16th NATIONAL CERTIFICATION EXAMINATION
FOR
ENERGY MANAGERS & ENERGY AUDITORS – September, 2015

PAPER – 3: Energy Efficiency in Electrical Utilities

Date: 20.09.2015 **Timings: 0930-1230 HRS** **Duration: 3 HRS** **Max. Marks: 150**

General instructions:

- *Please check that this question paper contains **8** printed pages*
- *Please check that this question paper contains **64** 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: OBJECTIVE TYPE **Marks: 50 x 1 = 50**

i) Answer all **50** questions
ii) Each question carries **one** mark
iii) Please hatch the appropriate oval in the OMR answer sheet with Black Pen or HB pencil

1.	Which of the following is not a part of vapour compression refrigeration cycle: a) compressor b) evaporator c) condenser d) <u>absorber</u>
2.	Which of the following can be attributed to commercial loss in electrical distribution system a) lengthy low voltage lines b) low load side power factor <u>c) faulty consumer service meters</u> d) undersize conductors
3.	Which loss in a distribution transformer is dominating; if the transformer is loaded at 68% of its rated capacity a) core loss b) <u>copper loss</u> c) hysteresis loss d) magnetic field loss
4.	When evaporator temperature is reduced a) refrigeration capacity increases b) <u>refrigeration capacity decreases</u> c) specific power consumption remains same d) compressor will stop
5.	What is the function of drift eliminators in cooling towers a) maximize water and air contact b) c<u>apture water droplets escaping with air stream</u> c) enables entry of air to the cooling tower d) eliminates uneven distribution of water into the cooling tower
6.	Trivector meter measures three vectors representing a) active, reactive and maximum demand b) active, power factor and apparent power c) active, harmonics and maximum demand d) <u>active, reactive and apparent power</u>

7.	Time of the Day metering (TOD) is a way to a) reduce the peak demand of the distribution company b) increase the revenue of the distribution company c) increase the peak demand d) increase the maximum demand in a industry
8.	The unit of specific humidity of air is: a) grams moisture/kg of dry air b) moisture percentage in air c) grams moisture/kg of air d) percentage
9.	The purpose of inter-cooling in a multistage compressor is to a) remove the moisture in the air b) reduce the work of compression c) separate moisture and oil vapour d) none of the above
10.	The percentage reduction in distribution loses when tail end power factor raised from 0.85 to 0.95 is a) 10.1% b) 19.9% c)71% d)84%
11.	The nomenclature T2,T5,T8 and T12 for fluorescent lamps are categorized based on a) diameter of the tube b) length of the tube c) both diameter and length of the tube d) power consumption
12.	The inexpensive way to improving energy efficiency of a motor which operates consistently at below 40% of rated capacity is by _____. a) operating in star mode b) replacing with correct sized motor c) operating in delta mode d) none
13.	The indicator of cooling tower performance is best assessed by a) wet bulb temperature b) dry bulb temperature c) range d) approach
14.	The illuminance of a lamp at one meter distance is 10 Lm/m^2. What will be the corresponding value at 0.7 meter distance a)14.28 b) 20.41 c) 10 d) none of these
15.	The fan system resistance is predominately due to a) more bends used in the duct b) more equipments in the system c) volume of air handled d) density of air
16.	The cooling tower size is _____________ with the entering WBT when heat load, range and approach are constant. a) directly proportional b) inversely proportional c) constant d) none of above
17.	The components of two part tariff structure for HT & EHT category consumers are a) one part for capacity(or demand) drawn and second part for actual energy drawn b) one part for actual Power Factor and second part for actual energy drawn c) one part for capacity(or demand) drawn and second part for actual reactive energy drawn d) one part for actual apparent energy drawn and second part for actual reactive energy drawn
18.	The adsorption material used in an adsorption air dryer for compressed air is

