

NATIONAL CERTIFICATION EXAMINATION 2005 FOR

ENERGY MANAGERS & ENERGY AUDITORS

Question Papers & Model solutions to the Question Papers

PAPER – 3: Energy Efficiency in Electrical Utilities

Date: 29.05.2005 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 **65** 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) Put a (✓) tick mark in the appropriate box in the answer book

1.	The voltage drops in transmission / distribution line depends on ____.
	a) reactance and resistance of the line b) current in the line c) length of the line <u>d) all of the above</u>
2.	Power factor is the ratio of
	<u>a) kW/kVA</u> b) kVA/kW c) kVAr/kW d) kVAr/kVA
3.	If the reactive power drawn by a particular load is zero, it means the load is operating at
	a) lagging power factor b) leading power factor <u>c) unity power factor</u> d) none of the above
4.	Select the ideal location of installing capacitor banks, which will reduce the distribution loss to the maximum extent.
	a) main sub-station bus bars <u>b) motor terminals</u> c) motor control centre d) distribution transformers

5.	A 10 HP/7.5 kW, 415 V, 14.5 A, 1460 RPM, 3 phase rated induction motor, after decoupling from the driven equipment, was found to be drawing 3 A at no load. The current drawn by the motor at no load is high because of a) faulty ammeter reading b) very high supply frequency at the time of no load test c) lose motor terminal connections <u>d) very poor power factor as the load is almost reactive</u>
6.	If voltage applied to a 415 V rated capacitors drops by 5 %, its VAR output drops by about_____. a) 5% <u>b) 10%</u> c) 19% d) none of the above
7.	Which of the following is not a positive displacement compressor a) Roots blower b) Screw Compressor <u>c) Centrifugal Compressor</u> d) Reciprocating Compressor
8.	Which of the factors will indicate the performance of a rewind induction motor? a) no load current b) stator winding resistance c) air gap <u>d) all the above</u>
9.	A six pole induction motor operating at 50 Hz, with 1% slip will run at an actual speed of a) 1000 RPM b) 1010 RPM <u>c) 990 RPM</u> d) none of the above
10.	With decrease in design speed of squirrel cage induction motors the required capacitive kVAR for reactive power compensation for the same capacity range will <u>a) increase</u> b) decrease c) not change d) none of the above
11.	The ratio of current drawn by the induction motor to its rated current does not reflect true loading of the motor at partial loads mainly due to a) increased motor slip <u>b) decreased operating power factor</u> c) decreased motor efficiency d) none of the above
12.	For every 4°C rise in the air inlet temperature of an air compressor, the power consumption will normally increase by___ percentage points for the same output. <u>a) 1</u> b) 2 c) 3 d) 4
13.	Typical acceptable pressure drop in mains header at the farthest point of an industrial compressed air network is <u>a) 0.3 bar</u> b) 0.5 bar c) 0.7bar d) 1.0 bar
14.	Vertical type reciprocating compressor are used in the cfm capacity range of <u>a) 50-150</u> b) 200-500 c) 500-1000 d) 1000 and above
15.	A battery of two reciprocating 250 cfm belt driven compressors installed in a centralized station, were found to be operating at the same loading period of 60% and unloading period of 40%. The least cost solution to reduce wastage of energy in this case would be a) switching off one compressor <u>b) reducing appropriately the motors pulley sizes</u> c) reducing appropriately the compressors pulley sizes d) none of the above

