Regn No: _____

Name: _____

(To be written by the candidate)

9th NATIONAL CERTIFICATION EXAMINATION – December, 2009
FOR
ENERGY MANAGERS AND ENERGY AUDITORS

PAPER – 3: Energy Efficiency in Electrical Utilities

Date: 20.12.2009 Timings: 0930-1230 HRS Duration: 3 HRS Max. Marks: 150

General instructions:

- *Please check that this question paper contains **15** 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, as per instructions

1	In the city electrical distribution scheme, a proposal is being prepared to upgrade 33 kV network to 66 kV. The distribution loss, corresponding to the same quantum of load in the proposed upgraded system will be **a) less by 25%** b) less by 33% c) less by 75% d) none of the above
2	Rating of power factor correction capacitors at induction motor terminals should be a) 100% of no load magnetizing kVAr of induction motor b) 90% of no load magnetizing kVAr of induction motor c) 120% of no load magnetizing kVAr of induction motor d) none of the above
3	Select the correct statement: a) the advantage of PF improvement by capacitor addition in an electric network is that active power component of the network is reduced b) the power factor indicated in the monthly electricity bill is the lowest power factor recorded at any time during the billing month

	c) PF capacitors operating at lower voltage then their rated values have higher operating kVArs then their rated values d) the power factor of an induction motor decreases with decrease in percentage motor loading
4	If the efficiencies of a power plant, transmission and distribution systems are 30%, 95% & 85% respectively, the cascade efficiency of power generation, and transmission system is given by a) 24.23% b) 28.5 % c) 80.75% d) 95%
5	Which of the following is not likely to create harmonics in an electrical system? a) soft starters b) variable frequency drives c) uninterrupted power supply source (UPS) **d) induction motors**
6	What is the % slip of a 4 pole induction motor if the shaft speed at 49.5 Hz supply frequency is 1460 rpm? a) 1.68 b) 2.66 c) 1.71 d) none of the above
7	During induction motor operation, magnetic field is established in a) stator winding only b) rotor winding only c) stator and rotor windings d) at carbon brushes
8	An induction motor rated for 7.5 kW and 90 % efficiency at full load, was drawing 5 kW. The percentage loading on the motor is a) 60 % b) 66.66% c) 74% d) none of the above
9	If the apparent power drawn over a recording cycle of 30 minutes is 3000kVA for 10 minutes, 2400kVA for 15 minutes and 2900 for 5 minutes, the MD recorder will commute MD as a) 3000 kVA b) 2400 kVA c) 2683 kVA d) none of the above
10	The performance of rewinding of an induction motor can be assessed by which of the following factors? a) load current b) stator resistance c) no load current d) both no load current and stator resistance
11	The pressure drop in mains header at the farthest point of an industrial compressed air network shall not exceed d) 2 bar **b) 0.3 bar** c) 0.5 bar d) 1.0 bar
12	The Free Air Delivery capacity of a reciprocating compressor is directly proportional to a) pressure b) volume c) **speed** d) all of the above
13	The inlet air temperature to a two stage reciprocating air compressor is $35^{o}C$. At which of the following 2^{nd} stage inlet temperatures the compressor will consume least power? a) $75^{o}C$ b) $65^{o}C$ c) $60^{o}C$ d) $50^{o}C$

