Regular set A

Regn No: ____________________
Name : ____________________
(To be written by the candidate)

17th NATIONAL CERTIFICATION EXAMINATION
FOR
ENERGY MANAGERS & ENERGY AUDITORS – September, 2016

PAPER – 4:Energy Performance Assessment for Equipment and Utility Systems

Date: 25.09.2016 Timings: 14:00-16:00 HRS Duration: 2 HRS

General instructions:

- *Please check that this question paper contains **6** printed pages*
- *Please check that this question paper contains **16** 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: BRIEF QUESTIONS

S-1	An air washer cools the water and a cooling tower cools the air. True or False.
Ans	**False.**
S-2	A 11 kW induction motor has an efficiency of 90% what will be its maximum delivered output?
Ans	**11 kW.**
S-3	The COP of a vapour absorption refrigeration system is lower than the COP of a vapour compression refrigeration system-True /false.
Ans	**True.**
S-4	An industrial electrical system is operating at unity power factor. Addition of further capacitors will reduce the maximum demand (kVA). True or False.
Ans	**False.**
S-5	Which parameter in the proximate analysis of coal is an index of ease of ignition?
Ans	**Volatile matter.**
S-6	The major source of heat loss in a coal fired thermal power plant is through flue gas losses in the boiler. True or false.
Ans	**False.**
S-7	With evaporative cooling, it is possible to attain water temperatures below the atmospheric wet bulb temperature. True or False
Ans	**False**
S-8	A pump is retrofitted with a VFD and operated at full speed. Will the power consumption increase or decrease or remain the same?
Ans	**Increase**
S-9	De-aeration in boiler refers to removal of dissolved gases. True or false
Ans	**True**

S-10	In a compressed air system, the function of the after cooler is to reduce the work of compression. True or False
Ans	**False**

…………. End of Section - I ………….

Section - II: SHORT NUMERICAL QUESTIONS

L-1	**In a petrochemical industry the LP & HP boilers have the same evaporation ratio of 14 using the same fuel oil. The operating details of LP & HP boiler are given below:** **Particulars / LP Boiler / HP Boiler** **Pressure: 10 Kg./cm^{2}a / 32 Kg./cm^{2}a** **Temperature: Saturated Steam / 400^{o}C** **Enthalpy of steam: 665 Kcal/kg / 732 Kcal/kg** **Enthalpy of feed water: 80^{o}C / 105^{o}C** **Evaporation Ratio: 14 / 14** **Find out the efficiency of HP boiler if the LP boiler efficiency is 80%.**
Ans	Effy η = ER. (hg – hf) / GCV Effy$_{L.P}$ η_1 = 0.8 = 14 x(665 – 80) / GCV Effy$_{H.P}$ η_2 = 14 x(732 – 105) / GCV Effy$_{H.P}$ η_2 / Effy$_{L.P}$ η_1 = (732 – 105)0.8 / (665 – 80) = 0. 8574 =85.74% **Or** Effy$_{L.P}$ η_1= 0.8 = 14 x(665 – 80) / GCV GCV= 14x(665-80) / 0.8 = 10237.5kcal/kg Effy$_{H.P}$ η_2 = 14 x(732 – 105) / GCV = 14 x(732 – 105) / 10237.5 = 0.8574 = 85.74%
L-2	**While carrying out an energy audit of a pumping system, the treated water flow (in open channel) was measured by the tracer method. 20% salt solution was used as the tracer which was dosed @ 2 lts/min. The water analysis about 500 mtrs away revealed salt concentration of 0.5%. Assuming complete mixing and no losses, calculate the water flow rate.**
Ans	20% salt solution = 200 gms of salt in 1 Litre of water 0.5% salt solution = 5 gms of salt in 1 litre of water Dosing rate = 2 lts/min Salt added in water = 2 x 200 = 400 gms/min Total flow = 400/5 = 80 lts/min Water flow rate = 80 – 2 = 78 lts/min **Or** C1V1 = C2V2 V2 = C1V1/C2 = 0.2x2/0.005 =80 lts/min Actual flow = total flow – dosage flow = 80-2 =78 lts/min

…………. End of Section - II ………….

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Section - III: LONG NUMERICAL QUESTIONS

N-1

In a chemical plant, a 3000 Million Cal/hr cooling tower with one CW pump caters to the cooling water requirements. The management had decided to refurbish the cooling tower as its performance is felt to be low. The operating parameters of the CW system before and after refurbishment are presented below.