16.	With increase in condensing temperature in a vapor compression refrigeration system, the specific power consumption of the compressor for a constant evaporator temperature will <u>a) increases</u> b) decreases c) sometime increases and sometime decreases d) remains the same
17.	With increase in evaporator temperature in a vapor compression refrigeration system, while maintaining a constant condenser temperature, the specific power consumption of the compressor will a) increase b) <u>decrease</u> c) sometime increase and sometime decrease d) remains the same
18.	The refrigeration load in TR when 15 m ³ /hr of water is cooled from 21° C to 15 ° C is about a) 7.5 b) 32 <u>c) 29.8</u> d) none of the above
19.	Coefficient of Performance (COP) for a refrigeration compressor is given by <u>a) Cooling effect (kW) / Power input to compressor (kW)</u> b) Power input to compressor (kW) / cooling effect (kW) c) $Q \times C_p \times (T_i - T_o) / 3024$ d) none of the above
20.	The efficiency of backward-inclined fans compared to forward curved fans is___ <u>a) higher</u> b) lower c) same d) none of the above
21.	_____ fans are known as “non-overloading“ because change in static pressure do not overload the motor a) radial b) forward- curved <u>c) backward-inclined</u> d) tube- axial
22.	A 100 cfm reciprocating compressor was observed to be operating at load - unload pressure setting of 6.0 kg/cm ² g and 7.5 kg/cm ² g respectively. This situation will result in a) increased leakage loss in air distribution system b) increased loading timings of the compressor c) increased energy consumption of the compressor <u>d) all the above</u>
23.	The specific ratio as defined by ASME and used in differentiating fans, blowers and compressors, is given by a) suction pressure/discharge pressure <u>b) discharge pressure/suction pressure</u> c) suction pressure/ (suction pressure + discharge pressure) d) discharge pressure/ (suction pressure + discharge pressure)
24.	In centrifugal fans, airflow changes direction a) once <u>b) twice</u> c) thrice d) none of the above
25.	Reducing the fan RPM by 10% decreases the fan power requirement by a) 10% <u>b) 27%</u> c) 33% d) none of the above
26.	It is possible to run pumps in parallel provided their _____ are similar a) suction head b) discharge heads <u>c) closed valve heads</u> d) none of the above

27.	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 <u>c) point of intersection of pump curve and system curve</u> d) none of the above
28.	Input power to the motor driving a pump is 30 kW. The motor efficiency is 0.9 and pump efficiency is 0.6. The power transmitted to the water is <u>a) 16.2 kW</u> b) 18.0 kW c) 27.0 kW d) none of the above
29.	The static pressure of a fan running at 500 RPM is 200 mm wc. If it has to be increased to 250 mmwc then the new speed of the fan would be <u>a) 625 RPM b) 400 RPM c) 1250 RPM d) 750 RPM</u> (One mark to be awarded to all)
30.	If inlet and outlet water temperatures of a cooling tower are 42°C and 34°C respectively and atmospheric DBT and WBT are 39 ° C and 30 ° C respectively, then the approach of cooling tower is a) 3° C <u>b) 4° C</u> c) 5° C d) 8° C
31.	Which one from the following types of cooling towers consumes less power? a) Cross-flow splash fill cooling tower b) Counter flow splash fill cooling tower <u>c) Counter flow film fill cooling tower</u> d) None of the above
32.	Which one of the following is true to estimate the range of cooling tower? a) Range = Cooling water inlet temperature – Wet bulb temperature b) Range = Cooling water outlet temperature – Wet bulb temperature <u>c) Range = $\frac{\text{Heat load in kCal/ h}}{\text{Water circulation in liters/ h}}$</u> d) None of the above
33.	Which of the following ambient conditions will evaporate minimum amount of water in a cooling tower a) 35 °C DBT and 25 °C WBT b) 40°C DBT and 36°C WBT c) 35 °C DBT and 28 °C WBT <u>d) 38 °C DBT and 37 °C WBT</u>
34.	Small by-pass lines are installed in pumps some times to ____. a) save energy b) control pump delivery head <u>c) prevent pump running at zero flow</u> d) reduce pump power consumption
35.	Cycles of concentration in circulating water (C.O.C) is the ratio of <u>a) dissolved solids in circulating water to the dissolved solids in make up water</u> b) dissolved solids in make up water to the dissolved solids in circulating water c) dissolved solids in evaporated water to the dissolved solids in make up water d) none of the above
36.	One lux is equal to ____. a) one lumen per ft² <u>b) one lumen per m²</u> c) one lumen per m³ d) none of the above