14	At which of the following discharge pressures, the reciprocating air compressor will consume maximum power a) 3 bar b) 3.5 kg/cm^2 c) <u>150 psi</u> d) 6 kg/cm^2
15	Which of the following is not true of air receivers? a) smoothens pulsating air output b) stores large volumes of air c) a source for draining moisture d) <u>increases the pressure of air</u>
16	A 1.5 ton air conditioner installed in a room and working continuously for two hours will remove heat of a) 3024 kCals b) 6048 kCals c) <u>9072 kCals</u> d) none of the above
17	Which of the following can be used as refrigerant both in vapour compressor and vapour absorption systems <u>a) Ammonia</u> b) R – 11 c) R-12 d) Lithium Bromide
18	Chilled water enters evaporator at 12^{0}C and leaves at 6^{0}C. The flow rate of chilled water was measured as 300 m^3/hr. The tons of refrigeration capacity is a) 0.595 b) <u>595.24</u> c) 35.7 d) none of the above
19	Centrifugal compressors are most efficient when they are operating at_____. a) 50% load b) <u>full load</u> c) 75% load d) all load conditions
20	The Coefficient of Performance (COP) of Vapour Absorption Refrigeration System (VAR) a) is higher than that of Vapour Compression Refrigeration (VCR) System **<u>b) is lower than that of Vapour Compression Refrigeration (VCR) System</u>** c) is same as that of Vapour Compression Refrigeration (VCR) System d) is normally 4 to 4.5
21	Backward-inclined fans are known as _____ because change in static pressure does not overload the motor a) overloading <u>b) non-overloading</u> c) radial d) axial
22	The fan characteristic curve is a plot of a) <u>static pressure vs flow</u> b) dynamic pressure vs flow c) total pressure vs flow d) suction pressure vs flow
23	A fan is drawing 16 kW at 800 RPM. If the speed is reduced to 600 RPM then the power drawn by the fan would be a) 12 kW b) 9 kW c) <u>6.75 kW</u> d) none of the above
24	The hydraulic power of a motor pump set is 8.5 kW. If the power drawn by the motor is 15.5 kW at a 89% efficiency, the pump efficiency is given by a) 54.8% b) <u>61.6%</u> c) 48.8% d) none of the above

25	For the same flow through which of the following diameter pipes, the pump will work with maximum pressure a) 80 mm b) 100 mm c) 120 mm d) 1400 mm
26	If inlet and outlet water temperatures of a cooling tower are 44^{o}C and 38^{o}C respectively and atmospheric DBT and WBT are 40 ^{o}C and 35 ^{o}C respectively, then the effectiveness of cooling tower is a)54.5 % b) 66.6% c) 75% d) none of the above
27	In which of the following fans air enters and leaves the fan with no change in direction a) forward curved b) backward curved c) radial d) propeller
28	The motor efficiency is 0.9 and the pump efficiency is 0.6.The input power to the motor driving the pump is 28 kW. The power transmitted to the water is a) 15.12 kW b) 28 kW c) 25.2 kW d) none of the above
29	A water pump is delivering 200 m^3/hr at ambient conditions. The impeller diameter is trimmed by 10%. The water flow at the changed conditions is a) 220 m^3/hr b) 180 m^3/hr c) 162 m^3/hr d) none of the above
30	The operating point in a pumping system is identified by a) point of intersection of system curve and efficiency curve b) point of intersection of pump curve and theoretical power curve c) point of intersection of pump curve and system curve d) point of intersection of NPSH curve and pump curve
31	Increasing the Cycles of Concentration (C.O.C) in circulating water in a cooling tower, the blow down quantity will a) increase b) decrease c) not change d) none of the above
32	At which of the following condenser temperatures, the power consumption of a vapour compression refrigeration system will be the least a) 26^{o}C b) 28 ^{o}C c) 29 ^{o}C d) 25 ^{o}C
33	Which of the following ambient conditions will not evaporate maximum amount of water in a cooling tower a) 41^{o}C DBT and 38^{o}C WBT b) 38 ^{o}C DBT and 37 ^{o}C WBT c) 36 ^{o}C DBT and 30 ^{o}C WBT d) 36^{o}C DBT and 31 ^{o}C WBT
34	If inlet and outlet water temperatures of a cooling tower are 39^{o}C and 33^{o}C respectively and atmospheric DBT and WBT are 35 ^{o}C and 28 ^{o}C respectively then the approach of cooling tower is a) 3^{o}C b) 4^{o}C c) 5^{o}C d) 6^{o}C
35	If flow rate is 100m^3/hr and the range is 8^{o}C for a cooling tower, then its heat load in kCal/hr will be. a) 800 b) 8,000 c) 80,000 d) **800,000**

