Regn No: ____ _____

Name: _____

(To be written by the candidates)

7th NATIONAL CERTIFICATION EXAMINATION – Nov. 2008
FOR
ENERGY MANAGERS & ENERGY AUDITORS

PAPER – 3:	**Energy Efficiency in Electrical Utilities**		
Date: 23.11.2008	Timings: 0930-1230 HRS	Duration: 3 HRS	Max. Marks: 150

Paper 3

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 Black HB Pencil, as per instructions

1	If the voltage level of the distribution system is raised from 11 kV to 22 kV for the same loading conditions, the distribution losses are reduced by a) 25% b) 50% c) 11% d) 22%
2	If the efficiencies of a power plant, transmission and distribution systems are 34%, 96% & 80% respectively, the cascade efficiency of transmission and distribution system is given by a) 26.11% b) 76.8 c) 96% d) 80%
3	Given the Gross Heat Rate of a thermal power plant, its efficiency is a) inverse of gross heat rate b) square of gross heat rate c) square root of gross heat rate d) none of the above
4	A 230 Volts single phase line supplies to a load of 25 amperes at 0.80 power factor. The active power supplied by the line will be a) 7.96W b) 5.75 kVA c) 0.575 MVA d) 4.6 kW

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5	Busbar three phase voltages at the main electrical panel were balanced. At one of the distribution panel board (DPB), connected with PF correction capacitors, the voltages were unbalanced by about 3%. What could be the possible reason? a) It was result of blown fuse in one phase of the 3 phase capacitor bank connected to the DPB. b) the connecting cables were faulty c) it was due to loose connections d) none of the above
6	Select the incorrect statement: a) harmonics occur as spikes at intervals, which are multiples of the supply frequency b) harmonics are multiples of the fundamental frequency c) induction motors are the major sources of harmonics generation d) transformers operating near saturation level create harmonics
7	The rating of the capacitor at motor terminals should not be greater than _____ a) magnetizing kVAr of the motor at full load b) magnetizing kVAr of the motor at no load c) magnetizing kVAr of the motor at half load d) magnetizing kVAr of the motor at 75% load
8	A three phase induction motor loaded at less than 50 %,if operated in star mode, will result in a) reduced operating voltage b) electrical downsizing of the motor c) improved efficiency and power factor d) all of the above
9	A eight pole induction motor operating at 50 Hz, will have a synchronous speed of a) 1500 rpm b) 1000 rpm c) 3000 rpm d) 750 rpm
10	What loading percentage can be ideally considered as a meaningful figure to decide on the best motor efficiency in the selection process? a) 50% b) 100% c) 75% d) none of the above
11	A three phase induction motor is drawing 21 Ampere at 420 Volts. If the operating power factor of the motor is 0.89 ,then the mechanical shaft power output of the motor is a) 15.27 kW b) 13.59 kW c) 7.85 kW d) not workable due to insufficient data
12	The total losses in a transformer operating at 50% load with designed no load and load losses at 2 kW and 20 kW respectively are a) 7 kW b) 12 kW c) 4.5 kW d) 22 kW

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13	The 5th and 7th harmonic in a 50 Hz power environment 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
14	Which of the following type does Screw compressor belongs to? a) Positive displacement compressor b) Dynamic compressors c) Both a & b d) None of the above
15	Screw compressor's other name is a) reciprocating compressor b) helical rotary compressor c) helical axial compressor d) centrifugal compressor
16	Which compressor best meets high volume low pressure requirements? a) reciprocating b) screw c) centrifugal d) lobe
17	The best location for installing capacitor banks for Power Factor improvement, which will result in maximum distribution losses reduction in a factory having 11 kV High Tension service connection a) main LT sub-station bus bars b) Unit capacitors as close as to the major load centers and balance distributed as per load factor at sub switch boards and balance through Automatic Power Factor Controller at main switch boards c) at the primary side of the transformer d) centralized at main switch board through Automatic Power Factor Controller
18	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
19	The refrigeration load in TR when 10 m^3/hr of water is cooled from 16°C to 8°C is about a) 23.8 b) 26.4 c) 116.6 d) none of the above
20	In a cooling tower the C.O.C is 3 and evaporation losses are 1%. The circulation rate is 1200 m^3 /min. The blow down requirement of the cooling tower is given by a) 6 m^3 /min b) 4 m^3 /min c) 60 m^3 /min d) none of the above
21	The driving force for refrigeration in vapour absorption refrigeration system is____ a) Mechanical energy b) Thermal energy c) Electrical energy d) All of the above