S.No	**Parameter**	**Before refurbishment**	**After refurbishment**
1	CW inlet temp to CT	35°C	35°C
2	Atmospheric air conditions	WbT -25 °C, DbT - 38 °C	WbT -25 °C, DbT - 38 °C
3	COC	3.5	5
4	Suction head of CW pump	-1m	-1m
5	Discharge pressure of CW pump	4kg/cm^2(g)	4kg/cm^2(g)
6	Efficiency CW Pump CW Pump motor CT fan CT fan motor	 54% 89% 55% 90%	 53% 89% 54% 90%
7	Pressure developed by CT fan	20mmwc	20mmwc
8	Effectiveness of CT	60 %	70%
9	L/G ratio	1.5	1.5
10	Density of air	1.29kg/m^3	1.29kg/m^3

As a result of cooling tower refurbishment the effectiveness has increased from 60% to 70 %. Also with improved water treatment the COC has increased to 5.

Find out

1. Reduction in power consumption of pump and fan due to improvements in cooling tower.
2. Reduction in make up water consumption (ignoring drift losses) in KL/day

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Ans

Parameter	Equation / formulae	Before refurbishment	After refurbishment	
Effectiveness	= **(T_{CWi}-T_{CW0})/(**T_{CWi}-WbT)	0.6=(35- T_{CWO})/(35-25) T_{CWO} = 29 ^oC	0.7=(35- T_{CWO})/(35-25) T_{CWO} = 28 ^oC	
CW flow rate Q	= heat load/(T_{CWi}-T_{CW0})	=(3000x10^6/10^3) / (35- 29) = 500000 kg/h = 500 m3/h	=(3000x10^6/10^3)/(35-28) = 428571 kg/h = 429 m^3/hr	
Evaporation loss	=1.8*.00085*CW flow x Range	1.8x0.00085x500x (35-29) = 4.59 m^3/h	1.8x.00085x429x(35-28) = 4.59 m^3/h	
Blow down loss	= Evaporation Loss/(COC-1)	= 4.59/(3.5-1) = 1.84 m^3/h	4.59/(5-1) = 1.15 m^3/h	
Total water loss	= Eva loss+ Blow down loss	= 4.59+1.84 =6.43 m^3/h	=4.59+1.15 =5.74 m^3/h	
Make-up water	***= Total water loss x 24hrs***	***= 6.43 x 24 = 154.2 m^3/day =154.2KL/day***	***= 5.74 x 24 = 137.76m^3/day =137.76 KL/day***	
Total head H	= discharge head-suction head	= 40-(-1) = 41 mWC	= 40-(-1) = 41 mWC	
Pump LKW	= ((Q*1000/3600)*(H*9.81))/1000	= (500*1000/3600)*(41*9.81)/1000 = 55.86KW	= (429*1000/3600)*(41*9.81)/1000 = 47.9 kW	
Pump input	= Pump LKW/Eff.Pump	=55.86/0.54 =103.4 kW	= 47.9/0.53 =90.4 kW	
Motor input	***= Pump input/motor eff***	***= 103.4/0.89 =116.2 kW***	***=90.4/0.89 = 101.6kW***	
Air flow in CT fan Q_f	=[(CW flow)x1000]/ [((L/G)]*1.29)	= (500x1000/(1.5x1.29) = 258398 m^3/h	= (429x1000/(1.5x1.29) = 221705m^3/h	
H_f	Pressure developed by fan H_f	= 20mmWC	= 20mmWC	
Air KW	= [(Qf in m^3/h)*(Hf in mmWC)]/(3600*102)	=(258398*20)/(3600*102) =14.07 kW	=(221705*20)/(3600*102) = 12.08 kW	
Fan motor input	*=Air KW/(FanEffi x Motor Eff)*	***=14.07/(0.55*0.9) = 28.43kW***	***=12.058/(0.54*0.9) = 24.9 kW***	

(1) Reduction in power of pump and motor = (116.2+28.43) - (101.6+24.9) = 18.13 kW

(2) Reduction in makeup water = 154.2-137.76 = 16.44 or 16.5 KL/day

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N-2	In a beverages industry the product stream (liquid) flowing at a rate of 5000 kgs/hr at 90°C is first cooled in counter type cooling water (CW) heat exchanger to 55 °C and then by a chilled water (ChW) heat exchanger, to reduce temperature of the product to 11°C. The specific heat of the product is 0.9 kCal/kg°C. The other operating data and parameters are:

