Winter-15 EXAMINATION

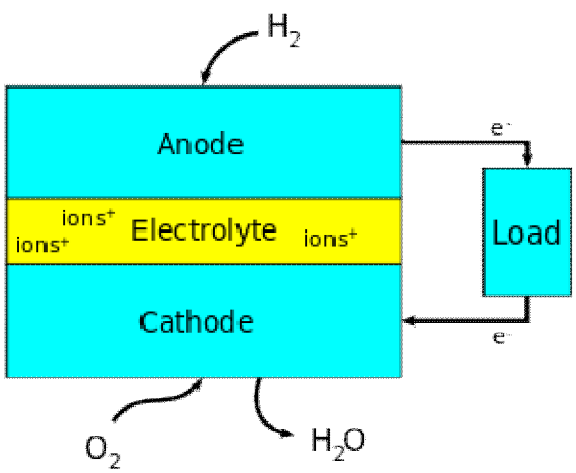
Model Answer

Important Instructions to examiners:

1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given more Importance (Not applicable for subject English and Communication Skills.
4) While assessing figures, examiner may give credit for principal components indicated in thefigure. The figures drawn by candidate and model answer may vary. The examiner may give credit for any equivalent figure drawn.
5) Credits may be given step wise for numerical problems. In some cases, the assumed constant values may vary and there may be some difference in the candidate’s answers and model answer.
6) In case of some questions credit may be given by judgment on part of examiner of relevant answer based on candidate’s understanding.
7) For programming language papers, credit may be given to any other program based on equivalent concept.

Q No.	Answer	Marks	Total marks
A	**Attempt any three**		**12**
a)	**Primary energy** is an energy form found in nature that has not been subjected to any conversion or transformation process. The primary energy sources are derived from: the sun, the earth's heat, the wind, water (rivers, lakes, tides, and oceans), fossil fuels - coal, oil, and natural gas, biomass, and radioactive minerals. **Secondary energy** Secondary energy refers to the more convenient forms of energy which are transformed from other, primary, energy sources through energy conversion processes. Examples are electricity, which is transformed from primary sources such as coal, raw oil, fuel oil, natural gas, wind, sun, streaming water, nuclear power, gasoline etc.	2 2	4
b)	**Performance assessment of pump:** 1) flow measurement by any one method (Ultrasonic flow meter can be used) 2) Determination of total head :(Use pressure gauge) Suction head (h_s) Discharge head (h_d) 3) Determination of hydraulic power (liquid H.P.) Ph = Q x (hd – hs) x density of the fluid 4) measurement of motor input power (Power analyzer) 5) pump shaft power Ps = Pm x efficiency of motor 6) pump efficiency Pump efficiency = H.P / pump shaft power	4	4
c)	**Energy monitoring & targeting** -The physical energy survey	2	4

	-outgoing monitoring and analysis of energy consumption information Energy survey is an investigation of the control and flow of energy. the aim of the survey is to gain understanding and identify cost-effective energy saving measures. Survey include an examination of energy conversion, distribution and end-use, together with management system, survey categories of no-cost, low- cost, medium- cost, high-cost measures. The second activity should consist of an examination of energy bills before they are paid and a comparison with expectations. This two activities referred as M & T. **Elements of M & T** 1)data collection from no. of possible sources including energy bills, manual meter reading, automatic meter reading, half-hourly data from utilities, plus in-house production information & meterological data, validation of utility bills 2)analysis & interpretation to turn the data into useful information 3)reporting of appropriate information 4)action responding to unexpected excess consumption	2	
d)	**Fuel cell** Construction: Fuel cells come in many varieties; however, they all work in the same general manner. They are made up of three adjacent segments: the anode, the electrolyte, and the cathode. Two chemical reactions occur at the interfaces of the three different segments. The net result of the two reactions is that fuel is consumed, water or carbon dioxide is created, and an electric current is created, which can be used to power electrical devices, normally referred to as the load. Working: At the anode a catalyst oxidizes the fuel, usually hydrogen, turning the fuel	4	4