	a) calcium chloride b) magnesium chloride c) activated alumina d) potassium chloride
19.	The actual measured load of 1000 k VA transformer is 400 k VA. Find out the total transformer loss corresponding to this load if no load loss is 1500 Watts and full load Copper Loss is 12,000 Watts a) 1920 watts b) 1500 watts c) 3420 watt d) 13500 watts
20.	The percentage imbalance when line-line voltages are 415 V, 418 V and 408 V is a) 1.047% b) 0.32% c) 1.44% d) none of the above
21.	Star – delta starter of an induction motor a) reduces voltage by inserting resistance in rotor circuit b) reduces voltage by inserting resistance in stator circuit c) reduces voltage through a transformer d) reduces the supply voltage due to change in connection configuration
22.	Slip power recovery system is applicable in case of a) squirrel cage induction motor. b) wound rotor motor c) synchronous motor d) DC shunt motor
23.	Rotating magnetic field is produced in a___________ a) single- phase induction motor b) three- phase induction motor c) DC series motor d) all of the above
24.	Power factor is highest in case of a) sodium vapour lamps b) mercury vapour lamps c) fluorescent lamps d) incandescent lamps
25.	Power factor Improvement will result in a) reduction in active power b) reduction in active current c) reduction in reactive power d) all the above
26.	Motor efficiency will be improved by a) reducing the slip b) increasing the slip c) reducing the diameter of the motor d) decreasing the length of the motor
27.	Lower power factor of a DG set demands a) lower excitation currents b) no change in excitation currents c) higher excitation currents c) none of the above
28.	L / G ratio in cooling tower is the ratio of a) length and girth b) length and gradient of temperature c) water mass flow rate and air mass flow rate d) water volume flow rate and air volume flow rate
29.	Installing larger diameter pipe in pumping system results in a) increase in static head b) decrease in static head c) increase in frictional head d) decrease in frictional head
30.	Installation of Variable frequency drives (VFD) allows the motor to be operated with a) constant current b) lower start-up current c) higher voltage d)none of the

	above
31.	In a no load test of a poly-phase induction motor, the measured power by the wattmeter consists of: a) core loss b) copper loss c) core loss, windage & friction loss d) stator copper loss, iron loss, windage & friction loss
32.	In a large compressed air system, about 70% to 80% of moisture in the compressed air is removed at the a) air dryer b) after cooler c) air receiver d) inter cooler
33.	Illuminance of a surface is expressed in a) radians b) lux c) lumens d) LPD
34.	If two identical pumps operate in series, then the combined shutoff head is a) it does not affect head b) more than double c) doubled d) less than
35.	If the speed of a reciprocating pump is reduced by 50 %, the head a) is reduced by 50% b) is reduced by 12.5% c) remains same d) none of the above
36.	If the observed temperature in air receiver is higher than ambient air temperature the correction factor for free air delivery will be: a) less than one b) greater than one c) equal to one d)equal to zero
37.	If the COP of a vapour compression system is 3.5 and the motor draws power of 10.8 kW at 90% motor efficiency, the cooling effect of vapour compression system will be: a) 34 kW b) 37.8 kW c) 0.36 kW d) none of the above
38.	If EER of One Ton Split AC is 3.5, what is its power rating? a) 1.0 k W b) 1.5 kW c) 0.8 kW d) None of the above
39.	Humidification involves a) reducing wet bulb temperature and specific humidity b) reducing dry bulb temperature and specific humidity c) increasing wet bulb temperature and decreasing specific humidity d) reducing dry bulb temperature and increasing specific humidity
40.	Higher COP can be achieved with_____. a) lower evaporator temperature and higher condenser temperature b) higher evaporator temperature and Lower condenser temperature c) higher evaporator temperature and higher condenser temperature d) lower evaporator temperature and Lower condenser temperature
41.	Friction losses in a pumping system is a) inversely proportional to flow b) inversely proportional to cube of flow c) proportional to square of flow d) inversely proportional square of flow
42.	Flow control by damper operation in fan system will