37.	Color rendering index of Halogen lamps compared to low pressure sodium vapor lamps is a) poor <u>b) excellent</u> c) average d) very poor
38.	Which of the following options reduces the electricity consumption in lighting system in a wide spread plant? a) replacing 150 W HPSV lamps with 250 W HPMV lamps b) maintaining 260 V for the lighting circuit with 220 V rated lamps <u>c) installing separate lighting transformer and maintaining optimum voltage</u> d) none of the above
39.	If voltage is reduced from 230 V to 190 V for a fluorescent tube light, it will result in a) increased power consumption <u>b) reduced power consumption</u> c) increased light levels d) no change in power consumption
40.	What is the typical frequency of a high frequency electronic ballast? a) 50 Hz b) 50kHz <u>c) 30 kHz</u> d) 60 Hz
41.	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 <u>c) kW & KVA</u> d) none of the above
42.	Lower power factor of a DG set demands _____ a) lower excitation currents <u>b) higher excitation currents</u> c) no change in excitation currents d) none of the above
43.	The main precaution to be taken care by the waste heat recovery device manufacturer to prevent the problem in a DG set during operation is: a) temperature rise <u>b) back pressure</u> c) over loading of waste heat recovery tubes d) turbulence of exhaust gases
44.	In a DG set, the generator is generating 1000 kVA, at 0.7 PF. If the specific fuel consumption of this DG set is 0.25 lbs/ kWh at that load, then how much fuel is consumed while delivering generated power for one hour. a) 230 litre b) 250 litre <u>c) 175 litre</u> d) none of the above
45.	Which of the following losses is the least in DG sets: a) cooling water loss b) exhaust loss c) frictional loss <u>d) alternator loss</u>
46.	Slip power recovery system is used in a) DC motor b) synchronous motor c) squirrel cage induction motor <u>d) slipring induction motor</u>
47.	The basic functions of an electronic ballast fitted to a fluorescent tube light exclude one of the following a) to stabilize the gas discharge b) to ignite the tube light c) to supply power to the lamp at very high frequency <u>d) to supply power to the lamp at supply frequency</u>

48.	Select the feature which does not apply to energy efficient motors by design: a) energy efficient motors last longer b) starting torque for efficient motors may be lower than for standard motors <u>c) energy efficient motors have high slips which results in speeds about 1% lower than standard motors</u> d) energy efficient motors have low slips which results in speeds about 1% higher than standard motors
49.	Energy savings potential of variable torque applications compared to constant torque application is: <u>a) higher</u> b) lower c) equal d) none of the above
50.	Maximum demand controllers are used to a) control the power factor of the plant b) switch off essential loads in a logical sequence <u>c) switch off non-essential loads in a logical sequence</u> d) none of the above

..... End of Section – I

Section – II: SHORT DESCRIPTIVE QUESTIONS

Marks: 10 x 5 = 50

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

S-1. Compute the maximum demand recorded for a plant where the recorded load is as mentioned below in the recording cycle of 30 minutes.

- 100 kVA for 10 minutes
- 200 kVA for 5 minutes
- 50 kVA for 10 minutes
- 150 kVA for 5 minutes

The MD recorder will be computing MD as:

$$\frac{(100 \times 10) + (200 \times 5) + (50 \times 10) + (150 \times 5)}{30} = 108.3 \text{ kVA}$$

S-2. Why is it beneficial to operate motors in star mode for induction motors loaded less than 50% ?

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. The motor gets derated and behaves as a smaller motor. Consequently the % loading of the motor increases. 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

S-3 In an engineering industry, while conducting a leakage test in the compressed air system, following data for a reciprocating air compressor was recorded:

Compressor capacity = 35 m³ per minute

Average load time = 90 seconds

Average unload time = 360 seconds

Find out the leakage quantity in m³ per day (assume 20 hours per day of operation)

% Leakage in the system

Load time (T) : 90 seconds

Un load time (t) : 360 seconds

% leakage in the system : $\frac{T}{(T + t)} \times 100$

$$\begin{aligned} &: 90 / (90 + 360) \times 100 \\ &: 20 \% \end{aligned}$$

$$\begin{aligned} \text{Leakage quantity} &: 0.2 \times 35 \\ &: 7 \text{ m}^3/\text{min} \times 60 \times 20 \\ &: 8400 \text{ m}^3/\text{day} \end{aligned}$$

S-4 What is the main difference between vapor compression refrigeration (VCR) and Vapour Absorption Refrigeration (VAR) system ?