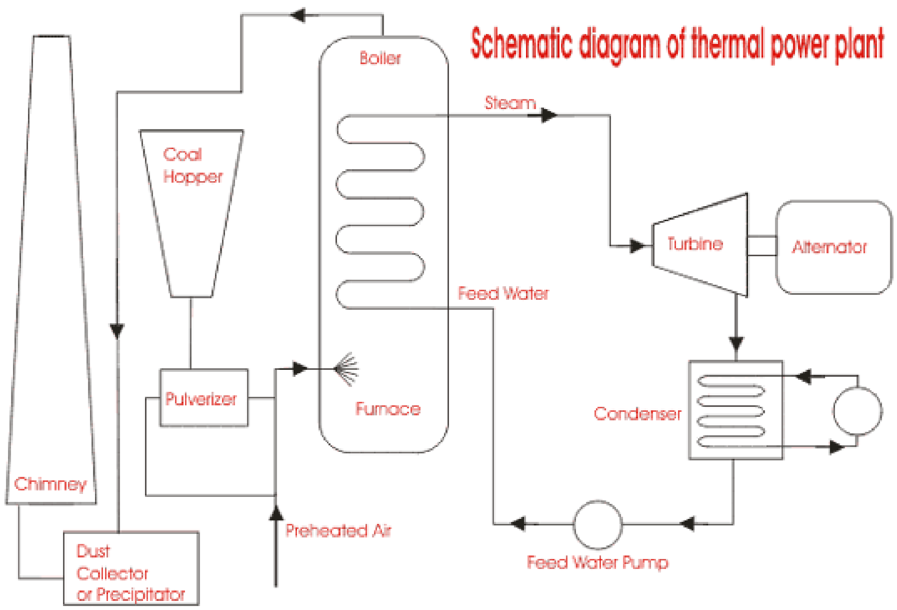
	into a positively charged ion and a negatively charged electron. The electrolyte is a substance specifically designed so ions can pass through it, but the electrons cannot. The freed electrons travel through a wire creating the electric current. The ions travel through the electrolyte to the cathode. Once reaching the cathode, the ions are reunited with the electrons and the two react with a third chemical, usually oxygen, to create water or carbon dioxide.  		
B	Attempt any one		6
a)	**Modes of heat transfer** 1. Conduction 2. Convection and 3. Radiation CONDUCTION: Conduction is the mode of heat transfer occurs from one part of a substance to another part of within the substance itself or with another substance which is placed in physical contact. In conduction, there is no noticeable movement oof molecules. You ight be think that then how this heat tranbsfer occurs? The heat	2	6

	transfer occurs here by the two mechanisms happen. 1. By the transfer of free electrons. (Good conductors like metals have a plenty of free electrons to make conductive heat transfer. 2. The atoms and molecules having energy will pass those energy they have with their adjacent atoms or molecules by means of lattice vibrations. CONVECTION: Conductive heat transfer occurs within a fluid itself and it is carried out by transfer of one fraction of the fluid to the remaining portion. Hence unlike conduction, transfer of molecules occurs during convection. Since movement of particles constitutes convection, it is the macro form of heat transfer. Also convection is only [possible in fluids where the particles can moved easily and the rate of convective heat transfer depends on the rate of flow to a great extend. Convection can be of two types: 1. Natural convection: In this type of convection, the movement of particles which constitutes convection occurs by the variation in densities of the fluids. As we already know, as temperature increases, the density decreases and this variation in density will force the fluid to move through the volume. This cause convection to occur. 2. Forced Convection: The difference between natural convection and forced convection is that in forced convection, a work is done to make movement in the fluid. This is done using a pump or blower. RADIATION Radiation is the third mode of heat transfer. This mode of heat transfer didn't require any medium to occur. Every matter having a temperature, pressure above absolute zero will emit energy in the form of electromagnetic waves and called radiation. It is the same way the energy of the Sun reach us. The key	2 2	