	a) increase energy consumption b) <u>reduce energy consumption</u> c) reduce system resistance d) none of the above
43.	Find the Total Harmonic Distortion (THD) for current for the following current readings. Current at 50 Hz fundamental frequency = 250 A, Third harmonic current = 50 A, fifth harmonic current = 35 A a) 58 % b) 48 % <u>c) 24%</u> d) 34 %
44.	Calculate the density of air at 11400 mmWC absolute pressure and 65^0C. (Molecular weight of air: 28.92 kg/kg mole and Gas constant:847.84 mmWC m^3/kg mole K) a) 1.2 kg/m^3 b) 1.5 kg/m^3 c) <u>1.15 kg/m^3</u> d) none of the above
45.	A spark ignition engine is used for firing which type of fuels: a) high speed diesel b) light diesel oil c) <u>natural gas</u> d) furnace oil
46.	A hotel building has four floors each of 1000 m^2 area. If the interior lighting power allowance for the hotel building is 43000W, the Lighting Power Density (LPD) is: <u>a) 10.75</u> b) 0.09 c) 43 d) data insufficient
47.	A DG set consumes 70 litres per hour of diesel oil. If the specific fuel consumption of this DG set is 0.33 litres/ kWh at that load, then what is the kVA loading of the set at 0.8 PF? a) 212 kVA b) <u>265 kVA</u> c) 170 kVA d) none of the above
48.	A company installed a 130 kVAr, 600 Volt capacitor but the power meter indicates that it is only operating at 119 kVAr. The reason out of the following could be a) operating at low load b) high voltage c) l<u>ow voltage</u> d) low current
49.	A 50 hp motor with a full load efficiency rating of 90 percent was metered and found to be operating at 25 kW. The percent motor load is a) 75% b) 50% <u>c) 60%</u> d) 25%
50.	A 22 kW, 415 kV, 45A, 0.8 PF, 1475 RPM, 4 pole 3 phase induction motor operating at 420 V, 40 A and 0.8 PF. What will be the rated efficiency <u>a) 85.0%</u> b) 94.5% c) 89.9% d) 88.2%

…………. End of Section – I ……………

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	List five energy saving measures for air conditioning system.

	• Insulate all cold lines / vessels using economic insulation thickness to minimize heat gains. • Optimize air conditioning volumes by measures such as use of false ceiling and segregation of critical areas for air conditioning by air curtains. Minimize 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 • Optimal thermo-static setting of temperature of air conditioned spaces • Sun film application Minimize the process heat loads by measures involving TR reduction and refrigeration temperature level reduction • Flow optimization • Heat transfer area increase to accept higher temperature coolant • Avoid wastages by heat gains • Avoid wastages by loss of chilled water • Avoid wastages by ideal flows. • Frequent cleaning and descaling of all heat exchangers At refrigeration and AC plant area • Minimize part load operations by matching loads and plant capacity on line; adopt variable speed drives for varying load. • Ensure regular maintenance of all AC plant components as per manufacturers guide lines. • Ensure adequate quantity of chilled water flows, cooling water flows • Avoid by pass flow by closing valves of ideal equipment • Adopt VAR system where economics permit as non CFC solutions • Make efforts to continuously optimize condenser and evaporator parameters for minimizing specific energy consumption and maximizing capacity ….. (5 marks for relevant points as above)
S-2	The total system resistance of a piping loop is 50 meters and the static head is 15 meters at designed water flow. Calculate the system resistance offered at 75%, 50% and 25% of water flow

	Solution: Total System Resistance of piping loop: 50m Static Head :15 m So, Dynamic Head at designed water flow: 35m ….. (2 mark)

Sl.No.	Flow%	Dynamic Head (m) = 35 x $(\%flow)^2$	Static Head (m)	Total Resistance (m)
1	75.0%	19.68	15	34.68
2	50.0%	8.75	15	23.75
3	25.0%	2.19	15	17.19

…. (3 marks-(each 1 mark))