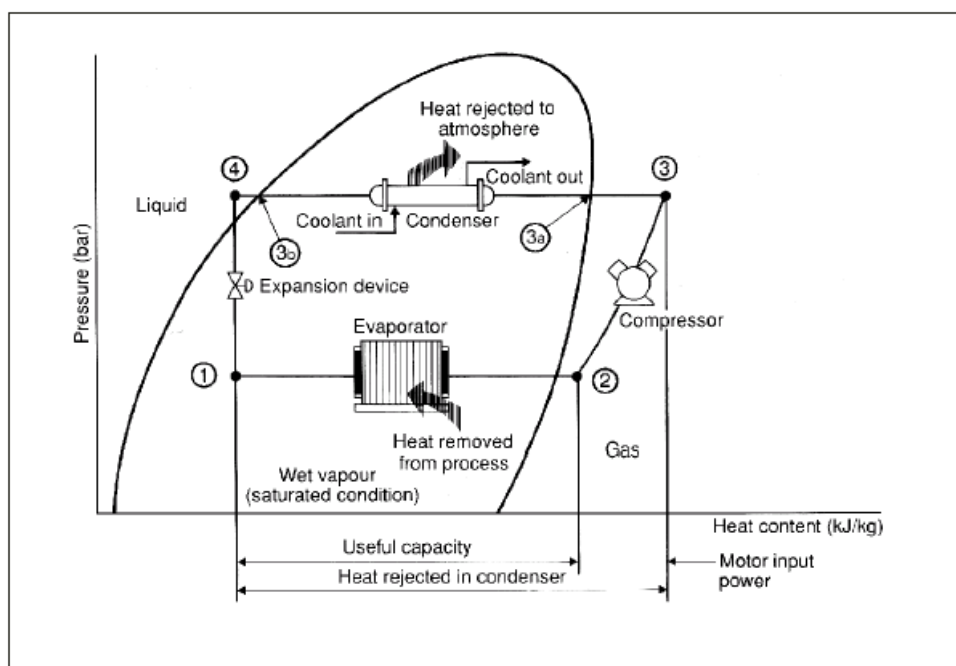
- VCR uses electric power for the compressor as main input while VAR uses a source of heat
- VCR uses compounds of hydrogen, fluorine and carbon as refrigerants while VAR uses water
- VCR works under pressure while VAR works under vacuum
- VCR has a high COP while VAR has a low COP
- *Any other relevant point.....*

S-5 How the heat is absorbed, or removed from a low temperature source and transferred to a high temperature source in a vapour compression system ?

Vapour Compression Refrigeration

Heat flows naturally from a hot to a colder body. In refrigeration system the opposite must occur i.e. heat flows from a cold to a hotter body. This is achieved by using a substance called a refrigerant, which absorbs heat and hence boils or evaporates at a low pressure to form a gas. This gas is then compressed to a higher pressure, such that it transfers the heat it has gained to ambient air or water and turns back (condenses) into a liquid. In this way heat is absorbed, or removed, from a low temperature source and transferred to a higher temperature source.

(OR)



1 - 2 Low pressure liquid refrigerant in the evaporator absorbs heat from its surroundings, usually air, water or some other process liquid. During this process it changes its state from a liquid to a gas, and at the evaporator exit is slightly superheated.

2 - 3 The superheated vapour enters the compressor where its pressure is raised. There will also be a big increase in temperature, because a proportion of the energy input into the compression process is transferred to the refrigerant.

3 - 4 The high pressure superheated gas passes from the compressor into the condenser. The initial part of the cooling process (3 - 3a) desuperheats the gas before it is then turned back into liquid (3a - 3b). The cooling for this process is usually achieved by using air or water. A further reduction in temperature happens in the pipe work and liquid receiver (3b - 4), so that the refrigerant liquid is sub-cooled as it enters the expansion device.

4 - 1 The high-pressure sub-cooled liquid passes through the expansion device, which both reduces its pressure and controls the flow into the evaporator

S-6 Find out the blow down rate from the following data. Cooling Water Flow Rate is 500 m³/hr. The operating range is 8°C. The TDS concentration in circulating water is 1800 ppm and TDS in make up water is 300 ppm.

$$\text{Evaporation Loss (m}^3\text{/hr)} = 0.00085 \times 1.8 \times \text{circulation rate (m}^3\text{/hr)} \times (T_1 - T_2)$$

$$= 0.00085 \times 1.8 \times 500 \times 8$$

$$= 6.12 \text{ m}^3\text{/hr}$$

$$\text{COC} = (\text{TDS in circulating water} / \text{TDS in make up water})$$

$$= 1800 / 300$$

$$= 6$$

$$\text{Blowdown} = \text{Evaporation loss} / (\text{COC} - 1)$$

$$= 6.12 / (6 - 1)$$

$$= 1.224 \text{ m}^3/\text{hr}$$

S-7 What is the role of an electronic ballast in a fluorescent tube light ?