	features about radiation are it do not require any medium and also laws of reflection is applicable for radiation.		
b	**Significance of Power factor** Working Power – the "true" or "real" power used in all electrical appliances to perform the work of heating, lighting, motion, etc. We express this as kW or kilowatts. Common types of resistive loads are electric heating and lighting. An inductive load, like a motor, compressor or ballast, also requires Reactive Power to generate and sustain a magnetic field in order to operate. We call this non-working power kVAR's, or kilovolt-amperes-reactive. Every home and business has both resistive and inductive loads. The ratio between these two types of loads becomes important as you add more inductive equipment. Working power and reactive power make up Apparent Power, which is called kVA, kilovolt-amperes. We determine apparent power using the formula, kVA2 = kV*A. Going one step further, Power Factor (PF) is the ratio of working power to apparent power, or the formula PF = kW / kVA. A high PF benefits both the customer and utility, while a low PF indicates poor utilization of electrical power.	3	6
	Given : active power = 55 kW V = 415 V , I = 80 Amp. Apparent power = [√3 x 415 x 80] / 1000 = 57.504	3	

	Power factor = active power / apparent power = 55 / 57.504 = 0.956		
2	**Attempt any four**		**16**
a)	**Types of energy audit:** i) preliminary audit ii) detailed audit i) preliminary energy audit: indentify the quantity and the cost of energy forms and in the plant. Energy consumption in various equipment/sections , process level. Relates energy inputs to production and highlights the wastage of energy in equipment / process areas. Recommendation for low cost energy conservation measures. Identify of major areas/ equipments require indepth study / analysis ii)detailed energy audit: a comprehensive audit provides a detailed project implementation plan for a facility , since it evaluate all major energy using systems. This type of audit offers the most accurate estimate of energy savings and cost.it considers the interactive effects of all projects, accounts for the energy use of all major equipments , and include detailed energy cost saving calculation and project cost. Detailed audit is carried out in three phases: Phase I : pre audit phase Phase II : audit phase Phase III : post audit phase	4	4

b)	**Salient features of energy conservation act , 2001 :** i)Specify energy consumption standards for notified equipment and appliances ii) Direct mandatory display of label on notified equipment and appliances. iii) Prohibit manufacture , sale, purchase and import of notified equipment and appliances not conforming to energy consumption standards. iv) Notify the energy intensive industries, other establishments , and commercial buildings as designated consumers. v) Establish and prescribe the energy consumption norms and standards for designated consumers. Vi) prescribe the energy conservation buildings code for efficient use of energy etc.	1 mark each for any four	4
c)	**Properties of liquid fuel**: i) Viscosity ii) Specific gravity iii) Calorific value iv) Flash point and fire point v) Ash content vi) Water content	1 mark each for any 4	4
d)	**Thermal power plant** The theory of thermal power station or working of thermal power station is very simple. A power generation plant mainly consists of alternator runs with help of steam turbine. The steam is obtained from high pressure boilers. In coal thermal power plant, the steam is produced in high pressure in the steam boiler due to burning of fuel (pulverized coal) in boiler furnaces. This steam is further supper heated in a super heater. This supper heated steam then enters into the turbine and rotates the turbine blades. The turbine is mechanically so coupled with alternator that its rotor will rotate with the rotation of turbine	2	4

	blades. After entering in turbine the steam pressure suddenly falls and corresponding volume of the steam increases. After imparting energy to the turbine rotor the steam passes out of the turbine blades into the condenser. In the condenser the cold water is circulated with the help of pump which condenses the low pressure wet steam. This condensed water is further supplied to low pressure water heater where the low pressure steam increases the temperature of this feed water, it is again heated in high pressure. 	2	
e)	**Energy security** The basic aim of energy security for a nation is to reduce its dependency on the imported energy sources for its economic growth. India will continue to experience an energy supply shortfall throughout the forecast period. Increasing dependence on oil imports means reliance on imports from the Middle East, a region susceptible to disturbances and consequent disruptions of oil supplies. Some of the strategies that can be used to meet future challenges to their	4	4