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22	Choose the correct match for the following centrifugal fan types. Type / Suitable for i) Backward curved — High pressure, high flow ii) Forward curved — High pressure, Medium flow iii) Radial — Medium pressure, high flow a) i) b) ii) c) iii) d) none of the above
23	The system resistance in a fan system refers to a) static pressure b) velocity pressure c) total pressure d) differential pressure
24	Modest flow reduction from 100% to 80% in a centrifugal fan is achieved more efficiently with the following flow control method. a) inlet damper b) outlet damper c) inlet guide vane d) none of the above
25	Identify correct statements as applicable to Air flow measurement and Fan Performance Assessment: a) Static pressure is the potential energy put into the system by the fan b) Velocity pressure is used to calculate air velocity c) Velocity pressure is the pressure along the line of the flow that results from the air flowing through the duct d) All the above
26	One ton of refrigeration (TR) is equal to a) 50.4 kCal/min b) 3516 W c) 200 BTU/min d) all of the above
27	For the same flow through which of the following diameter pipes, the pump will work with maximum pressure a) 100 mm b) 150 mm c) 200 mm d) 250 mm
28	Net Positive Suction Head Available (NPSHA) of a pump means: a) the value of the suction head, expressed as a head of liquid b) the head of liquid column with respect to the center line of the pump c) the value, by which the pressure in the pump suction exceeds the liquid vapour pressure, expressed as a head of liquid d) none of the above
29	Comfortable air conditioned space for a convention center may have which of the following best suitable conditions: a) about 22 to 25 degree centigrade and 50 to 55% relative humidity b) less than 22 degree centigrade and less than 50% relative humidity c) about 22 to 25 degree centigrade and 50 to 55% relative humidity and adequate air changes d) none of the above

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30	A fan with 25 cm pulley diameter is driven by a 1470 rpm motor through a v-belt system. If the motor pulley is reduced from 20 cm to 15 cm at the same motor rpm and fan pulley diameter, the fan speed will reduce by a) 1176 rpm b) 882 rpm c) 294 rpm d) none of the above
31	If flow rate is 100m^3/hr and the range is 8°C for a cooling tower, then its Heat load in TR will be. a) 0.265 b) 265 c) 800 d) none of the above
32	Better indicator of performance of a cooling tower is --- a) approach b) range c) wet bulb temperature d) dry bulb temperature
33	The load of a HVAC system corresponding with 15 m^3/hr of chilled water inlet temperature at 15°C and with a return water temperature of 21°C is about: a) 7.5 TR b) 32 TR c) 29.8 TR d) none of the above
34	The hydraulic power of a motor pump set is 6.9 kW. If the power drawn by the motor is 14.0 kW at 88% efficiency, the pump efficiency is given by a) 49.3% b) 56% c) 43.4% d) none of the above
35	The smoothening of the pulsating output of a reciprocating compressor is done by a) receiver b) intercooler c) after cooler d) drain traps
36	Which of the following is the best definition of illuminance? a) Time rate of flow of light energy b) Luminous flux incident on an object per unit area c) Flux density emitted from an object without regard for direction d) Flux density emitted from an object in a given direction
37	Identify the wrong statement from the following: The various options available in electricity distribution loss optimization include: a) relocating transformers and sub-stations near to load centers b) re-routing and re-conductoring such feeders and lines where the losses / voltage drops are higher. c) power factor improvement by installing capacitors only at EHT substation level d) optimum loading of transformers in the system
38	Which of the following motive loads has scope for energy savings by retrofitting Variable speed drives: a) punch press b) vibrating conveyor c) rock crusher d) centrifugal process pumps requiring flow control
39	A 10 kVAr, 415 V rated power factor capacitor was found to be having terminal supply voltage of 440 V. The capacity of the power factor capacitor at the operating supply voltage would be approximately a) 10 kVAr b) 9.43 kVAr c) 11.24 kVAr d) none of the above