S-3	In a DG set, the generator is rated at 1000 kVA, 415V, 1390 A, 0.8 PF, 1500 RPM. The full load specific energy consumption of this DG set as measured by the energy auditor is 4.0 kWh per liter of fuel and air drawn by the DG set is 14 kg/kg of fuel. The energy auditor has recommended a waste heat recovery (WHR) system. Also the auditor indicated that the waste heat recovery potential is 2.6×10^5 kCal/hr at the existing engine exhaust gas temperature of 583°C. Estimate the exhaust temperature to chimney after installation of proposed WHR system. The specific gravity of fuel oil is 0.86 and specific heat of flue gas is 0.25 kCal/kg ^{0}C.

Solution:

1	Rated kVA of Diesel Generator (given)	1000	
2	Rated kW @ 0.8 pf	800	0.5 mark
3	Specific fuel consumption (kWh/lts) (given)	4	
4	Specific gravity of fuel oil (given)	0.86	
5	Oil consumption at full load in kg/hr ((2*4)/3)	172	1 mark
6	Air supplied per kg of fuel (kg) (given)	14	
7	Mass of flue gas (14+1)	15	
8	Mass of flue gas kg per hour (7*5)	2580	1 mark
9	Waste heat recovery potential kCal/hr (given)	2,60,000	
10	Delta T across waste heat recovery system (Heat kCal/hr)/(mass of flue gas kg/hr*specific heat, $kcal/kg^0C$) = (260000/2580x0.25)	403	1.5 mark
11	Present Flue gas temp. or temp. before waste heat recovery system (given)	583	
12	Exit flue gas temp. after waste heat recovery system (583 – delta T)	180	1 mark

S-4

The input power to a fan is 30kW for a 2500 Nm^3/hr fluid flow. The fan pulley diameter is 300mm. If the flow to be reduced by 15% by changing the fan pulley, what should be the diameter of fan pulley and power input to fan.

Solution

1	Input power to fan kW	30	
2	Fluid flow Nm^3/hr	2500	
3	Diameter of Fan pulley (mm)	300	
4	Governing Equation is $N_1D_1=N_2D_2$	Eqn-1	1 mark
5	$N_2 = 0.85N_1$	given	
6	From Eqn-1 $D_2=(D_1)*(N_1/N_2)$; $= (300)*(N_1/0.85N_1)$	352mm	2 marks
7	$(KW_1/KW_2) = (N_1^3/N_2^3)$; Hence, $KW_2=(N_2/N_1)^3*(KW_1)$ $=(0.85 N_1/N_1)^3*(30)$	18.42KW	2 marks
So Power requirement for fan will be 18.4 kW.			
Fan pulley to be changed to 352 mm diameter.			

S-5

Define Lux and Luminous efficacy

	Ans Lux (lx) is the illuminance produced by a luminous flux of one lumen, uniformly distributed over a surface area of one square meter. It is also defined as the International System unit of illumination, equal to one lumen per square meter. ….. (2.5 marks) Luminous efficacy is defined as the ratio of luminous flux emitted by a lamp to the power consumed by the lamp. Efficacy is energy efficiency of conversion from electricity to light form. ….. (2.5 marks)
S-6	During an energy audit of a power plant cooling tower, the following observations were made. • Power plant generation = 785 MW • Circulation rate =107000 m^3 /hr • Cooling tower range = 10.5^{o}C • Power plant design COC value = 3.8^{0}C As an auditor find out a) The total water consumption per hour, b) Specific water consumption in m^3/MW generation. The plant is pursuing an up-gradation treatment plan to increase COC to 7.0. c) What would be the potential water savings in m^3/hr and m^3/MW generation?
	Ans