36	Which method uses infrared, acoustic, ultrasonic or microwave sensors for lighting control? a) time-based control b) daylight-linked control c) occupancy-linked control d) localized switching
37	If voltage is increased from 230 V to 250 V for a fluorescent tube light, it will result in a) reduced power consumption **b) increased power consumption** c) decreased light levels d) no change in power consumption and light levels
38	The 5^{th} and 7^{th} harmonic in a 50 Hz power supply system will have: a) voltage and current distortions with 55 Hz & 57 Hz b) voltage and current distortions with 500 Hz & 700 Hz **c) voltage and current distortions with 250 Hz & 350 Hz** d) no voltage and current distortion at all
39	Automatic power factor controller using kVAr control, requires sensing of a) current b) voltage c) capacitance d) both a and b
40	The COP of a vapour compression system is 3.0. If the motor draws power of 11 kW at 90% motor efficiency, the cooling effect of vapour compression system will be a) 29.7 kW b) 37.8 kW c) 0.36 kW d) none of the above as cooling effect is always measured in TR
41	Which of the following can also act as a heat pump? a) centrifugal pump b) centrifugal compressor c) air conditioner d) none of the above
42	A slide valve is used for capacity control in which of the following refrigeration compressors? a) reciprocating b) centrifugal c) screw d) scroll
43	In a DG set, a 3 phase alternator is supplying on an average 100 A at 420 V and 0.9 pf to a load. If the specific fuel consumption of this DG set is 0.30 lts/ kWh at that load, then how much fuel is consumed while delivering generated power for one hour? a) 11.34 litre b) 19.64 litre c) 21.82 litre d) 218.23 litre
44	The largest potential for electricity savings with variable speed drives is generally for: **a) variable torque applications** b) constant torque loads c) constant power load d) combination of above
45	The electronic ballast fitted in a tube light fitting does not have one of the following characteristics a) lower operational losses than conventional ballasts b) tuned circuit to deliver power at 28-32 KHz **c) requiring a starter** d) low temperature rise

46	Maximum demand controller is used to **a) switch off non-essential loads in a logical sequence** b) switch off essential loads in a logical sequence c) controls the reactive power of the plant d) all the above.
47	In a fluid coupling, connecting an induction motor and a fan a) motor speed can be changed by the fluid coupling b) fan speed can be changed by the fluid coupling c) both motor and fan speed can be changed by the fluid coupling d) none of the above is possible
48	In a "V" belt coupled fan drive, the measured speed at motor end 6" diameter pulley is 1480 rpm and that at fan end 10" diameter pulley is 820 RPM. What is the slippage loss in %? **a) 7.66** b) 8.29 c) 6.67 d) insufficient data, cannot be worked out
49	Select the incorrect statement: a) slip ring induction motors are normally less efficient than squirrel cage induction motors b) high speed squirrel cage induction motors are normally less efficient than low speed Squirrel cage induction motors c) the capacitor requirement for PF improvement at induction motor terminal increases with decrease in rated speed of the induction motor d) induction motor efficiency increases with increase in its rated capacity
50	Coefficient of Performance (COP) for a refrigeration compressor is given by a) kW/TR b) power input to compressor (kW) / cooling effect (kW) c) cooling effect (kW) / Power input to compressor (kW) d) none of the above

……. End of Section – I …….

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

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

S-1 a) A 10 kVAr, 415 V rated power factor capacitor was found to be having terminal supply voltage of 440 V. Calculate the capacity of the power factor capacitor at the operating supply voltage.

b) What would be the nearest kVAr compensation required for changing the power factor of a 500 kW load from 0.9 lead to unity power factor ?

Ans: a) Capacitor capacity at 440V= (440/415)2 X 10= 11.24 kVAR

(3 Marks)

b) No further compensation is required as the power factor is already leading

(2 Marks)

S-2 Fill in the blanks

a) Heat Rate of a thermal power plant is expressed in _____
b) With increase in design speed of induction motors ,the required capacitive kVAr for reactive power compensation for the same capacity range will ____
c) An air dryer in a compressed air system reduces _____ point of air.
d) A Pitot tube measures the difference between _____and_____ pressures of the fluid
e) The friction loss in a pipe carrying a fluid is proportional to the_____power of pipe diameter

Ans:

a) kCal/kWh
b) decrease
c) dew
d) total and static
e) fifth

(1 Mark each)

S-3 A pump is delivering 40 m^3/hr of water with a discharge pressure of 29 metre. The water is drawn from a sump where water level is 6 metre below the pump centerline. The power drawn by the motor is 7.5 kW at 89% motor efficiency. Find out the pump efficiency.