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40	Normally, water pipe lines are designed with water velocity of a) less than 1 m/s b) up to 2m/s c) more than 2 m/s d) none of the above
41	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
42	The factors affecting Waste Heat Recovery from exhaust flue gases of DG set are: a) DG set loading b) Temperature of exhaust flue gases after turbo charger c) Back pressure on the DG set d) all of the above
43	Colour rendering index is measured in the scale of --- a) 1-100 b) 1-100% c) 100-500 d) 100-1000
44	Eddy current drive is used to --- a) keep the output speed constant b) vary the output speed c) improve the power factor d) reduce the eddy current losses
45	Which combination of readings as indicated by the panel mounted instruments of a DG Set would give the indications of proper capacity utilisation of diesel engine and generator a) kW & Voltage b) kVA & kVAr c) kW & KVA d) none of the above
46	Select the feature which does not apply to energy efficient motors by design: a) starting torque for efficient motors may be higher than for standard motors b) energy efficient motors last longer c) energy efficient motors have low slips which results in speeds about 1% higher than standard motors d) reduced air gap between the rotor and stator than standard motor
47	In a DG set, the generator is generating 400 kVA, at 0.8 PF. If the specific fuel consumption of this DG set is 0.3 litres / kWh at that load, then how much fuel is consumed while delivering generated power for one hour. a) 1066 litres b) 96 litres c) 1333 litres d) none of the above
48	DC excitation is used in which of the following for varying the speed ? : a) Variable frequency drive b) Synchronous motor c) Slip ring motor d) None of the above

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49	Slip power recovery system is used in --- a) DC motors b) synchronous motors c) slip-ring induction motors d) squirrel cage induction motors
50	The core losses of a transformer are the least if the core is made up of a) silicon alloyed iron (grain oriented) b) copper c) amorphous core – metallic glass alloy 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 If inlet and outlet water temperatures of a cooling tower are 43^{o}C and 35^{o}C respectively and atmospheric DBT and WBT are 39 ^{o}C and 32 ^{o}C respectively, find out the range, approach and the effectiveness of cooling tower.

Range:43-35=8 deg C

Approach:= 35-32= 3deg C

Cooling Tower Effectiveness = Range / (Range + Approach).
= 8/ (8+3)
= 0.727

S-2 **The COP of a vapour compression refrigeration system is 3.1. If the compressor motor draws power of 15 kW at 91% motor efficiency, find out the tonnage of the refrigeration system.**

Answer:

Power input to compressor	**=**	**0.91 x 15**
	=	**13.65kw**
Cooling effect		**= 13.65 x 3.1**
	=	**42.315 kw**
42.315 kW x 860 kcal/kwh	**=**	**363390 kcals/hr**
Refrigeration tonnage		**= 363390/3024**
	=	12.03 Tonnes

S-3 A Reciprocating Compressor with 220 CFM capacity is connected with a 75 HP motor. The energy manager of the plant noticed frequent unloading and loading of compressor .In your opinion, what reasons he may conclude for this situation and accordingly propose the remedial actions.
Answer:

There could be three reason(s)
1. Requirement of compressed air for plant is very less.
2. Compressor selected is higher capacity.
3. Malfunctioning of unloader valves.

To replace existing Motor with smaller capacity motor after measuring actual requirement of compressed air, this could be done by measuring loading and unloading time of compressor.
OR
To increase driven side Pulley size. It will reduce capacity of compressor as well power consumption
OR
To go for VFD

S-4 List any 5 energy conservation opportunity in a pumping system.