S.No.	Item Ref.	Calculation		value	units	
1	Evaporation loss	0.00085*Circulation rate in m^3/hr * (CT range in deg C)*1.8	0.00085 * 107000 * (10.5)*1.8	1719	m^3/hr	0.5 mark
2	Blow-down loss	Evaporation loss/(COC-1)	1719/ (3.8-1)	614	m^3/hr	0.5 mark
3	Total as run hourly consumption	S.No 1 + S.No 2	(1719+614)	2333	m^3/hr	0.5 mark
4	Specific water consumption	S.No. 3/785	(2333/785)	2.97	m^3/MW	0.5 mark
5	Blow down at improved COC of 7.0	Evaporation loss/(COC-1)	1719/(7-1)	286.5	m^3/hr	0.5 mark
6	Total water consumption at improved COC	S.No 1 + S.No 5	(1719+286.5)	2005.5	m^3/hr	0.5 mark
7	Specific water consumption at	S.No 6/785	(2005.5/785)	2.56	m^3/MW	0.5 mark

	improved COC					
8	Total water saving per hour	S.No 3 - S.No 6	(2333-2005.5)	327.5	m^3/hr	0.5 mark
9	Water saving/MW generation	S.No 8/785	(327.5/785)	0.417	m^3/MW	1 mark

S-7 Explain with equation for COP_{Carnot} that:

(a) higher COP_{Carnot} is achieved with higher evaporator temperature and lower condenser temperature.
(b) COP_{Carnot} does not take into account the type of compressor
(c) How is the COP normally used in the industry given?

Ans:

a) The theoretical Coefficient of Performance (Carnot), COP_{Carnot} - a standard measure of refrigeration efficiency of an ideal refrigeration system- depends on two key system temperatures, namely, evaporator temperature Te and condenser temperature Tc with

COP being given as: $COP_{Carnot} = Te / (Tc - Te)$.

….. (2 marks)

b) This expression also indicates that higher COP_{Carnot} is achieved with higher evaporator temperature and lower condenser temperature. But COP_{Carnot} is only a ratio of temperatures, and hence does not take into account the type of compressor.

….. (2 marks)

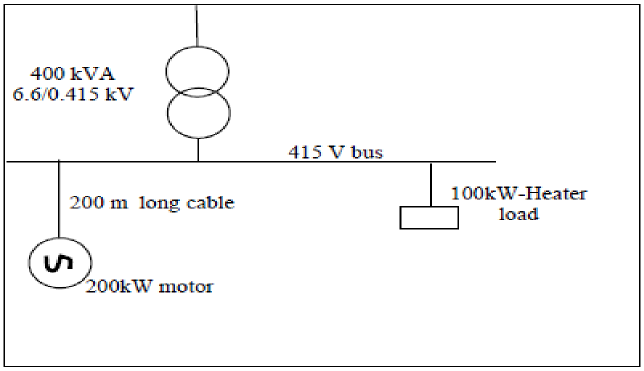
c) Hence the COP normally used in the industry is given by

COP = [Cooling effect (kW)/Power input to compressor (kW)]

where the cooling effect is the difference in enthalpy across the evaporator and expressed as kW

….(1 mark)

S-8 The following single line diagram depicts the location of a 100 kW heater load and a 200 kW motor (which is 200 metres away from the 415V, LT bus). The main incoming line power factor of the system is 0.85 lag. Calculate the rating of capacitors to improve PF of main incoming line to 0.9 lag.



Ans:

Total Inductive load requiring PF compensation = 200kW (since the other 100 kW is a resistive load)

….. (1 mark)

Operating PF cos ø1= 0.85 lag.

Desired PF cos ø2= 0.90 lag

kVAr required = $kW((\tan(\cos^{-1}ø_1)-\tan(\cos^{-1}ø_2))$

….. (1 mark)

$= 200(\tan(\cos^{-1}0.85)-\tan(\cos^{-1}0.90))$

= 200(tan(31.78)-tan(25.84))

= 200(0.619-0.484)

= 200(0.135)

= 27 kVAr

….(3 marks)

……………… 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 Compare the performance of centrifugal chiller with vapour absorption chiller using the data given below:

Sl. No.	Parameter	Centrifugal Chiller	VAM
1	Chilled water flow (m^3/h)	192	183
2	Condenser water flow (m^3/h)	245	360
3	Chiller inlet water temperature (^0C)	13	14.5
4	Condenser water inlet temperature (^0C)	28	32
5	Chiller outlet water temperature (^0C)	7.8	9.2
6	Condenser water outlet temperature (^0C)	36.2	40.7
7	Chilled water pump consumption (kW)	32	31
8	Condenser water pump consumption (kW)	38	52
9	Cooling tower fan consumption (kW)	9	22

If the compressor of centrifugal chiller consumes 205 kW, the steam consumption for VAM is 1620 kg/Hr. Calculate the following:

i) Refrigeration load delivered (TR) for both systems?
ii) Condenser Heat load (TR) for both systems?
iii) Compare auxiliary power consumption for both systems, give reason?
iv) If electricity cost is Rs.4.0/kWh and steam cost is Rs.0.45/kg compare the operating cost for both systems.

Solution:

a) Compression Chiller vs. VAM

Sl. No.	Parameter	Centrifugal Chiller	VAM	
1	Refrigeration load delivered (TR) = Mass of Chilled water flow x Specific heat x Delta T of Chilled water = Sl. No.1 m^3/hr * 1000kg/m^3 *1 kcal/kg ^0C * (Sl. No. 3. – Sl. No. 5) / 3024	330.16	320.73	2 marks
2	Condenser heat load delivered (TR) = Mass of condenser water flow x Specific heat * Delta T of condenser water = Sl. No.2 m^3/hr * 1000kg/m^3 *1 kcal/kg ^0C * (Sl. No. 6 – Sl. No. 4) / 3024	664.35	1035.71	2 marks
3	Auxiliary Power Consumption (kW) = (Sl. No. 7 + Sl. No. 8 + Sl. No. 9)	79	105	

	The auxiliary power consumption in case of VAM system is higher because heat rejection in VAM condenser is comparatively higher than centrifugal chiller with approximate similar cooling load.			2 marks
4	Total Energy Consumption:	284 kW (Auxiliary Power of 79kW and Chiller consumption of 205 kW)	Auxiliary Power of 105 kW and Steam consumption of 1620 kg/hr	2 marks
5	Operating Energy Cost per Hour of Operation	Rs. 1136/- (284 * 4 = Rs. 1136/-)	Rs 1149/- (105 * 4 = Rs. 420/- plus 1620 * 0.45 = Rs. 729/-)	2 marks

L-2

a) Calculate the ventilation rate for an engine room of 20m length, 10.5m width and 15m height; if the recommended Air Changes per Hour (ACH) is 20.

b) Air at 25,200 m^3/hr and at 1.2 kg/m^3 density is flowing into an air handling unit of an inspection room. The enthalpy difference between the inlet and outlet air is 2.38 kcal/kg. If the motor draws 22 kW with an efficiency of 90%, find out the kW/TR of the refrigeration system. (1 cal = 4.183)

Solution:

a) Ventilation Rate:

Room Length (m)	20
Room Height (m)	15
Room Width (m)	10.5
Air Changes per Hr (ACH)	20
Ventilation rate (m^3/Hr) = Length (m) * Height (m) * Width (m) * ACH	63000

….. (5 marks)

b)

Refrigeration tonnes = $Q \times \rho \times (h_2-h_1)$
= 25200 x 1.2 x (2.38) kcal/kg
= 71,971 kcal/hr

…..(2 marks)