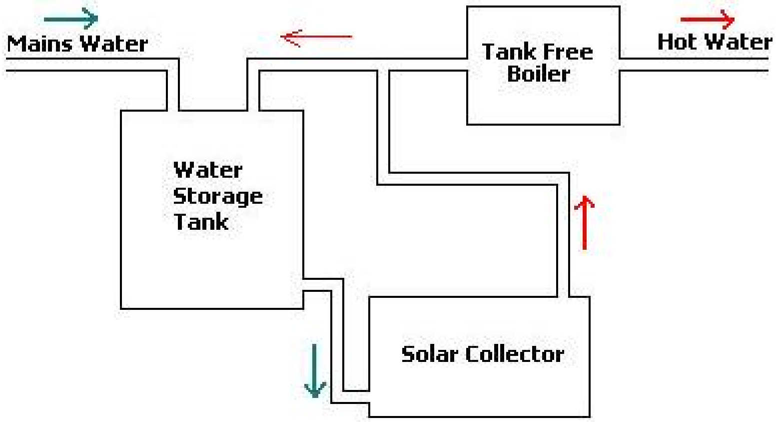
	energy security are • Building stockpiles • Diversification of energy supply sources • Increased capacity of fuel switching • Demand restraint • Development of renewable energy sources • Energy efficiency • Sustainable development		
3	**Attempt any four**		**16**
a)	**Components of wind mill** **1) Rotor:** Blades are attached to rotor and it connected by shaft to generator. **2) Blades:** Wind lift and drag force will act on blades which are connected to rotor. **3) Shaft:** It is used to transmit mechanical power produced by blades to generator. **4) Generator:** It is device used to produce electricity using mechanical energy. **5) Tower:** It is assembly on which wind turbine is placed at certain height.	1 mark each for any 4	4
b)	**Advantages of direct method:** • Plant people can evaluate quickly the efficiency of boilers • Requires few parameters for computation • Needs few instruments for monitoring **Disadvantages of direct method:** • Does not give clues to the operator as to why efficiency of system is	2 2	4

	lower • Does not calculate various losses accountable for various efficiency levels		
c)	**Benchmarking** Benchmarking is the process of comparing one's business processes and performance metrics to industry bests or best practices from other companies. **Gross production related:** kWh/MT clinker or cement produced (cement plant) kWh/kg yarn produced (textile unit) kWh/MT , kcal/kg, paper produced (paper plant) kcal/kWh power produced (heat rate of power plant) million cal/MT urea or ammonia (fertilizer plant) kWh/MT of liquid metal output (in a foundry) **utility related :** kW/ ton of refrigeration (on air conditioning plant) % thermal efficiency of a boiler plant % cooling tower effectiveness in a cooling tower kWh/Nm^3 of compressed air generated kWh/liter in a diesel power generation plant	1 1.5 1.5	4
d)	**Principle of biomass gasifier:** **Gasification** is a process that converts organic or fossil fuel based carbonaceous materials into carbon monoxide, hydrogen and carbon dioxide. This is achieved by reacting the material at high temperatures (>700 °C), without combustion, with a controlled amount of oxygen and/or steam. The resulting gas mixture is called syngas (from synthesis gas or synthetic gas) or producer gas and is itself a fuel. The power derived from gasification and	3	4

	combustion of the resultant gas is considered to be a source of renewable energy if the gasified compounds were obtained from biomass. **Applications** 1) For power generation 2) In furnaces 3) In boiler	1	
e)	**The Perform Achieve Trade (PAT)** is an innovative, market-based trading scheme announced by the Indian Government in 2008 under its National Mission on Enhanced Energy Efficiency (NMEEE) in National Action Plan on Climate Change (NAPCC). It aims to improve energy efficiency in industries by trading in energy efficiency certificates in energy-intensive sectors.The 2010 amendment to the Energy Conservation Act (ECA) provides a legal mandate to PAT. Participation in the scheme is mandatory for Designated Consumers under the ECA. It is being administered by the BEE that sets mandatory, specific targets for energy consumption for larger, energy-intensive facilities. The PAT Scheme is being implemented in three phases-the first phase runs from 2012-2015 covering 478 facilities from eight energy-intensive sectors, namely aluminum, cement, chor-alkali, fertilizer, iron and steel, pulp and paper, textiles and thermal power plants. This accounts for roughly 60% of India's total primary energy consumption. It targets energy consumption reductions of 6.6 million tons of oil equivalent in the 478 covered facilities. The scheme imposes mandatory specific energy consumption targets on the covered facilities with less energy efficient facilities having a greater reduction target than the more energy efficient ones.. A facility's baseline is determined by its historic specific energy consumption between 2007-2010. Facilities making greater reductions than their targets receive "EsCerts" or "energy	4	4