Answer

- Ensure adequate NPSH at site of installation
- Ensure availability of basic instruments at pumps like pressure gauges, flow meters.
- Operate pumps near best efficiency point.
- Modify pumping system and pumps losses to minimize throttling.
- Adapt to wide load variation with variable speed drives or sequenced control of multiple units.
- Stop running multiple pumps - add an auto-start for an on-line spare or add a booster pump in the problem area.
- Use booster pumps for small loads requiring higher pressures.
- Increase fluid temperature differentials to reduce pumping rates in case of heat exchangers.
- Repair seals and packing to minimize water loss by dripping.
- Balance the system to minimize flows and reduce pump power requirements.
- Avoid pumping head with a free-fall return (gravity); Use siphon effect to advantage:
- Conduct water balance to minimise water consumption
- Avoid cooling water re-circulation in DG sets, air compressors, refrigeration systems, cooling towers feed water pumps, condenser pumps and process pumps.

- In multiple pump operations, carefully combine the operation of pumps to avoid throttling
- Provide booster pump for few areas of higher head
- Replace old pumps by energy efficient pumps
- In the case of over designed pump, provide variable speed drive, or downsize / replace impeller or replace with correct sized pump for efficient operation.
- Optimise number of stages in multi-stage pump in case of head margins
- Reduce system resistance by pressure drop assessment and pipe size optimisation

S-5 List any five advantages of PF improvement by capacitor addition in an electric distribution system

.

Answer:

a) Reduced kVA (Maximum demand) charges in utility bill

b) Reduced distribution losses (KWH) within the plant network

c) Better voltage at motor terminals and improved performance of motors

d) A high power factor eliminates penalty charges imposed when operating with a low power factor

e) Investment on system facilities such as transformers, cables, switchgears etc for delivering load is reduced.

S-6 A water pump is delivering 300 m^3/hr flow at 40 meter head at ambient conditions. The pump shaft power is 52kW. The impeller diameter is trimmed by 6% . Find out the new water flow,head and pump shaft power at the changed condition.

Q_1 = 300 m^3 / hr.

D_2 = 0.94 D_1

Q_2 = ?

Q α D

$$\frac{Q_1}{Q_2} = \frac{D_1}{D_2}$$

$$\frac{300}{Q_2} = \frac{D_1}{0.94\ D_1}$$

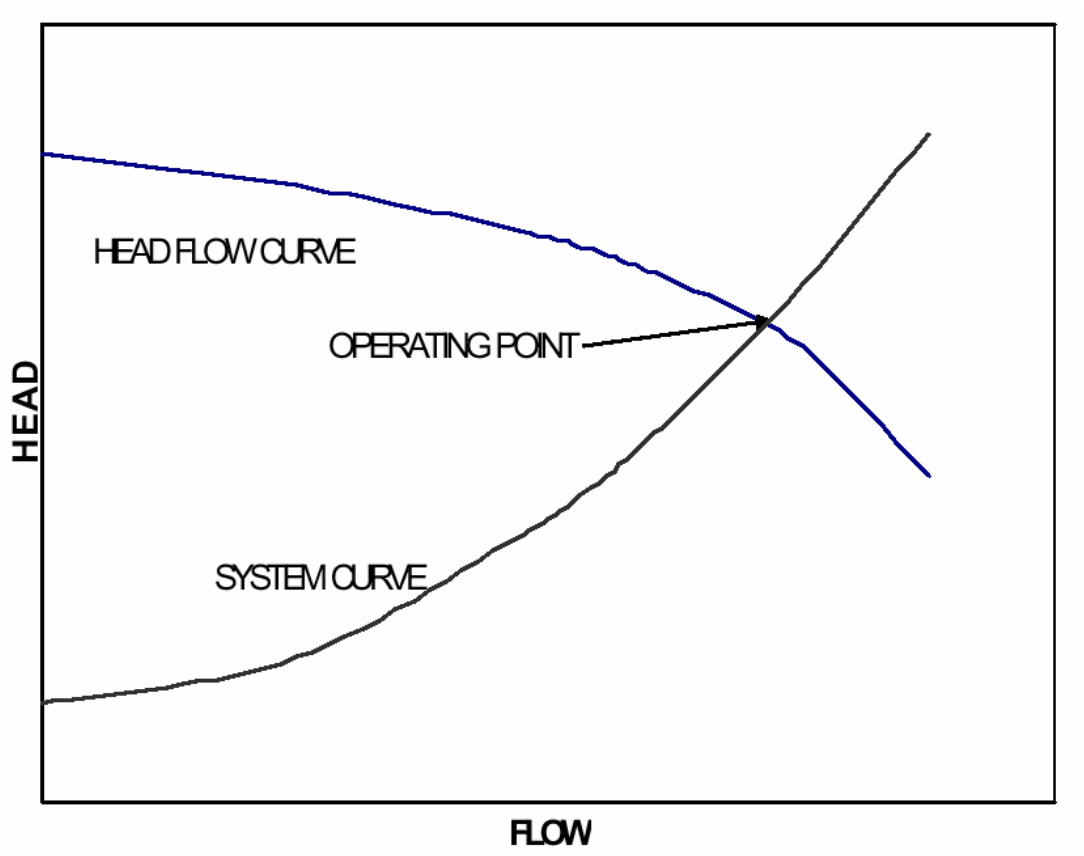
Q_2 = 0.94 x 300
Q_2 = 282 m^3 /hr.