Ans:

Hydraulic power P_h = Q (m^3/s) xTotal head, h_d - h_s (m) x ρ (kg/m^3) x g (m/s^2) / 1000

Q = 40/3600 m^3/s , h_d - h_s = 29 – (-6) = 35 m

Hydraulic power P_h = (40/3600) x 35 x 1000 x 9.81 / 1000

= 3.815 kW

(2 Marks)

Pump shaft power = 7.5 kW x 0.89

= 6.675 kW

(2 Marks)

Pump efficiency = hydraulic power / pump shaft power

= 3.815 /6.675
= 57.15 %

(1 Mark)

S-4 Define one 'Ton of Refrigeration (TR)'. How do you calculate TR across the Air Handling Units?

Ans: A ton of refrigeration is defined as the quantity of heat to be removed in order to form one ton of ice in 24 hours when the initial temperature of water is 0 °C. This is equivalent to 50.4 Kcal/min or 3024 Kcal/h in metric system

(2 Marks)

Refrigeration load in TR is assessed as ;

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

Where Q is the air flow in CMH

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**

(3 Mark)

S-5 Estimate the cooling tower capacity (TR) and approach with the following parameters

Water flow rate through CT	= 120 m^3/hr
Specific heat of water	= 1 kCal/kg °C
Inlet water temperature	= 42 °C
Outlet water temperature	= 36 °C
Ambient WBT	= 32 °C

Ans:

Cooling tower capacity (TR) = (flow rate x density x sp.heat x diff. temp)/ 3024

= 120 x 1000 x 1.0 x (42-36)/ 3024

= 238 TR

(3 Marks)

Approach = 36- 32 = 4^{o}C

(2 Marks)

S-6 A fan is delivering 20,000 Nm^3/hr. of air at static pressure difference of 70 mm WC. If the fan static efficiency is 55%, find out the shaft power of the fan.

Ans:

Q = 20,000 Nm^3 / hr. , ΔP_{st} = 70 mmWC, η_{St} = 55% , P = ?

= 20,000/3600 = 5.56 m^3/sec

$$\text{Fan static } \eta_{St} = \frac{\text{Volume in } m^3/\text{sec} \times \Delta P_{st} \text{ in mmWc}}{102 \times \text{Power input to shaft}}$$

(3 Marks)

$$0.55 = \frac{5.56 \times 70}{102 \times P}$$

Shaft power drawn = 6.94 kW

(2 Marks)

S-7 a) Briefly explain the difference between a 'filament lamp' and a 'gas discharge lamp'?

b) State any 3 best practices in a lighting system for energy savings?

Ans:

a) Filament lamps like incandescent lamps produce light by virtue of a filament heated to incandescence by the flow of electric current through it. The light from a gas discharge lamp is not produced by heating a filament, but by the excitation of gas contained in either a tubular or elliptical outer bulb.

(2 Marks)

b) Installation of energy efficient fluorescent lamps in place of "Conventional" fluorescent lamps.

1. **Installation of Compact Fluorescent Lamps (CFL's) in place of incandescent lamps.**
2. **Installation of metal halide lamps in place of mercury / sodium vapour lamps.**
3. **Installation of High Pressure Sodium Vapour (HPSV) lamps for applications where colour rendering is not critical.**
4. **Installation of LED panel indicator lamps in place of filament lamps.**
5. **Light distribution**
6. **Grouping of lighting system, to provide greater flexibility in lighting control**
7. **Installation of microprocessor based controllers**
8. **Optimum usage of daylighting**
9. **Installation of "exclusive" transformer for lighting**
10. **Installation of servo stabilizer for lighting feeder**
11. **Installation of high frequency (HF) electronic ballasts in place of conventional ballasts**

(3 Marks for any three points)

S-8 Calculate the free air delivery (FAD) capacity of a compressor in m^3/min for the following observed data:

Receiver capacity:	0.5 m^3
Initial pressure (with empty receiver):	0 kg/cm^2 (g)
Final pressure:	7 kg/cm^2 (g)
Initial air temperature:	32^oC
Final air temperature:	51 ^oC
Additional holdup volume:	0.03 m^3
Compressor pump up time:	4.5 minutes
Atmospheric pressure:	1.026 kg/ cm^2 absolute