In an electric circuit the ballast acts as a stabilizer. Fluorescent lamp is an electric discharge lamp. The two electrodes are separated inside a tube with no apparent connection between them. When sufficient voltage is impressed on these electrodes, electrons are driven from one electrode and attracted to the other. The current flow takes place through an atmosphere of low-pressure mercury vapour.

Since the fluorescent lamps cannot produce light by direct connection to the power source, they need an ancillary circuit and device to get started and remain illuminated. The auxiliary circuit housed in a casing is known as ballast.

S-8. Explain how stator and rotor I^2R losses are reduced in an energy efficient motor.

Stator $I^2 R$: Use of more copper and larger conductors increases cross sectional area of stator windings. This lowers resistance (R) of the windings and reduces losses due to current flow (I).

Rotor $I^2 R$: Use of larger rotor conductor bars increases size of cross section, lowering conductor resistance (R) and losses due to current flow (I)

S-9. A centrifugal pump is pumping 70 m³/hr of water with a discharge head of 5 kg/cm² g and a negative suction head of 3 metres. If the power drawn by the motor is 16 kW, find out the pump efficiency. Assume motor efficiency as 90% and water density as 1000 kg/m³.

$$\text{Hydraulic power } P_h = Q \text{ (m}^3/\text{s)} \times \text{Total head, } h_d - h_s \text{ (m)} \times \rho \text{ (kg/m}^3) \times g \text{ (m/s}^2) / 1000$$

$$Q = 70/3600 \text{ m}^3/\text{s}, h_d - h_s = 50 - (-3) = 53 \text{ m}$$

$$\text{Hydraulic power } P_h = (70/3600) \times 53 \times 1000 \times 9.81 / 1000$$

$$= 10.1 \text{ kW}$$

$$\text{Pump shaft power} = 16 \text{ kW} \times 0.9$$

$$\begin{aligned}\text{Pump efficiency} &= 14.4 \text{ kW} \\ &= \text{hydraulic power} / \text{pump shaft power} \\ &= 10.1 / 14.4 \\ &= 70 \%\end{aligned}$$

- S-10. A genset is operating at 800 kW loading with 480°C exhaust gas temperature. The DG set generates 8 kg gas/ kWh generated, and specific heat of gas at 0.25 kCal/ kg °C. A heat recovery boiler is installed after which the exhaust gas temperature reduces to 180 °C. How much steam will be generated at 3 kg/ cm² with enthalpy of 650.57 kCal/ kg. Assume boiler feed water temperature as 80°C.

$$\begin{aligned}\text{Quantity of flue gas} &= 800 \times 8 \\ &= 6400 \text{ kg/hr} \\ \text{Heat recovered} &= 6400 \times 0.25 \times (480 - 180) \\ &= 4,80,000 \text{ kcal/hr} \\ \text{Quantity of steam generated} &= 4,80,000 / (650.57 - 80) \\ &\text{(Reduce one mark if efficiency is assumed)} \\ &= 841 \text{ kg/hr}\end{aligned}$$

..... *End of Section - II*

Section – III: LONG DESCRIPTIVE QUESTIONS

Marks: 5 x 10 = 50

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

L-1. (a) A 3 phase, 415 V, 110 kW induction motor is drawing 50 kW at a 0.75 PF.

Calculate the capacitor rating requirements at motor terminals for improving PF to 0.95. Also, calculate the reduction in current drawn and kVA reduction, from the point of installation back to the generating side due to the improved PF.

(b) A process plant consumes of 125,000 kWh per month at 0.9 Power Factor (PF). What is the percentage reduction in distribution losses per month if PF is improved up to 0.96 at load end?

a) kVAr Rating = kW [Tan ϕ_1 – tan ϕ_2]

$$\text{Cos } \phi_1 = 0.75, \phi_1 = \text{Cos (inv) } 0.75 = 41.41, \text{ Tan } \phi_1 = 0.882$$

$$\text{Cos } \phi_2 = 0.95, \phi_2 = \text{Cos (inv) } 0.95 = 18.2, \text{ Tan } \phi_2 = 0.329$$