Cooling Water heat exchanger			**Chilled Water heat exchanger**		
	Inlet temp	Outlet temp		Inlet temp	Outlet temp
Product	90°C	55 °C	Product	55°C	11 °C
Cooling Water	25 °C	32 °C	Chilled water	7 °C	12 °C

The chilled water is supplied by a reciprocating chiller, whose motor is drawing 60 KW with a motor efficiency of 87%. The management decides to upgrade cooling water heat exchanger by providing additional heat exchanger area to further enhance heat recovery i.e. to reduce the temperature of product at its outlet to 40°C.

A. Depict the heat exchanger in existing and upgraded (improved) heat recovery case in a simple block diagram
B. Calculate

i. The additional heat exchanger area (as a % of the existing area) for cooling water heat exchanger, assuming there is no change in cooling water circulation rate and the overall heat transfer coefficient.
ii. The COP of the chiller.
iii. Reduction in refrigeration /chiller load and yearly energy savings at 600 hours per month operation, assuming energy consumption is proportional to load delivered.

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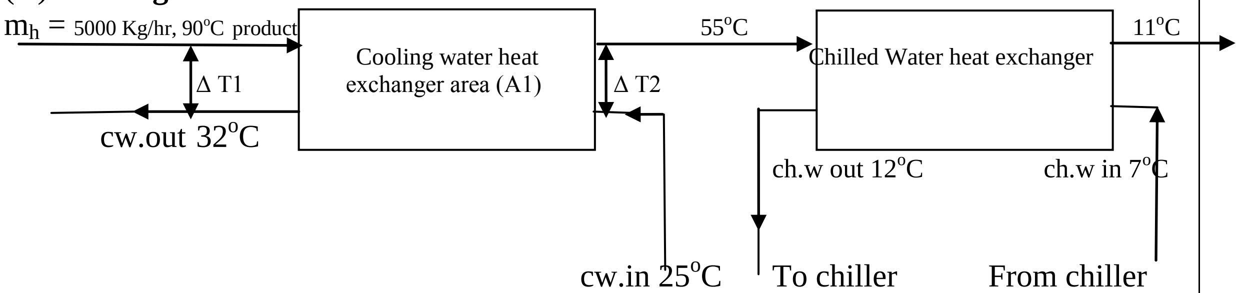
Ans

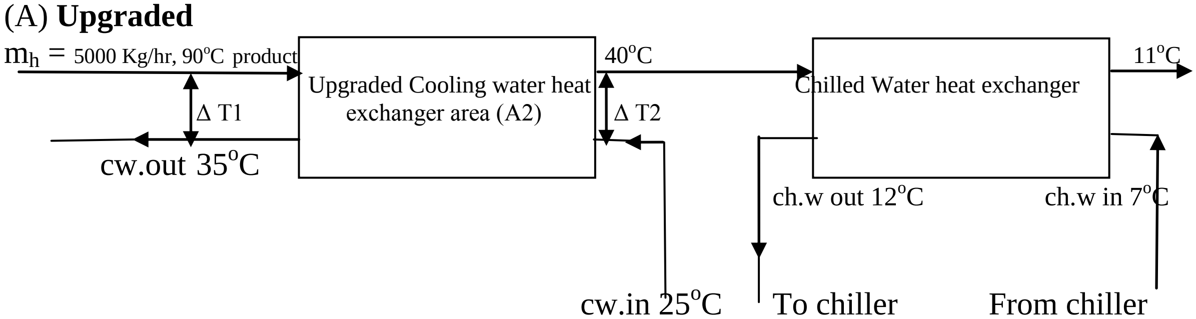
(A) **Existing**



Heat load on CW heat exchanger Heat rejected by product stream	=	heat gained by CW
$Q1 = m_c \times 1 \times (\Delta T_c)$	=	5000 X 0.9 X (90 – 55)
Q_1	=	1,57,500 Kcal/hr
m_c = Cooling Water flow rate	=	(5000X0.9 X 35)/(32 – 25) = 22,500 Kg/hr.
Heat exchanger duty with increased heat recovery Q_2	=	5000 X 0.9 X (90 – 40) = 2,25,000 Kcal/hr
Cooling water temp. Rise with increased heat exchanger duty for cooling product stream to 40°C	=	$\frac{5000 \times 0.9 \times (90-40)}{22,500} = 10^oC$