Ans:

$$= \frac{P_2 - P_1}{P_0} \times \frac{V}{t} \times \left(\frac{273 + t_1}{273 + t_2} \right)$$

(3 Marks)

$$= \frac{7 - 0}{1.026} \times \frac{(0.5 + 0.03)}{4.5} \times \left(\frac{273 + 32}{273 + 51} \right)$$

= 0.7564 m^3/min

(2 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 a) A small scale industry has a constant load of 380 kVA. It has installed two transformers of 500 kVA each. The no load loss and full load copper loss of each 500 kVA transformer is 750 W and 5410 W respectively. From the energy efficiency point of view the small scale industry management wants to take a decision on whether to operate a single transformer or two transformers equally sharing the load. What is your recommendation ?

b) A no load test conducted on a three phase delta connected induction motor gave the following values:

No load power	= 890 W
Stator resistance per phase at 30^oC	= 0.233 Ohms
No load current	= 14.5 A

Calculate the fixed losses for the motor.

Answer a)

1 x 500 kVA	
Transformer loss at 380 kVA load	**No load loss + [kVA load/Rated kVA]^2 x full load loss = 750 + [(380/500)^2 x 5410] = 750 + (0.5776 x 5410)**
	750 + 3124.8
	3874.8 W
2 x 500 at 50% load (190 kVA) each	**2 x [750 + {(190/500)^2 x 5410}]**
	2 x [750+(0.1444x5410)]
	2 x (750 + 781.2)
	2 x (1531.2)
	= 3062.9 W

Two transformers are better because the losses are the least and there is a saving of 812.4 watts.

(5 Marks)

Answer b)

No load power	**890 W**
Stator resistance at 30^{o}C	**0.233 Ohms**
No load current	**14.5 A**
Stator Copper loss at no load	**3 x (14.5/√3)^2 x 0.233 Ohms**
	= 48.985 W
Fixed losses	**890 – 48.985**
	= 841 W

(5 Marks)

L-2 A 15 kW, 415 V, 26 A, 4 pole, 50 Hz, 3 phase rated squirrel cage induction motor has a full load efficiency and power factor of 90% and 0.89 respectively.

An energy auditor measures the following operating data of the motor

(a) Supply voltage = 408 V
(b) Current drawn = 15 A
(c) PF = 0.81
(d) Supply frequency = 49.9 Hz
(e) RPM = 1488

Find out the following at the motor operating conditions:

1. Power input in kW
2. % motor loading
3. % slip

Ans:

1. Power input = 1.7321 x 0.408 x 15 x 0.81 = 8.586 kW

(4 Marks)

2. % motor loading = power input/ rated input x 100 = 8.586/ (15/0.9)
= 8.586/ 16.666 = 63.6%

(3 Marks)

3. Synchronous RPM at 49.9 Hz,
N_S = 120 f/ P = 120 x 49.9/ 4 = 1497 RPM
% slip = (N_s – N)/ N_s x 100 = (1497 – 1488) / 1497 = 12/ 1497 x 100 = 0.8016%

(3 Marks)

L-3 a) What is the impact of condensing temperature and evaporator temperature on the Coefficient of Performance (COP) of a refrigeration system?

b) Why is it beneficial to operate induction motors in star mode operating at loads below 50 % of rated capacity?

c) In a throttle valve-controlled pumping system with oversized pump, name any 3 solutions for improving energy efficiency..

Ans: a) COP increases with reduction in condensing temperature and rise in evaporator temperature.

(2 Marks)

b) For motors which consistently operate at loads below 50 % of rated capacity, an inexpensive and effective measure might be to operate in star mode. A change from the standard delta operation to star operation involves re-configuring the wiring of the three phases of power input at the terminal box.

Operating in the star mode leads to a voltage reduction by a factor of '$\sqrt{3}$'. Motor output falls to one-third of the value in the delta mode, but performance characteristics as a function of load remain unchanged. Thus, full-load operation in star mode gives higher efficiency and power factor than partial load operation in the delta mode. However, motor operation in the star mode is possible only for applications where the torque-to-speed requirement is lower at reduced load.