Head= (**D_1/0.94 D_1**)2 = (1.06383)2 =1.1412
40/H2 = 1.1412

H2 = 40/1.1412
=35 m

Power= (**D_1/0.94 D_1**)3= (1.06383)3=1.204
52/P2 =1.204
P2= 52/1.204
= 43.18 kW

S-7 Draw a sketch of a typical centrifugal pump characteristic curve along with system resistance. (Note: No explanation is required)



S-8 Why does the power factor of a induction motor decreases with the decrease in the applied load on the motor?

The power factor of the motor is given as: $\text{Power Factor} = \text{Cos}\,\phi = \frac{\text{kW}}{\text{kVA}}$

As the load on the motor decreases, the magnitude of the active current or active power decreases. However, there is no corresponding decrease in the magnetizing current or reactive power, which is proportional to the supply voltage. With the result, the apparent current or apparent power does not decrease in the same proportion to that of the active current or active power. Therefore, the motor power factor decrease, with decrease in the applied load.

…… End of Section - II ……

Section – III: LONG DESCRIPTIVE QUESTIONS

Marks: 6 x 10 = 60

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

L-1 A V-belt driven centrifugal fan is supplying air in a process plant. The performance test conducted by an energy auditor on the fan generated the following data:

Ambient temperature	30^{o}C
Density of air at 0^{o}C	1.293 kg/m^{3}
Diameter of the discharge air duct	0.8 m
Velocity pressure measured by Pitot tube in discharge duct	45 mmWC
Pitot tube coefficient	0.9
Static pressure at fan inlet	- 20 mmWC
Static pressure at fan outlet	185 mmWC
Power drawn by the motor coupled with the fan	65 kW
Belt transmission efficiency	96%
Motor efficiency at the operating load	90 %

The energy auditor concludes after analyzing the above data that the efficiency of the fan is about 35.9%. Do you agree with his above observation? If not, can you find the mistake made by the auditor?

Ans:

Ambient temperature	**30°C**
Diameter of the discharge air duct	**0.8 m**
Velocity pressure measured by Pitot tube	**45 mmWC**
Static pressure at fan inlet	**- 20 mmWC**
Static pressure at fan outlet	**185 mmWC**
Power drawn by the motor	**70 kW**
Transmission efficiency	**96%**
Motor efficiency	**90 %**
Area of the discharge duct	**3.14 x 0.8 x 0.8 x 1/4**
	0.502672 m^2
Pitot tube coefficient	**0.9**
Corrected gas density	**(273 x 1.293) / (273 + 30) = 1.165**
Air velocity	$\frac{Cp \times \sqrt{2 \times 9.81 \times \Delta p \times \gamma}}{\gamma}$
	$\frac{0.9 \times \text{Sq rt.}(2 \times 9.81 \times 45 \times 1.165)}{1.165}$
	24.776 m/s
Volume	**24.776 x 0.502672**
	12.4543 m^3/s
Power input to the shaft	**65 x 0.96 x 0.9**
	56.16kW
Static Fan Efficiency % = $\frac{\text{Volume in } m^3 / \text{Sec} \times \text{total static pressure in mmwc}}{102 \times \text{Power input to the shaft in (kW)}}$	
Fan static Efficiency	$\frac{12.4543 \times (185 - (-20)}{102 \times 56.16}$
	44.57%

No, the fan static efficiency is 44.567%. The auditor , while working out the total static pressure has committed a mistake. He has taken suction pressure as positive.

