, it is the door area. **r**

L-2	Fill in the blanks for the following 1. The ratio of solar heat gain that passes through fenestration to the total incident solar radiation that falls on the fenestration is called ________ 2. Presenting the load demand of a consumer against time of the day is known as______ curve 3. The vector sum of active power and reactive power is ____. 4. The ratio of isothermal power to actual measured input power of an air compressor is known as------: 5. The type of main input energy used for refrigeration in vapor absorption refrigeration plants is____ 6. One ton of refrigeration is equivalent to ______kW 7. Stray losses in an induction motor generally are proportional to the square of the ________current 8. The capacitor kVAR selected for PF Correction at the induction motor terminals , should not exceed ____ % of the no-load kVAR of the motor. 9. The ratio of luminous flux emitted by a lamp to the power consumed by the lamp is called_________________. 10. In an amorphous core distribution transformer, ______ loss is less than a conventional transformer
Ans	1. Solar Heat Gain Coefficient (SHGC) 2. Load or hourly load 3. Apparent Power 4. Isothermal efficiency 5. Thermal energy (or steam or waste heat or gas or any energy related to thermal energy) 6. 3.51 7. rotor 8. 90 9. Luminous efficacy 10. No load or core
L-3	**A free air delivery test was carried out before conducting a leakage test on a reciprocating air compressor in an engineering industry and following were the observations:** **Receiver capacity : 8.0 m^3** **Initial pressure : 0.1 kg / cm^2g** **Final pressure : 7.0 kg / cm^2g** **Additional hold-up volume : 0.3 m^3** **Atmospheric pressure : 1.026 kg / cm^2 abs.** **Compressor pump-up time : 3.5 minutes** **Further the following observations were made during the conduct of leakage test during the lunch time when no pneumatic equipment/ control valves were in operation:** **a) Compressor on load time is 24 seconds and unloading pressure is 7 kg/cm^2g** **b) Average power drawn by the compressor during loading is 87 kW** **c) Compressor unload time and loading pressure are 79 seconds and 6.6 kg/cm^2 g respectively.** **Find out the following:** **(i) Compressor output in m^3/hr(neglect temperature correction)** **(ii) Specific Power Consumption, kW/ m^3/hr** **(iii) % air leakage in the system** **(iv) leakage quantity in m^3/hr** **(v) power lost due to leakage**

Ans	(i) Compressor output m^3/minute : $\frac{(P_2 - P_1)\times \text{Total Volume}}{\text{Atm. Pressure}\times \text{Pumpup time}}$: $\frac{(7.0-0.1)\times 8.3}{1.026\times 3.5}$ = 15.9482 m^3/minute : 956.89 m^3/hr (ii) output : 956.89 m^3/hr power consumption : 87 kW Specific power consumption : 87/956.89 = 0.0909 kW/m^3/hr (iii) % Leakage in the system Load time (T) : 24 secs. Un load time (t) : 79 secs % leakage in the system : $\frac{T}{(T+t)}$x100 : $\frac{24}{(24+79)}x100$: 23.3% iv) Leakage quantity : 0.233x956.89 :222.955 m^3/hr v) Power lost due to leakage : Leakage quantity x specific power consumption : 222.955 x 0.0909 : 20.27 kW
L-4	**a) In a Thermal Power Station, steam input to a turbine operating on a fully condensing mode is 110 Tonnes/Hr. The heat rejection requirement of the steam turbine condenser is 556 kCals/kg of steam condensed. The cooling water temperatures at the inlet to and outlet from the turbine condenser were measured to be 28°C and 38° C respectively. Find out the circulating cooling water flow.** **b) An energy audit was conducted to find out the ton of refrigeration (TR) of an Air Handling Unit (AHU). The audit observations are as under.**

Parameter	**AHU**
Evaporator area (m^2)	**9.5**
Inlet velocity (m/s)	**1.9**
Inlet air DBT (°C)	**21.5**
RH (%)	**75.0**
Enthalpy (kJ/kg)	**53.0**
Out let air DBT (°C)	**17.4**

	RH (%)	**90.0**
	Enthalpy (kJ/kg)	**46.4**
	Density of air (kg/m^3)	**1.2**

Find out the TR of AHU.