Cooling water outlet temp with the above case = 25 + 10 = 35°C

(A) **Upgraded**



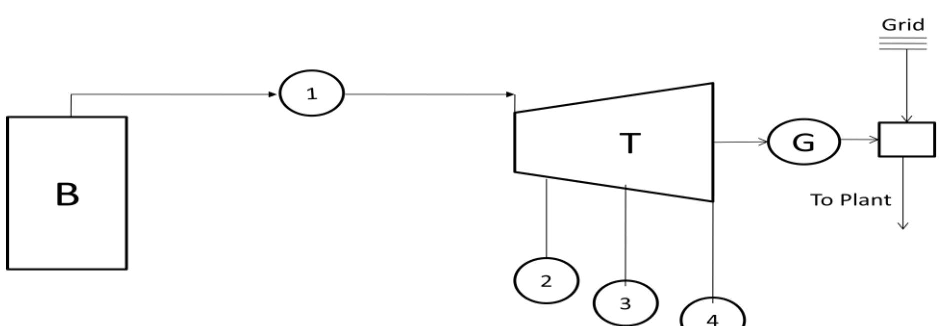
…..2.5 marks

$LMTD_1$ with existing case	$= \frac{\Delta T_1 - \Delta T_2}{L_n \Delta T_1 / \Delta T_2}$ $= \frac{(90-32)-(55-25)}{L_n (90-32)/(55-25)} = 42.49^oC$

$LMTD_2$ with additional heat recovery	$= \dfrac{(90 - 35) - (40 - 25)}{L_n (90 - 35) / (40 - 25)} = 30.77^oC$
$Q_2 = U \times A_2 \times LMTD_2$ $Q_2 = 2,25,000 = U \times A_2 \times 30.77$	$Q_1 = U \times A_1 \times LMTD_1$ $Q_1 = 1,57,500 = U \times A_1 \times 42.49$
$A_2 / A_1 = (2,25,000 / 1,57,500) \times (42.49 / 30.77) = 1.973$	

Additional area required	=	97.3% of existing heat exchanger area of CW heat exchanger
Refrigeration load in existing case	=	5000 X 0.9 X (55 – 11)
	=	1,98,000 Kcal/hr
	=	1,98,000 /3024
	=	65.476 TR
Motor input power	=	60 KW
Motor eff.	=	87%
C.O.P. of refrigeration chiller	= =	198000 /(60 X 0.87 X 860) 4.41
Input KW / TR	=	60 / 65.476 = 0.916
Reduction in refrigeration load due to lower input temperature of the product to chilled water heat exchanger	= =	5000 X 0.9 X (55 – 40) / 3024 22.32 TR
Yearly energy savings at 600 hrs. operation per month	= =	22.32 X 0.916 X 600 X 12 1,47,204.86 Kwh

N-3 In a continuous process industry Steam and Power are supplied through a cogeneration plant interconnected with grid. The design and actual operating parameters of the cogeneration plant as represented in the schematic are given in the table below.



Double Extraction – Condensing Steam Turbine Cogeneration System

		Design	actual
B -	Boiler	75tph,64kg/cm^2(a), 450^{o}C @82% efficiency	68.75tph, 64kg/cm^2(a), 450^{o}C @81% efficiency
T -	Steam Turbine	Double Extraction – Condensing type	
G -	Generator	10MW	7.2MW

Stream Ref	**Steam flow location**	**Steam Flow (tph)**	**Steam Pressure (kg/cm^2)**	**Steam Temp (^{o}C)**	**Steam enthalpy (kCal/kg)**
1	Steam input to turbine	68.75	64	450	745
2	First extraction	18.75	17	270	697
3	Second extraction	31.25	9	200	673
4	Condenser in	18.75	0.1	-	550
	Condenser out	18.75	-	-	46

The industry is installing a 1200 TR double effect absorption chiller to meet the refrigeration load due to product diversification. Additional steam will be generated by the boiler, which will go into the turbine and be extracted at 9kg/cm^2(a) to meet the VAM requirement. The additional power thus generated will reduce the imported grid power.