Fan static Efficiency = $\frac{12.4543 \times (185 - (20)}{102 \times 56.16}$

= 35.87%

L-2: a) Two FD fans , one fan on each side of the Boiler, are supplying the total combustion air requirement for a boiler. These fans are connected to a common header through discharge dampers. Each fan is having 260 kW rating and provided with VSDs. Each fan is designed to cater 60% of Boiler capacity (MCR).

It was observed by an energy auditor that when one FD fan was in service (when the boiler requirement is below 60% MCR), power drawn by that fan is 105 kW at 570 rpm where as the total power drawn by keeping both the fans in service for the same steam generation (below 60% MCR) is around 70 kW only (each fan is drawing 35 kW at 430 rpm).

In your opinion what could be the reasons for low power consumption with both fans in service than a single fan for generation of same quantity of steam? (Note: No calculation or working is required. Only brief explanation is sufficient)

Answer:

When one fan was in service as it was common discharge header system the possibility of recirculation of part of air from the running fan cannot be ruled out due to passing of discharge dampers and inlet vane of the fan that is not in service. This increases the air requirement for maintaining the same excess oxygen conditions, hence increase in load on the running fan.

Second reason can be that when only one fan is in service as airflow is from one side only, increases the system resistance than when same air is distributed from both the sides. This forces the single fan to develop more head for the same total airflow, hence operation at higher RPM. With both fans in service the system resistance will be low distributed flow.

Because of the above reasons there is a net saving of energy when both fans are in service than single fan.

b) On the advice of an energy auditor, a chemical plant replaced the existing standard induction motor powering a centrifugal pump with a new energy efficient induction motor of same kW ratings and number of poles. The plant energy manager observed that the temperature rise of the stator windings of energy efficient induction motor was comparatively higher than that of the standard induction motor. Briefly explain any reason for this situation

Answer

Due to lower slip level in energy efficient motor (EEM), operate at slightly higher speeds, and result in operation at a higher point in the load curve of the pump. This increase in load is proportional to approximately the cube of the increase in speed. This means motor must produce more horsepower (ie, EEM may be operating above its rated power).

Because the temperature rise in a motor increases slightly less than the square of the horse power output, the net effect is that the temperature rise of the rotor is roughly proportional to the fifth power of the increase in rotor speed.

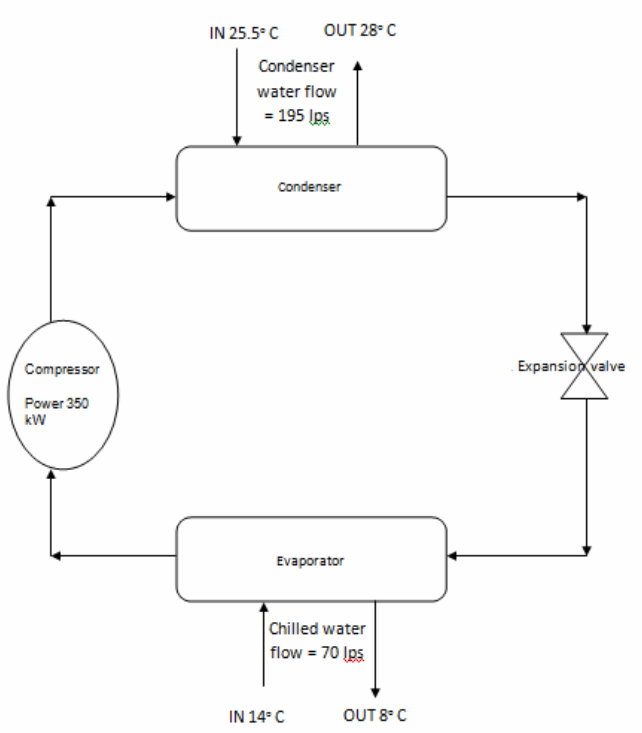
L-3 Give very short answers for the following