(4 Marks)

c) 1.Trim impeller,
2. smaller impeller,
3. variable speed drive,
4. two speed motor, and
5. lower rpm motor

(4 Marks)

L-4 A compressed air leakage test was conducted by an energy auditor in an engineering industry, which normally runs 3 nos. of 500 cfm reciprocating compressors. The compressed air system is maintained at the normal loading-unloading settings of 6.6

kg/cm^{2}g and 7.0 kg/ cm^{2}g respectively. The following was observed for a period of 10 minutes trial by running a 500 cfm compressor during an off day:

On load time = 30 secs
Unload time = 110 secs.

Subsequently some of the air leakage points were attended and the leakage test was repeated. The following was observed while maintaining the same loading & unloading pressure settings and trial period:

On load time = 18 secs
Unload time = 145 secs.

The average power drawn during the above 2 trials was observed as 71 kW during load and 16 kW during unload condition. Calculate the annual cost savings for 4000 hr/ year of compressor operation. Assume energy charge of Rs. 6.00 per kWh.

Ans:

Leakage quantity when loading is 30 secs and unloading is 110 secs
= (30x 500) / (30+110) = 0.21428 x 500 cfm = 107 cfm

(2 Marks)

Leakage quantity when loading is 18 secs
and unloading is 140 secs.

= (18 x 500) / (18+145) = 0.11x500=55 cfm

(2 Marks)

Specific power consumption = 71kWh / (500 x 60 cfh) = 0.0023666 kW/ ft^3

(2 Marks)

Reduction in leakage quantity =107 – 55 = 52 cfm = 3120 cfh

Energy savings per hour =3120 x 0.0023666 = 7.383792 kWh

(2 Marks)

Cost savings @ Rs.6/kWh @4000hrs/annum

=7.383792 kWh x 4000hrs/annum x Rs.6 /kWh= Rs.1,77,211/ annum

(2 Marks)

L-5 a) Define Range, approach and effectiveness in cooling tower operation

b) An induced draft-cooling tower is designed for a range of 8° C. The energy auditor finds the operating range as 2 °C. In your opinion what could be the reasons for such situation

Answer a):

i) "Range" is the difference between the cooling tower water inlet and outlet temperature.

ii) "Approach" is the difference between the cooling tower outlet cold water temperature and ambient wet bulb temperature. Although, both range and approach should be monitored, the `Approach' is a better indicator of cooling tower performance.

iii) Cooling tower effectiveness (in percentage) is the ratio of range, to the ideal range, i.e., difference between cooling water inlet temperature and ambient wet bulb temperature, or in other words it is = Range / (Range + Approach).

(6 Marks)

Answer b)

1. **There may be excess cooling water flow rate**
2. **There may be reduced heat load from the process**
3. **Some of the cooling tower cells fan is switched off**
4. **Approach may be poor because of high humid condition**
5. **Nozzles may be blocked**

(4 Marks)

L 6 In an alkali chemical plant, salt brine flow at the rate of 18 m^3/ hr is cooled down from 12 °C to 7 °C using chilled water. The chiller unit compressor motor draws 31 kW power and total input power to the allied accessories is 16 kW. The operating efficiency of the motor is 90%. The salt brine density is 1.2 kg/litre and specific heat capacity is 0.97 kCal/kg °C.

a) What is the refrigeration load (TR) imposed by the brine cooling?

b) What is the COP of refrigeration compressor?

c) What is the overall specific power consumption in kW/TR ?

Answer:

a) The refrigeration load in TR = Q. Cp. (Ti – To) / 3024

where Q= mass flow rate of brine in kg/hr
Cp = specific heat capacity of brine in kCal/ kg deg.C
Ti & To= inlet and outlet temperature

Refrigeration load imposed by the brine TR:

TR= {18,000* 1.2 * 0.97 (12-7)}/3024
= 34.64 TR

(4 Marks)

b) COP of refrigeration compressor = $\frac{\text{3.516 * TR}}{\text{Power input to the compressor (kW)}}$

= 3.516 * 34.64 / (31*0.9)
= 4.365

(3 Marks)

C) Overall specific power consumption in kW/ TR = 31 + 16/ 34.64 = 47/ 34.64
= 1.3568 kW/ TR

(3 Marks)

……. End of Section - III …….