The following additional data has been provided:

Maximum allowable steam flow the extraction at 9 Kg/cm^{2}a	40 TPH
Minimum allowable steam to condenser	9 TPH
Critical power requirement of the plant	3800 KW
Power import from grid	500 KW
Cost of grid power	Rs.4.25 / Kwh
G.C.V. of coal	4000 Kcal/Kg.
Cost of coal	Rs. 4000/ton
Feed Water temperature	105^{o}C
Feed Water enthalpy	105 Kcal/Kg.
Combined efficiency of gear box and generator	96%
Steam requirement for double effect absorption chiller	4.5 Kg./TR hr at 9 Kg/cm^{2}a
Annual hours of operation.	8000 hrs/y
Steam rate at 9 Kg/cm^{2}a at 2nd extraction for 1 KW turbine output	12 (Kg/hr)/kW

Ignore auxiliary power consumption and also return condensate from extracted steam to process.

Calculate

(i) The Energy Utilization Factor (EUF) for the existing operating case

(ii) The net additional annual operating cost, after installation of VAM.

(iii) The Energy Utilization Factor (EUF) after installation of VAM.

Ans	(i) Energy Utilization Factor (EUF) (before VAM installation) = $\frac{\text{Q thermal + P electrical}}{\text{Fuel Consumption X G.C.V.}}$ Q thermal = $m_2 h_2 + m_3 h_3 + m_4 h'_4$ Q in = $\frac{m (h_1 - h_f)}{\eta \text{ X G.C.V.}}$ Q thermal = 18750 X 697 + 31250 X 673 + 18750 X 46 = (18.75 X 697 + 31.25 X 673 + 18.75 X 46) X 10^3 Kcal/hr = (13068 X 21031 + 862.5) X 10^3 Kcal/hr = 34962.5 X 10^3 Kcal/hr P_e = 7200 X 860 = 6192 X 10^3 Kcal/hr Fuel Consumption = $\frac{(745 - 105) \text{ X } 68.750\text{x}1000}{0.81\text{X } 4000 \text{ X } 1000}$ = 13.58 TPH EUF = $\frac{34962.5 \text{ X } 10^3 + 6192 \text{ X } 10^3}{13.58 \text{ X } 10^3 \text{ X } 4000}$ x 100 = 75.76% (ii) Refrigeration Load = 1200 TR 1TR requires 4.5 Kg./hr steam at 9 Kg./cm^{2}a Steam consumption in double effect absorption chiller = 1200 X 4.5 = 5400 Kg./hr. Increase in steam extraction at 9 Kg./ cm^{2}a = 5400Kg/hr Every 12 Kg./hr extraction at 9 kg/ cm^{2}a gives 1 KW output at turbine , efficiency of generator and gear box = 0.96 Additional power recovery due to increase in extraction = (5400 / 12) X 0.96 = 432 KW Additional coal consumption due to increase in extraction = (745 – 105)X 5400/(0.81x4000) = 1066 kg/h Additional cost of coal = 4000x1.066 = Rs 4266.6 /hr ***…..2 marks*** Monetary realisation by reducing import cost of purchased electricity = 4.25 Rs./unit = 432 X 4.25 = 1836 Rs./hr

Net additional annual operating cost after VAM installation = (4266.6-1836)*8000
= Rs 1.94 crore/y

(iii)

Stream Ref	Steam flow location	Steam Flow (tph)	Steam Pressure (kg/cm^2)	Steam Temp (^oC)	Steam enthalpy (kCal/kg)
1	Steam input to turbine	68.75+5.4 =74.15	64	450	745
2	First extraction	18.75	17	270	697
3	Second extraction	31.25+5.4 =36.65	9	200	673
4	Condenser in	18.75	0.1	-	550
	Condenser out	18.75	-	-	46

Energy Utilization Factor (EUF)= (after VAM installation)

$$EUF = \frac{\text{Q thermal + P electrical}}{\text{Fuel Consumption X G.C.V.}}$$

Q thermal = $m_2 h_2 + m_3 h_3 + m_4 h'_4$

$$\text{Q in} = \frac{m\,(h_1 - h_f)}{\eta \text{ X G.C.V.}}$$

Q thermal = 18750 X 697 + 36650 X 673 + 18750 X 46
=(18.75 X 697 + 36.65 X 673 + 18.75 X 46) X 10^3 Kcal/hr
= (13068 X 21031 + 862.5) X 10^3 Kcal/hr
= 38596.7 X 10^3 Kcal/hr