$$\text{kVAr Rating} = 50 \text{ kW (0.882 – 0.329)}$$

$$= 27.65 \text{ kVAr}$$

$$\text{Current drawn at 0.75 PF} = 50 / \sqrt{3} \times 0.415 \times 0.75$$

$$= 92.8 \text{ A}$$

$$\text{Current drawn at 0.95 PF} = 50 / \sqrt{3} \times 0.415 \times 0.95$$

$$= 73.3 \text{ A}$$

$$\text{Reduction in current drawn} = 92.8 – 73.3$$

$$= 19.5 \text{ A}$$

$$\text{Initial kVA at 0.75 PF} = 50 / 0.75$$

$$= 66.7 \text{ kVA}$$

$$\text{kVA at 0.95 PF} = 50 / 0.95$$

$$= 52.6 \text{ kVA}$$

$$\text{Reduction in kVA} = 66.7 – 52.6$$

$$= 14.1 \text{ kVA}$$

(OR)

$$\begin{aligned}
 \text{Reduction in kVA} &= (\sqrt{3} VI)_{\text{old}} - (\sqrt{3} VI)_{\text{new}} \\
 &= (\sqrt{3} \times 0.415 \times 92.8) - (\sqrt{3} \times 0.415 \times 73.3) \\
 &= 66.68 - 52.65 \\
 &= 14.03 \text{ kVA}
 \end{aligned}$$

$$\begin{aligned}
 \text{b) \% Reduction in distribution losses} &= \left[1 - (PF_1 / PF_2)^2 \right] \\
 &= [1 - (0.9/0.96)^2] \\
 &= 0.121 \\
 &= 12.1 \%
 \end{aligned}$$

L-2. a) A V-belt driven reciprocating instrument air compressor was found to be maintaining a distribution system pressure of 7 kg/cm²g. 20% of the instrument air was used for control valves installed in a boiler house and requiring 6.5 kg/cm²g, whereas balance 80% of the instrument air was used for other application requiring 4 kg/cm²g. What would you like to advise in this situation?

1. Have a separate small compressor operating at 6.5 to 7 kg/cm²g to meet the boiler house control valve requirement located near the boiler house.
2. The existing compressor can operate with the pressure setting changed to 4 to 5 kg/cm²g
3. Since 20 % of the load on the existing compressor is transferred to new compressor and with the reduced pressure setting leakage loss will be less. Now this compressor will be unloading for a longer time. Hence reduce motor pulley sizes to reduce the RPM thus reducing the output and the unloading time.

b) An energy auditor observes the following load unload condition on two similar reciprocating air compressor installed in two separate industrial locations (A & B)

	A	B
Load setting (kg/cm ² g)	6.5	6.5
Unload setting (kg/cm ² g)	6.8	7.5

The energy auditor concludes that at location B, the compressed air system in operation is inefficient. Do you agree with his observation. Justify your reply with atleast two reasons in support of your argument

Energy auditor is right as

- a) system B will operate at higher pressure and hence will consume more power**
- b) leakage loss of the system B will increase due to more header/system pressure**
- c) Loading time will also be more and hence more unloading power consumption**

L-3. List down 10 energy conservation opportunities in pumping systems.

- 1. Operate pumps near best efficiency point**
- 2. Modify pumping system and pumps losses to minimize throttling**
- 3. Adapt to wide load variation with variable speed drives or sequenced control of multiple units**
- 4. Use booster pumps for small loads requiring higher pressures**
- 5. Increase fluid temperature differentials to reduce pumping rates in case of heat exchangers**
- 6. Balance the system to minimize flows and reduce pump power requirements**
- 7. Avoid pumping head with a free-fall return (gravity); Use siphon effect to advantage**
- 8. Conduct water balance to minimise water consumption**
- 9. Avoid cooling water re-circulation in DG sets, air compressors, refrigeration systems, cooling towers feed water pumps, condenser pumps and process pumps**
- 10. In multiple pump operations, carefully combine the operation of pumps to avoid throttling**
- 11. Replace old pumps by energy efficient pumps**

12. In the case of over designed pump, provide variable speed drive, or downsize / replace impeller or replace with correct sized pump for efficient operation
13. Optimise number of stages in multi-stage pump in case of head margins
14. Reduce system resistance by pressure drop assessment and pipe size optimisation
15. Ensure adequate NPSH at site of installation
16. Ensure availability of basic instruments at pumps like pressure gauges, flow meters.
17. Stop running multiple pumps - add an auto-start for an on-line spare or add a booster pump in the problem area.
18. Repair seals and packing to minimize water loss by dripping.