	saving certificates" which can be traded with facilities that are having trouble meeting their targets, or banked for future use. The PAT scheme establishes plant-specific targets rather than a sectoral target, with the average reduction target being 4.8% that is to be achieved by the end of the first phase (2015).		
4A	**Attempt any three**		**12**
a)	**Energy conservation measures in boiler** **Performance of Heat Transfer Areas**: The heat transfer areas of the boiler must be monitored. The soot blowing of the boiler must be done religiously as build up of soot acts like an insulator and reduces the heat transfer rate. That means for generating the same amount of steam more fuel will be needed. The same goes for the build-up of scale in the tubes. The stack temperature must be monitored regularly and any increase in it means that heat recovery is not optimum. If the funnel temperature increases about 40 deg C after last cleaning it indicates that boiler cleaning must be done. **Heat Loss Due to Inadequate Insulation**: The boiler and steam lines along with condensate return to the hot well must be well insulated. Over a period of time insulation is damaged or worn out. Any analysis by an infra red camera or infra red thermometer can identify the hot spots and optimize fuel consumption. **Optimum Hot Well temperature**: The hot well temperature must be maintained at temperature specified by manufacturers which is generally about 80 to 85 deg C. A lower temperature will cause colder feed water to enter the boiler thus increasing the fuel cost due to loss of sensible heat. An overheated hot well will cause vapour lock in the feed pump and loss of suction. **Steam Trap Losses**: Steam traps are used to discharge condensate once it is	1 mark each for any four	4

	formed, to prevent live steam from escaping and to remove air and non condensable gases from the line. **Radiation and Convection Losses**: The boiler body loses lots of heat from the exposed surfaces to the surroundings. In cold climate the loss is greater. Effective insulation can reduce these losses. **Optimize Boiler Steam pressure:** Running a boiler at lower pressure after optimizing steam usage will lower the fuel consumption. **Installation of variable speed drives**: The air dampers use throttling to obtain capacity control. **Reducing Steam Leakage**: Though this is a simply understood principle that steam leakage leads to energy and fuel loss, it is common to see many leakages of steam unattended due to either fear or apathy. Just by controlling the leakages many of the boiler operational problems can be avoided.		
b)	**Solar water heater:** Solar water heating (SWH) is the conversion of sunlight into renewable energy for water heating using a solar thermal collector. Solar water heating systems comprise various technologies that are used worldwide increasingly. In a "close-coupled" SWH system the storage tank is horizontally mounted immediately above the solar collectors on the roof. No pumping is required as the hot water naturally rises into the tank through thermo siphon flow. In a "pump-circulated" system the storage tank is ground- or floor-mounted and is below the level of the collectors; a circulating pump moves water or heat transfer fluid between the tank and the collectors. SWH systems are designed to deliver hot water for most of the year. However, in winter there sometimes may not be sufficient solar heat gain to deliver sufficient hot water.	2	4

		2	
c)	The objective of good combustion is to release all of the heat in the fuel. This is accomplished by controlling **the "three T's"** of combustion which are (1) Temperature high enough to ignite and maintain ignition of the fuel, (2) Turbulence or intimate mixing of the fuel and oxygen, and (3) Time sufficient for complete combustion • For example, in oil heat systems, the amount of time oil vapor has to combust (or reside in the flame front or burning zone) has been improved dramatically with the advent of flame retention burners. The primary difference between this type burner and the older conventional style burner is that the flame retention burners violently spin the air/fuel mixture resulting in better mixing. This reduces the amount of excess combustion air necessary to insure each fuel droplet is completely surrounded by oxygen and burns completely. As the amount of combustion air is reduced, efficiency increases. • As the temperature difference (DT or Delta T) between the source of heat and the material being heated increases, so does the rate of heat transfer. This heat transfer rate is measurable in forced air systems and boilers. By reducing the amount of combustion air introduced into the	4	4

	combustion process to the absolute minimum necessary, we increase the DT between the flame/flue gases and the distribution air or boiler water. • Turbulation of the fuel, air and heat source provides for more complete combustion by keeping these components in contact with each other for a longer period of time. Agitation of flue gases in a heat exchanger serves to provide a continual circulation of hotter flue gasses in contact with the heat exchanger surfaces.		
d)	(see table below)	1 mark for each point	4
B	**Attempt any one**		**6**
a	**Specific heat**: The specific heat is the amount of heat per unit mass required to raise the temperature by one degree Celsius. **Latent heat**: Amount of heat that changes the state of a material (from solid to liquid or liquid to gas) without raising its temperature any further.	1 1	4