P_e = (7200+432) X 860
= 6563.5 X 10^3 Kcal/hr

Fuel Consumption = 13.58 TPH +1.066 TPH = 14.646TPH

$$EUF = \frac{38596.7 \text{ X } 10^3 + 6563.5 \text{ X } 10^3}{14.646 \text{ X } 10^3 \text{ X } 4000} \text{x100} = 77.08\%$$

N-4	**Answer ANY ONE OF THE FOLLOWING among A, B, C and D**
A)	The operating parameters observed w.r.t. design in a 110 MW power generation unit are given below:

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	(table below)

Parameters	Design	Operation
Generator output	110 MW	110 MW
Steam generator outlet super heat temperature	540°C	525°C
Steam generator outlet pressure	140 Kg/cm^{2}a	130 Kg/cm^{2}a
Feed water inlet temperature	135°C	135°C
Boiler η	87.5%	87.5%
GCV of Coal	3800	3800
Turbine exhaust pressure	0.09 Kg./cm^{2}a	0.11 Kg./cm^{2}a
Dryness fraction of exhaust steam	0.87	0.89
Turbine heat rate	2362.5 Kcal /Kwh	------
Efficiency generator	96%	96%
Energy loss in gear box	4420 KW	4420 KW
Enthalpy of steam at 520°C, 130 Kg/cm^{2}a,		810 Kcal/Kg.
Enthalpy of steam at 0.11 Kg./cm^{2}a		550 Kcal/Kg

Calculate the

I. Actual steam flow to the turbine
II. Specific steam consumption of turbine
III. % increase in gross unit heat rate compared to design
IV. Increase in monthly (720 hours/month) coal consumption due to deviation in operation w.r.t. design at a plant load factor of 80%

Ans

Generator output	=	110 MW	
η of generator		96%	
Generator input	= =	110 / 0.96 114.58 MW	
Energy loss in gear box	= =	4420 KW 4.42 MW	
Turbine output	=	Total input at gear box + energy loss in gear box	
Turbine out put	= =	114.58 + 4.42 119 MW	
Turbine out put	=	m_s (810 – 550) X (1 / 860)	

	m_s (810 – 550) X (1 / 860)	=	119 X 1000	
	Steam flow rate through the turbine	= =	***3,93,615 Kg /hr*** ***393.615 Tonne/hr***	
	Specific steam consumption	= =	***(393.615 X 1000) / (110 X 1000)*** ***3.58 Kg./kW***	
	Boiler η	=	$\frac{M_s (h_g – h_w)}{GCV \times m_f}$ X 100	
	Coal consumption m_f		$\frac{393615 (810 – 135)}{0.875 \times 3800}$ ***79906.8 Kg./hr***	
	Specific coal consumption	= =	***79906.8 / (110 X 1000)*** ***0.726 Kg./Kwh***	
	Actual unit heat rate	= =	***0.726 X 3800*** ***2758.8 Kcal/Kwh***	
	Design turbine heat rate η of steam generator or boiler		***2362.5 Kcal / KW*** ***87.5%***	
	Design unit heat rate	= =	***2362.5 / 0.875*** ***2700 Kcal/Kwh***	
	% increase in heat rate w.r.t. design	= =	***[(2758.8 – 2700) / 2700] X 100*** ***2.17 %***	
	Specific coal consumption for design heat rate	= =	***2700/3800*** ***0.71kg/kwh***	
	Additional coal consumption per month with a PLF of 80%	= =	$\frac{(0.726 – 0.71) \times 110 \times 1000 \times 0.8 \times 720}{1000}$ ***1013.76 tonnes***	

Or

B) In a textile process house the production from the stenter machine is 72000 mtrs per day. The effective operation of stenter is 20 hours per day. The percentage moisture in the dried cloth (output) is 6% and its temperature is 75^{o}C and wet cloth inlet is at 25^{o}C . The stenter is heated by steam at 8 kg/cm^{2}a and the daily steam consumption for the stenter is 16.5 tonnes. The efficiency of the stenter dryer is 47%. Calculate the

(i) Linear speed of the stenter machine
(ii) Inlet moisture
(iii) Feed rate of the stenter.

The following data have been provided

Weight of 10 meter of dried cloth = 1 kg.
Enthalpy of the steam to the stenter = 665 kcal/kg.