L-4. In an air conditioning duct of 0.6 m x 0.6 m size, the average velocity of air measured by vane anemometer is 30 m/s. The static pressure at inlet of the fan is 25 mm WC and at the outlet is 35 mm WC. The motor coupled with fan through belt drive draws 19 A at 410 V at a power factor of 0.8. Find out the efficiency of the fan. Assume motor efficiency = 90% and belt transmission efficiency of 98% (density correction can be neglected).

Ans:

$$\begin{aligned} \text{Volume flow rate of the fan, } Q &= \text{Velocity} \times \text{Area} \\ &= 30 \times 0.6 \times 0.6 \\ &= 10.8 \text{ m}^3/\text{Sec} \end{aligned}$$

$$\begin{aligned} \text{Power input to the fan shaft} &= \text{Motor input power} \times \text{motor efficiency} \times \text{transmission efficiency} \\ &= (\sqrt{3} \times 0.410 \times 19 \times 0.8 \times 0.9 \times 0.98) \\ &= 9.52 \text{ kW} \end{aligned}$$

$$\begin{aligned} \text{Fan efficiency} &= \frac{\text{Volume in m}^3/\text{Sec} \times \text{total pressure in mm wc}}{102 \times \text{Power input to the shaft in (kW)}} \\ &= \frac{10.8 \times 35 - (-25)}{102 \times 9.52} \times 100 \end{aligned}$$

$$\text{Fan efficiency} = 66.7 \%$$

- L -5 An efficiency assessment test was carried out for a standard squirrel cage induction motor in a process plant. The motor specifications are as under.

Motor rated specification: 50 HP/ 415 Volt, 60 Amps, 1475 rpm, 3 phase, delta connected

The following data was collected during the no load test on the motor.

Voltage = 415 Volts
Current = 18 Amps
Frequency = 50 Hz
Stator resistance per phase = 0.27 Ohms
No load power = 1080 Watts

Calculate the following:

- (i) Iron plus friction and windage losses.
- (ii) Stator resistance at 120°C.
- (iii) Stator copper loss at operating temperature at 120°C.
- (iv) Full load slip and rotor input assuming rotor losses are slip times rotor input.
- (v) Motor input assuming that stray losses are 0.5% of the motor rated power.
- (vi) Motor full load efficiency and full load power factor.

(i) Let Iron plus friction and windage loss, $P_i + f_w$

No load power, $P_{nl} = 1080$ Watts

Stator Copper loss, $P_{st-30^\circ C}$ ($P_{st.cu}$)

(This temperature is assumed and hence any temperature used may be given marks)

$$= 3 \times (18 / \sqrt{3})^2 \times 0.27$$

$$= 87.49 \text{ Watts}$$

$$P_i + f_w = P_{nl} - P_{st.cu}$$

$$= 1080 - 87.49$$

$$= 992.51 \text{ W}$$

(ii) Stator Resistance at 120°C,

$$R_{120^\circ C} = 0.27 \times \frac{120 + 235}{30 + 235}$$

$$= 0.362 \text{ ohms per phase}$$

(iii) Stator copper losses at full load, $P_{st.cu}$ 120°C

$$= 3 \times (60 / \sqrt{3})^2 \times 0.362$$

$$= 1303.28 \text{ Watts}$$

(iv) Full load slip

$$S = (1500 - 1475) / 1500 \\ = 0.0167$$

$$\text{Rotor input, } P_r = P_{\text{output}} / (1-S) \\ = 37300 / (1-0.0167) \\ = 37933.49 \text{ Watts}$$

(v) Motor full load input power, P input

$$= P_r + P_{\text{st.cu } 120^{\circ}\text{C}} + (P_i + f_w) + P_{\text{stray}} \\ = 37933.49 + 1303.28 + 992.51 + (0.005^* \times 37300) \\ = 40415.78 \text{ Watts}$$

*where, stray losses = 0.5% of rated output (assumed)

(vi) Motor efficiency at full load

$$\text{Efficiency} = \frac{P_{\text{output}}}{P_{\text{input}}} \times 100 \\ = (37300 / 40415.78) \times 100 \\ = 92.3 \%$$

$$\text{Full Load PF} = \frac{P_{\text{input}}}{\sqrt{3} \times V \times I_{\text{fl}}} \\ = (40415.78 / \sqrt{3} \times 415 \times 60) \\ = 0.937$$

..... *End of Section – III*