Table for d):

Sr No	**Non conventional energy sources**	**Conventional energy sources**
1	These sources can renew again and again.	These sources are exhaustible after use.
2	These sources are pollution free.	These sources are creating pollution.
3	Capital investment is more but fuel cost zero for power generation	Capital investment is less but fuel cost is more for power generation
4	e.g Solar, Wind, Biomass, Hydro	e.g Coal, crude oil, Gas

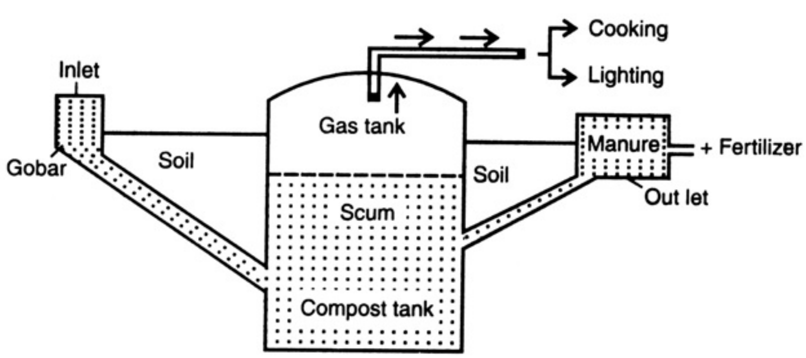
	Given data T1= 100^{o}C T2= 50^{o}C λ = 540 kca/kg Cp = 1 kcal/kg **For 1 kg steam** Q = m[λ + (Cp ΔT)]= 1[540+(1x50)] = 590 Kcal Q= 590 x 4.184 = 2468.56 KJ ***(students answer may change as per quantity of mass taken)***	4	
b	**Instruments used for energy audit:** • Electrical measuring instruments- to measure current, voltage, power, PF • Combustion analyzer- For flue gas analysis • Thermometer (contact thermometer)- For temperature measurement • Infrared thermometer- For temperature measurement • Flow meter – Doppler effect, ultra sonic – for flow measurement • Leak detector- To find change in pressure • Lux meter – to measure intensity of light	1 mark each for any six	6
Q 5	**Attempt any two**		**16**
a)	**Direct method** This is also known as 'input-output method' due to the fact that it needs only the useful output (steam) and the heat input (i.e. fuel) for evaluating the efficiency. This efficiency can be evaluated using the formula: Boiler Efficiency (η) = (Heat output/Heat input)x 100	8	8

	Boiler Efficiency (η) =[Qx(hg-hf)/q X GCV] x 100 Parameters to be monitored for the calculation of boiler efficiency by direct method are: 1. Quantity of steam generated per hour (Q) in kg/hr. 2, Quantity of fuel used per hour (q) in kg/hr. 3. The working pressure (in kg/cm2(g)) and superheat temperature (oC), if any 4.The temperature of feed water (oC) 5. Type of fuel and gross calorific value of the fuel (GCV) in kcal/kg of fuel And where hg – Enthalpy of saturated steam in kcal/kg of steam hf – Enthalpy of feed water in kcal/kg of water		
b)	**Simple payback period**: Payback period is the time in which the initial cash outflow of an investment is expected to be recovered from the cash inflows generated by the investment. It is one of the simplest investment appraisal techniques. ***Formula of payback period:*** $\text{Payback period} = \dfrac{\text{Investment required for a project}}{\text{Net annual cash inflow}}$ Importance: According to this method, the project that promises a quick recovery of initial investment is considered desirable. If the payback period of a project computed by the above formula is shorter than or equal to the management's maximum desired payback period, the project is accepted otherwise it is rejected. For example, if a company wants to recoup the cost of a machine	4	8