TR = 71,971 /3024
= 23.8 TR

	…..(1 mark) Power input to the compressor 22 x 0.9= 19.8 kW …..(1 mark) kW/TR 19.8/23.8 = 0.83 …..(1 mark)
L-3	In a diary plant 3 numbers of cooling water pumps, identical in characteristics are installed in parallel to supply cooling. During normal operation two of the pumps are operational while one pump is on standby. All pump combinations develop a discharge pressure of 3.4 kg/cm^2 (a). The installed water flow meter at the common header during an energy audit reads the following: Operating Pump No. — Flow Rate (m^3/hr) Pump No 1 & 2 — 545 Pump No 2 & 3 — 535 Pump No 3 & 1 — 550 The power drawn by motors of cooling water pump 1, 2 & 3 are 33 kW, 31.5 kW & 32.5 kW respectively. While the operating motor efficiency for pump no. 1 & 2 is 92% the motor efficiency for pump no. 3 is 91.5%. If the water level in suction of all pumps is 3 meter below pump central line. Calculate the following: i) Individual pump efficiencies ii) Specific energy consumption (kWh/m^3) iii) Which is the best operating pump combination
	Solution: Let flow of pump 1,2 & 3 be X, Y and Z respectively. From given: X + Y = 545 ---------(1) Y + Z = 535 ---------(2) X + Z = 550 ---------(3) Subtracting eqn (2) from eqn (1): X – Z = 10 --------(4) Adding eqn (3) and eqn (4): 2X = 560 X= 280 Putting X value in eqn (1) and (2): Y = 265 and Z = 270 Therefore, individual pump flow rates are: 280 m^3/hr, 265 m^3/hr and 270 m^3/hr

respectively.

…. (3 marks)

Pump Ref:	1	2	3	
A) Flow Rate (M^3/hr) *(calculated)*	280	265	270	
B) Discharge Head (m) =3.4 kg/cm^2 (a) = 2.4 kg/cm^2 (g) =24 m *(given)*	24	24	24	
C) Suction Head (m) (g) *(given)*	-3	-3	-3	
D) Total Head (Discharge Head - Suction Head)* *(B-C)*	27	27	27	1 mark
E) Liquid kW [flow (m^3/s)*total head (m)*density (1000 kg./m^3) * 9.81 (m/s^2)/1000]	20.60	20.22	19.87	2 marks
F) Power Drawn by motor kW *(given)*	33	31.5	32.5	
G) Motor eff. % *(given)*	92.0%	92.0%	91.5%	
H) Pump input power kW (FxG)	30.36	28.98	29.74	1 mark
I) Pump eff. % (E/H)	67.9%	69.8%	66.8%	1 mark
J) Specific Energy Consumption (kWh/M^3) (F/A)	0.118	0.119	0.120	1 mark

Pump No. 1 & 2 are the best performing operating combination. …… (1 mark)

Note:
*The total head has been calculated subtracting Discharge Gauge pressure from suction gauge pressure. The candidates can also calculate total head as difference of absolute pressures as follows:

Discharge Head= 3.4 kg/cm^2 (a)
Suction Head = 1- 0.3 kg/cm^2 = 0.7 kg/cm^2
Total Head Developed = 3.4 – 0.7 = 2.7 kg/cm^2 = 27 m

L-4

a) In a chemical industry, cooling water of 9000 m^3/hr and 6000 m^3/hr from two independent heat exchangers with temperature of 41^{0}C and 52^{0}C respectively are fed to one cooling tower after proper mixing at top basin. If measured heat rejection by the cooling tower is 45,000TR, calculate effectiveness and evaporation loss of the cooling tower at 31^{0}C WBT.

b) 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 -20 mmWC and at the discharge is 30 mmWC. A three phase induction motor draws 10.8 A at 415 V with a power factor of 0.9. Find out efficiency of the fan if motor efficiency = 88% (neglect density correction)

	Solution:

a)

Sl. No.	Particulars	Stream 1	Stream 2	
1	Flow Rate (m^3/hr) (given)	9000	6000	
2	Temp. ^{0}C (given)	41	52	
3	Mix. Flow Rate (m^3/Hr) (Sl.1 +2)	15000		
4	Mix. Hot Water Temp. ^{0}C [(Flow1 * Temp. 1) + (Flow 2 *Temp. 2)]/ (Flow1 + Flow 2)	45.4		1 mark
5	Heat Rejection (TR) (given)	45000		
6	Range of Cooling Tower ^{0}C: (Heat Rejection TR * 3024) / (Flow M^3/hr * 1000)	9.072		1 mark
7	WBT ^{0}C (given)	31		
8	Cold Water Temp. ^{0}C (Mix. Hot Water Temp. – Range)	36.328		0.5 mark
9	Approach ^{0}C (Cold Water Temp. – WBT)	5.328		0.5 mark
10	Effectiveness (Range/ (Range + Approach))	63		1 mark
11	Evaporation Loss (m^3/hr) = 0.00085*1.8*Mix. Flow m^3/hr*Range	208.2		1 mark

b)