	Enthalpy of condensate at the exit of stenter = 130 kcal/kg. Ignore losses in start-up and stoppage.
Ans	Production per day = 72000 meters Actual hours of operation = 20 hours/ day **Linear speed of the stenter = 72000 / (20x60) = 60 meters per min** Dried cloth output = 72000 / (20x10) = 360 kg/hr. Moisture in dry cloth = 6% Bone dry cloth = 360 x 0.94 = 338.4 kg/hr Moisture in outlet cloth m_o = (360 – 338.4) / 338.4 = 0.0638 Kg./Kg. bone dry cloth Steam consumption per day = 16.5 tonnes = 16500 / 20 = 825 Kg./hr. Heat load on the dryer =Energy input in steam x Dryer Efficiency = Steam flow rate x (Enthalpy steam – Enthalpy condensate) x Efficiency Dryer = 825 x (665 – 130) x 0.47 = 207446.3 Kcal/hr. Further Heat load on the dryer = w x (m_i – m_o) X [(T_{out} – T_{in}) + 540] Kcal/hr. w =weight of bone dry cloth rate kg/hr m_i = weight of cloth inlet moisture Kg./Kg. bone dry cloth T_{out} = dried cloth outlet temperature= 75^oC T_{in} = wet cloth inlet temperature = 25^oC 338.4 x (m_i – 0.0638) X [(75 – 25) + 540] = 207446.3 Kcal/hr m_i = 1.1028 Kg./Kg. bone dry cloth(1.1028) / (1.1028+1)x100 % inlet moisture in wet cloth = 52.44 % total moisture in inlet cloth = 1.1028x338.4= 373.2 kg/hr feed rate(inlet cloth rate), = total inlet moisture/hr +bone dry cloth/hr = 373.2+338.4 = 711.6 Kg./hr.
	or
C)	The preheater exhaust gas from a cement kiln has the following composition on dry basis :CO2 – 23.9%, O2 – 5.9%, CO – 0.2%, remaining is N2. The static pressure and temperature measured in the duct are -730 mmWC and 350^{0}C respectively. The velocity pressure measured with a pitot tube is 19 mmWC in a duct of 2800 mm diameter (Pitot tube constant = 0.89). The atmospheric pressure at the site is 10350 mmWC and universal gas constant is 847.84 mmWCm^3/kg mol k. The specific heat capacity of preheater exhaust gas is 0.25 kcals/kg^{0}C.

	The static pressure developed by PH exhaust fan is 630mmWC and power drawn is 1582 kW. Calculate the efficiency of fan given that the motor efficiency is 92%. The management had decided to install a 1.3 MW power plant with a cycle efficiency of 15% by using this preheater exhaust gas. Calculate the exhaust gas temperature at the outlet of waste heat recovery boiler of the power plant.
Ans	Molecular weight exhaust gas (dry basis) M = $\%CO_2 x M_{CO2} + \%O_2 x M_{O2} + \%CO x M_{CO} + \%N_2 \text{ x } MN_2$ = {(23.9 x 44) + (5.9 x 32) + (0.2 x 28) + (70 x 28)}/100 = 32.06 kg/kg mole Exhaust Gas density at operating temperature = γ= [PM / RT] = [(10350 – 730) x 32.06) / { 847.84 x (273+350) } = 0.584 kg/m^3 Duct Area = $3.14 \text{ x}(2.8/2)^2 = 6.15 \text{ m}^2$ Volume flow rate $= A\ Cp\ (2 \times g \times \Delta P / \gamma)^{1/2} = 6.15 \times 0.89\ (2 \times 9.81 \times 19 / 0.584)^{1/2}$ = $138.3 \text{ m}^3/s$ Volume flow rate= $497880 \text{ m}^3/ h$ Fan efficiency = <u>volumetric flow rate x pressure developed</u> (102 x power drawn x motor eff) $= \frac{138.3 \times 630}{(102 \times 1582 \times 0.92)} \times 100 = 58.69\%$ Mass flow rate of preheater exhaust gas = Volume flow rate x density = 497880*0.584 = 2,90,762 kg/hr Heat equivalent of power generated from power plant =1.3MW =1300 x 860 = 1118000 kCals/hr Heat given up to power plant by exhaust gas = $290762 \times 0.25 \times (350-T_o) \times 0.15$ $T_o = 350 - (1118000/(290945 \times 0.25 \times 0.15)) = 247.5^0$**C**
	or
D)	For a commercial building, using the following data, (i) Determine the building cooling load in TR (ii) Calculate the supply air quantity to the cooling space in m^3/s Outdoor conditions : DBT = 40°C, WBT = 28°C, Humidity = 19 g of water / kg of dry air Desired indoor conditions : DBT = 25°C, RH = 60 %, Humidity = 12 g of water / kg of dry air