	within 5 years of purchase, the maximum desired payback period of the company would be 5 years. The purchase of machine would be desirable if it promises a payback period of 5 years or less. **Given data:** Investment : 20,000/- Annual saving : 35000/- Annual maintenance: 8000/- Simple payback period = Total investment/ (annual saving – annual maintenance) = 20000/(35000-8000) = 0.74 years	4	
c)	**Effect of speed variation:** A centrifugal pump is a dynamic device with the head generated from a rotating impeller. There is therefore a relationship between impeller peripheral velocity and generated head. Peripheral velocity is directly related to shaft rotational speed, for a fixed impeller diameter and so varying the rotational speed has a direct effect on the performance of the pump. All the parameters will be change if the speed is varied and it is important to have an appreciation of how these parameters vary in order to safely control a pump at different speeds. The equation relating rotodynamic pump performance parameters of flow , head and power absorbed , to speed are k/as the affinity laws: $Q \propto N$ $H \propto N^2$ $P \propto N^3$ Q = FLOW RATE H = HEAD P = POWER ABSORBED N = ROTATING SPEED	4	8

	As can be seen from the above laws, doubling the speed of the centrifugal pump will increase the power consumption by 8 times. Conversely a small reduction in speed will result in drastic reduction in power consumption. This form the basis for energy conservation in centrifugal pumps with varying flow requirements. The most commonly used method to reduce the pump speed is variable speed drive(VSD) VSD allow pump speed adjustments overa continuous range , avoiding the need to jump from speed to speed as multiple-speed pumps. VSD control pump speed. Running pump operating parameters at full speed [N] Q_1 = 38 m^3/h , H_1 =65 m , P_1 = 12.5 kW Power consumption at reduced speed (80 % of full speed) $P2 = P1 \ x \ (N_2/N_1)^3$ $P2 = 12.5 \ X \ (0.80 N_1/N_1)^3$ [here $N_2 = 0.80 N_1$] = 12.5 x 0.512 = 6.4 kW Reduction in power = 12.5 - 6.4 = 6.1 kW	4	
6	**Attempt ant two**		16
6 a)	**1) Range -** is the difference between the cooling tower water inlet and outlet temperature. **2) 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 Maximum cooling is possible upto wet bulb temperature. **Energy saving opportunities in cooling tower**	1.5 1.5 1	8

	• Follow manufacturer's recommended clearances around cooling towers and relocate or modify structures that interfere with the air intake or exhaust • Optimize cooling tower fan blade angle on a seasonal and/or load basis • Correct excessive and/or uneven fan blade tip clearance and poor fan balance • In old counter-flow cooling towers, replace old spray type nozzles with new square spray nozzles that do not clog • Replace splash bars with self-extinguishing PVC cellular film fill • Install nozzles that spray in a more uniform water pattern • Clean plugged cooling tower distribution nozzles regularly • Balance flow to cooling tower hot water basins • Cover hot water basins to minimize algae growth that contributes to fouling • Optimize the blow down flow rate, taking into account the cycles of concentration (COC) • limit • Replace slat type drift eliminators with low-pressure drop, self-extinguishing PVC cellular units • Restrict flows through large loads to design values	4	
b)	**Biogas** **Construction** It consits of inlet tank, digester and outlet tank. Sluury is prepeared in inlet tank. Mass is digeated in digester. Gas is collected at the top dome. Digested mass comes our from outlet tank. Gas is taken out by outlet pipe from top. **Working**	 3	8

	• The feed material is mixed with water in the influent collecting tank The fermentation slurry flows through the inlet into the digester. • The bacteria from the fermentation slurry are intended to produce biogas in the digester. • The process of anaerobic digestion occurs in a sequence of stages involving distinct types of bacteria. • Hydrolytic and fermentative bacteria first break down the carbohydrates, proteins and fats present in biomass feedstock into fatty acids, alcohol, carbon dioxide, hydrogen, ammonia and sulfides. • This stage is called "hydrolysis" (or "liquefaction"). • Next, acetogenic (acid-forming) bacteria further digest the products of hydrolysis into acetic acid, hydrogen and carbon dioxide. • Methanogenic (methane-forming) bacteria then convert these products into biogas. • The combustion of digester gas can supply useful energy in the form of hot air, hot water or steam.  	3 2	
c)	**Performance assessment of H.E.:** The **logarithmic mean temperature difference** (also known as **log mean temperature difference** or simply by its initialism **LMTD**) is used to determine the temperature driving force for heat transfer in flow systems, most	2	8