Ans

a)

Heat rejected = Heat pickup by cooling water

Steam flow rate x heat rejection = cooling water flow rate x Cp x ΔT

110 (TPH) x 1000 (kg/T) x 556 = Cooling water flow rate x 1 kCal/kg ^oC x (38-28) ^oC

Cooling water flow rate = 6116 m^3/hr

b)

$$TR = \frac{Q \times \rho \times (h_{in} - h_{out})}{3024}$$

Where, Q is the air flow in m^3/h
ρ is density of air kg/m^3
h_{in} is enthalpy of inlet air kCal/kg
h_{out} is enthalpy of outlet air kCal/kg

Q (m^3/hr) = Area (m^2) X Inlet velocity (m/s) X 3600 (s/hr)
= 9.5 X 1.9 X 3600 = 64980 m^3/hr

ρ = 1.2 kg/m^3

h_{in} = 53.0 kJ/kg = 12.667 kCal/kg
h_{out} = 46.4 kJ/kg = 11.089 kCal/kg

TR = 64980 X 1.2 X (12.667 – 11.089) / 3024 = 40.69 TR

L-5

a) The efficiency at various stages from power plant to end-use is given below.

Efficiency of power generation in the power plant - 30 %
T & D losses - 23 %
Distribution loss of the plant - 6 %.
Equipment end use efficiency - 65 %.

What is the overall cascade system efficiency from generation to end-use?

b) The energy audit observations at a cooling tower (CT) in a process industry are given below:

Cooling Water (CW) Flow : 3000 m3/hr
CW in Temperature: 41deg. C
CW Out Temperature: 33 deg C
Wet Bulb Temperature: 24 deg. C
Find out Range, Approach, Effectiveness and cooling tower capacity in kCal per hour of the CT ?

Ans

a) Overall cascade system efficiency from generation to end-use =
= 0.30X (1- 0.23)X(1- 0.06)X0.65
= 0.1411=14.11%

b) Range = (Inlet -Outlet) Cooling Water Temperature deg. C
Approach = (Outlet Cooling Water - Air Wet Bulb) Temperature deg. C

Range= (41 – 33) = 8 deg. C
Approach = (33 – 24) = 9 deg C

% CT Effectiveness= Range/(Range + approach)X100
% Effectiveness = 100X[Range/(Approach + Range)]
= 8/[8+9]X100 = 47.05 %

Cooling capacity, kCal/hr = heat rejected = CW flow rate in kg per hour X (CW inlet hot water tem. to CT, deg. C- CW outlet cold well temp , deg. C)

Cooling capacity = 3000X1000X (41 - 33) = 24,000,000 kCal per hour = 24 Million kCal per hour

L-6

During energy audit of a process plant, the electricity bills were analysed. The plant has a contract demand of 5000 kVA with the power supply company. The average maximum demand of the plant is 3850 kVA/month at a power factor of 0.95. The maximum demand is billed at the rate of Rs.600/kVA/month. The minimum billable maximum demand is 75 % of the contract demand. An incentive of 0.5 % reduction in energy charges component of electricity bill are provided for every 0.01 increase in power factor over and above 0.95. The average energy charge component of the electricity bill per month for the plant is Rs.18 lakhs.

The plant decides to improve the power factor to unity. Determine the power factor capacitor kVAr required, annual reduction in maximum demand charges and energy charge component. What will be the simple payback period if the cost of power factor capacitors is Rs.1100/kVAr.

Ans

kW drawn	3850 x 0.95 = 3657.5 kW
Kvar required to improve power factor from 0.95 to 1	kW (tan θ_1 – tan θ_2)
	kW (tan ($\cos^{-}\theta_1$) – tan ($\cos^{-}\theta_2$)
	3657.5 (tan ($\cos^{-}0.95$) – tan ($\cos^{-}1$)
	3657.5(0.329 - 0)
	1203 x 1100 kVAr
Cost of capacitors @Rs.1100/kVAr	Rs.13,23,300
Maximum demand at unity power factor	3657.5/1 = 3657.5 kVA
75 % of contract demand	5000x0.75=3750 kVA
Reduction in Demand charges	3850-3750= 100kVa, as the plant has to pay MD charges on minimum billable demand of 3750, and not on the improved MD of 3657.5 kVA in this case
	100kVA/month x 12 months x Rs.600 kVA/ month= Rs.7,20,000
Percentage reduction in energy charge from 0.95 to 1 @ 0.5 % for every 0.01 increase	2.5 %
Monthly energy cost component of the bill	Rs.18,00,000
Reduction in energy cost component	18,00,000 x (2.5/100)
	Rs.45,000/month
Annual reduction	Rs.45,000 x 12
	Rs.5,40,000
Savings in electricity bill	Rs.7,20,000+ 5,40,000= 12,60,000
Investment	Rs.13,23,300
Payback period	13,23,300/12,60,000
	1.05 years or 12.6 months

……. End of Section – III ……….….