	Total area of wall = 324 m^2, out of which 50% is window area. U – Factor (Wall) = 0.33 W/m^2K U – Factor (Roof) = 0.323 W/m^2K U – factor [fixed windows with aluminium frames and a thermal break] = 3.56 W/m^2K Other data: • 20 m x 25 m roof constructed of 100 mm concrete with 90 mm insulation & steel decking. • CLTD at 17:00 hr : Details : Wall = 12°C; Roof = 44°C; Glass Window = 7°C • SCL at 17 : 00 hr : Details : Glass Window = 605 W/ m^2 • Shading coefficient of Window = 0.74 • Space is occupied from 8:00 to 17:00 hr by 30 people doing moderately active work. • Sensible heat gain / person = 75 W ; Latent heat gain / person = 55 W ; CLF for people = 0.9 • Fluorescent light in space = 21.5 W/m^2 ; CLF for lighting = 0.9 • Ballast factor details = 1.2 for fluorescent lights & 1.0 for incandescent lights • Computers and office equipment in space produces 5.4 W/m^2 of sensible heat • One coffee maker produces 1050 W of sensible heat and 450 W of latent heat. • Air changes/hr of infiltration = 0.3 • Height of building = 3.6 m • Supply air dry bulb temperature is 15^0C
Ans	**(i) Cooling Load Determination:** **I. External Heat Gain** (i) Conduction heat gain through the wall = U – factor x net area of wall x CLTD = 0.33 x (324*0.5) x 12] = 641.5 W (ii) Conduction heat gain through the roof = U – factor x net area of roof x CLTD = 0.323 x (20 x 25) x 44 = 7106 W (iii) Conduction heat gain through the windows = U – factor x net area of windows x CLTD = (3.56 x 162 x 7) = 4037 W (iv) Solar radiation through glass = Surface area x Shading coefficient x SCL = (162 x 0.74 x 605) = 72527 W **II. Internal Heat Gain** (i) Heat gain from people =Sensible heat gain + Latent heat gain

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Sensible heat gain = (No. of people x Sensible heat gain / person x CLF)
=(30 x 75 x 0.9) = 2025 W

Latent heat gain = No. of people x Latent heat gain / person
= (30 x 55) = 1650 W
Therefore, Heat gain from people = (2025 + 1650) = 3675 W

(ii) Heat gain from lighting = (Energy input x Ballast factor x CLF)
Energy input = (Amount of lighting in space / unit area)x Floor area
= 21.5 x (20 x 25) = 10750 W

Therefore, heat gain from lighting = (10750 x 1.2 x 0.9) =11610 W

(iii) Heat generated by equipment :

Sensible heat generated by coffee maker =1050 W
Latent heat generated by coffee maker = 450 W
Sensible heat gain by computers and office equipment = 5.4 x 500 = 2700 W
Therefore, Heat generated by equipment = 4200 W

(iv)Heat gain through air infiltration = (Sensible heat gain + Latent heat gain)

Sensible heat gain =(1210 x airflow x ΔT)
Airflow = (Volume of space x air change rate) / 3600
= { (20 x 25 x 3.6) x 0.3 } / 3600
= 0.15 m^3 / s

Therefore, sensible heat gain =1210 x 0.15 x (40 – 25) =2722.5 W

Latent heat gain =3010 x 0.15 x (19 – 12) =3160.5 W

No.	Space Load Components	Sensible Heat Load (W)	Latent Heat Load (W)
1.	Conduction through exterior wall	641.5	---
2.	Conduction through roof	7106	---
3.	Conduction through windows	4037.0	---
4.	Solar radiation through windows	72527	---
5.	Heat gained from people	2025	1650
6.	Heat gained from lighting	11610	---
7.	Heat gained from equipment	3750	450
8.	Heat gained by air infiltration	2722.5	3160.5
	Total space cooling load	**104419**	**5260.5**
Total Cooling Load = **109679.5W/3516 =31.2 TR**			

(ii) Supply Air Quantity Calculation:
Supply air flow = Sensible heat gain / {1210 * (Room dry bulb temperature – Supply dry bulb temperature)}
= 104419 W / {1210 J/m^{30}K*(25 – 15)^{0}C}
= 8.63 m^3/s

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