1	Area of the Duct: (0.5*0.5) m^2	0.25	
2	Avg. velocity (m/s) (given)	28	
3	Air Flow (m^3/s) (Sl. 1* Sl. 2)	7	1 mark
4	Suction static Pr. (mmWC) (given)	-20	
5	Discharge Static Pr. (mmWC) (given)	30	
6	Power drawn by the motor (kW): (1.732 * 415*10.8*0.9/1000)	6.99	1 mark
7	Air Power kW: = Flow (m^3/s)* (Dis. Pr – Suc. Pr.) mmWC /102	3.43	1 mark
8	Power to fan Shaft kW (Motor Drawn power * Motor eff. Of 88%)	6.15	1 mark
9	Fan Static Eff. (%) = Air Power*100%/Shaft Input	55.76	1 mark

L-5	One of the process industries has installed 18 MW cogeneration plant. The Cogeneration plant maximum condenser load is 7 MW and the extraction steam of 57 TPH is used for process and also for vapour absorption machine. The condenser heat load is 550 Kcal/kg of steam and the steam rate is 5 kg/KW for condenser power. The heat load of VAM in 127 Kcal/min/TR and the capacity of VAM is 1100 TR. Estimate cooling tower heat load in Kcal/hr. If the tower is designed for 6°C range, calculate the water flow in cooling tower. The design approach temperature of the CT is 5°C.

	Ans. Condenser load = 7 MW Steam rate for condenser = 5 kg/KW Total steam required for condenser power = 7000 X 5 = 35000 Kg/hr. …. (2 marks) Condenser heat load = 35000 x 550 = 19250000 Kcal/hr. …. (2 marks) Heat load of VAM = 1100 x 127 x 60 = 8382000 Kcal/hr. …. (2 marks) Total heat load = 19250000 + 8382000 = 27632000 Kcal/hr. …. (2 marks) Range of tower = 6 deg C Cooling water Flow required=27632000/6=4605333 lts or 4605 m^3. …. (2 marks)
L-6	a) List five disadvantages of low Power Factor ? b) An industry is losing money as penalty on account maintaining a poor power factor of 0.88.The power utility has specified a minimum power factor of 0.9 to avoid penalty. The penalty on energy cost is 1% for every 0.01 power factor less than the minimum prescribed. Also an incentive on energy cost is available @ 1.5% for every 0.01 improvement above 0.95. If the monthly energy bill of the industry is Rs 6 lakhs, calculate the annual cost saving potential if power factor is improved to unity from the current level.
	Answer : (Any five -1 mark each) a) Disadvantages of low power factor are 1.) Large Line Losses (Copper Losses) 2.) Large kVA rating and Size of Electrical Equipments 3.) Greater Conductor Size and Cost 4.) Poor Voltage Regulation and Large Voltage Drop 5.) Low Efficiency 6.) Penalty from Electric Power Supply Company on Low Power factor b) Minimum PF to be maintained to avoid penalty = 0.9 Present penalty = 1.00 % (on energy bill) for every 0.01 P.F. For 0.02 PF = 1.00 x 2 = 2.0% (1 mark) Incentives = 1.5 x 5 = 7.5% (1 mark) Energy saving potential = 9.5% Cost reduction potential per month = 6 lakh x 9.5% = Rs.57000 (2 mark) Annual cost Reduction = 57000x12 = Rs.684000 (1 mark)

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