1. Which expression to state the energy efficiency of a chiller does not follow the trend “a higher number means a more efficient system”?
2. Which parameter needs to be measured to assess the percentage loading of a motor by slip method neglecting voltage correction?
3. What is meant by the term “specific power requirement” with respect to air compressors? State the units.
4. Which three variables need to be measured to calculate the efficiency of a pump?
5. Which loss is assumed in the efficiency determination of an induction motor?

ANS:

1) The expression “power per ton” (in kW/ton) does not follow the trend. The higher the number the more inefficient the chiller.
2. Motor speed
3. The ratio of power consumption (in kW) to the volume delivered at ambient conditions. Unit is kW per cubic meter per hour or kW/(m^3/hr)
4) The variables to be measured (i) volumetric flow (ii) pressure difference across the pump and (iii) electrical power input to the motor driving the pump .
5. Stray losses

L-4 The parameters measured for of a centrifugal chiller are as follows:



i. Evaluate the CoP of centrifugal chiller

ii. Find the ratio of evaporator refrigeration load(TR) to condenser heat rejection load(TR)

Ans. i. Refrigeration load (TR) : (m x c_p x ▲t)/3024

: 70 x 3600 x 1 x (14-8)/3024

: 500 TR

Coefficient of performance $COP = \dfrac{\text{Cooling effect (kW)}}{\text{Power input to compressor (kW)}}$

= (500TRx3024/860) / 350= 5.023

ii. Evaporator cooling load (TR) : 500 TR

Condenser heat rejection load (TR) : 195 x 3600 x (28 – 25.5)/3024

: 580 TR

Ratio : $\dfrac{Evaporator}{Condenser} = \dfrac{500}{580} = 0.86$

L-5 The suction head of a pump is 5 m below the pump centerline. The pump discharge pressure is 2.9kg/cm^2. The flow rate of water is 95 m^3 /hr. Find out the pump efficiency if the actual power input by the motor is 15kW. Assume motor efficiency at the operating load as 89%.

Discharge Head	**:**	**2.9 kg/cm^2 equals 29 metre head.**
Suction Head	**:**	**- 5 metre.**
Total Head	**:**	**29 – (-5) = 34 metre.**
Hydraulic Power	**:**	**(95/3600) x 1000 x 9.81 x 34/1000 = 8.80 kW**
Pump Efficiency	**:**	**100 x 8.80/(15x0.89) = <u>65.92%</u>**

L-6 **A 7.5 kW, 415 V, 14.5 Amp,4 pole, 50 Hz rated, 3 phase squirrel cage induction motor has a half load efficiency of 86% and power factor of 0.72. Find the following if the motor operates at 50% of its rated output.**

a) current drawn by the motor
b) Ratio of the current drawn to its rated current. Is this exactly 50% at half loading? If not, briefly explain the reasons for the same.
c) RPM at a half load slip of 1.8%

ANS:

a) P_{in} (Input power) = 7.5x0.5/ 0.86 = 4.3605 kW

I(Input current) = 4.3605/ (√3 x 0.415 x 0.72) = 8.425 A

b) Ratio of the current drawn to its rated current = 8.425/14.5=58.1%
NO, this ratio is not exactly half.

The current drawn by the motor is the resultant sum of the active and reactive current of the induction motor. The reactive current drawn is independent of load as it is supply voltage dependent, and hence remains constant as long as the supplied voltage remains constant. On the other hand, active current drawn is directly proportional to load and changes in direct proportion to the load. Therefore, the resultant of active current and reactive current, which is the current drawn by the motor, does not change in direct proportion to the change in load as one of the current component is load independent. Therefore, current drawn by the induction motor at any part load may not be a true reflection of the load.

c) Ns = 120 x f / p = 120 x 50 / 4 = 1500 RPM
N = Ns (1- S)
= 1500 (1- 0.018)
= 1473 RPM

…… End of Section – III ……