notably in heat exchangers. The LMTD is a logarithmic average of the temperature difference between the hot and cold feeds at each end of the double pipe exchanger. The larger the LMTD, the more heat is transferred. The use of the LMTD arises straightforwardly from the analysis of a heat exchanger with constant flow rate and fluid thermal properties.

We assume that a generic heat exchanger has two ends (which we call "A" and "B") at which the hot and cold streams enter or exit on either side; then, the LMTD is defined by the logarithmic mean as follows:

$$LMTD = \frac{\Delta T_A - \Delta T_B}{\ln\left(\frac{\Delta T_A}{\Delta T_B}\right)} = \frac{\Delta T_A - \Delta T_B}{\ln \Delta T_A - \ln \Delta T_B}$$

where ΔT_A is the temperature difference between the two streams at end *A*, and ΔT_B is the temperature difference between the two streams at end *B*. With this definition, the LMTD can be used to find the exchanged heat in a heat exchanger:

$$Q = U \times Ar \times LMTD$$

Where *Q* is the exchanged heat duty (in watts), *U* is the heat transfer coefficient (in watts per kelvin per square meter) and *Ar* is the exchange area. Note that estimating the heat transfer coefficient may be quite complicated.

Step A:

Monitoring and reading of steady state parameters of the H.E. under evaluation are tabulated as below:

parameters	units	inlet	Outlet
Hot fluid flow	Kg/h		
Cold fluid	Kg/h		

flow			
Hot fluid temp.	Deg. C		
Cold fluid temp.	Deg. C		
Hot fluid P	Bar g		
Cold fluid P	Bar g		

6

Step B:physical properties of stream can be tabulated as:

parameters	unit	Inlet	outlet
Hot fluid density	Kg/h		
Cold fluid density	Kg/h		
Hot fuid viscosity	MPas		
cold fuid viscosity	MPas		
Hot fuid them. coductivity	kW/(mK)		
Cold fuid ther. conductivity	kW/(mK)		
Hot fuid heat capacity	KJ/Kg.K		
Cold fuid heat capacity	KJ/Kg.K		

Step c:

Calculate the thermal parameters of H.E. & compare with the design data:

parameters	Unit	Test date	Design data
Heat duty	kW		
Hot fluid side P drop	Bar		
Cold fluid side P drop	Bar		
Temp. Range hot fluid	Deg. C		
Temp. Range cold fluid	Deg. C		
Capacity ratio , R	-		
Effectiveness , S	-		
Corrected LMTD	Deg. C		
H.T.Coeff. , U	KW/(m^2.K)		

Step D:

1) heat duty , Q = Q_s + Ql

Qs = sensible heat , Ql = latent heat

For sensible heat

Qs = (m x Cp x dT)hf

Qs =(m x Cp x dT)cf

For latent heat

	Ql = (m x latent heat)hf Ql = (m x latent heat)cf 2) Hot fluid side P drop , (dP)hf = Pi –Po 3) Cold fluid side P drop , (dP)cf = Pi –Po 4) Temp. Range hot fluid , dT = Ti - To 5) Temp. Range cold fluid , dt = ti – to 6) Capacity ratio , R = (Ti- To) / (to – ti) 7) Effectiveness , S = (to- ti) / (Ti –ti) 8) LMTD: LMTD for counter current flow LMTD for co-current flow Correction factor for LMTD, $F = \frac{(R + 1)^{1/2} \text{ X } \ln [(1 – S R) / (1 – S)]}{(1 – R) \text{ x } \ln \{ 2 – S [R + 1 –(R + 1)^{1/2}] / 2 – S [R + 1 + (R + 1)^{1/2} \}}$ 9) Corrected LMTD = F x LMTD 10) Overall heat transfer coeff. , U = Q / (A x Corrected LMTD)		