SUPPLEMENTARY **Paper 4 – Set B**

Regn No: ____________________

Name : ____________________
(To be written by the candidate)

16th 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	If the speed of a reciprocating compressor is reduced with a VFD, the power drawn will reduce as cube of speed. True or False
Ans	**False**
S-2	A fluid coupling varies the speed of the driven equipment by varying the speed of the motor. True or False
Ans	**False**
S-3	With increase of steam pressure, the enthalpy of evaporation and specific volume increases. True or False
Ans	**False**
S-4	A pump handling water is now handling brine at same flow and head. Will the power consumption increase or decrease or remain the same
Ans	**Increase**
S-5	If the steam generation in a boiler is reduced to 45 %, the radiation loss from the surface of boiler will reduce by the same ratio. True or false
Ans	**False**
S-6	The speed of an A.C. induction motor is proportional to number of poles. True or False
Ans	**False**
S-7	A pump is retrofitted with a VFD and operated at full speed. Will the power consumption increase or decrease?
Ans	**Increase**
S-8	Which parameter in the proximate analysis of coal is an index of ease of ignition ?.

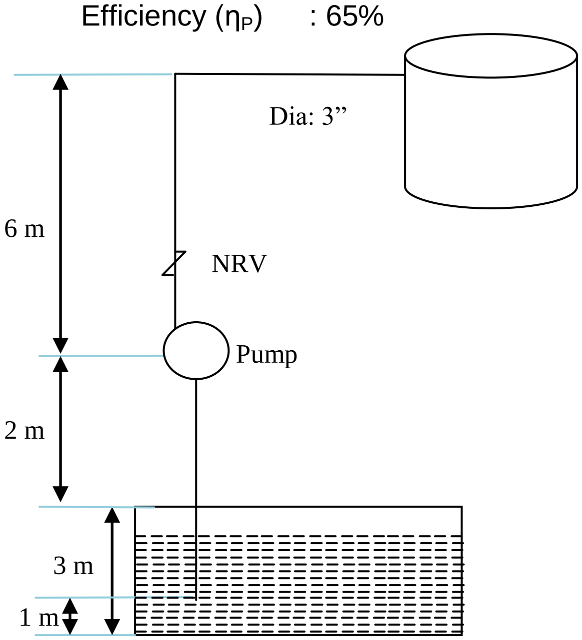
Ans	**Volatile matter**
S-9	With evaporative cooling, it is possible to attain water temperatures below the atmospheric wet bulb temperature. True or False
Ans	**False**
S-10	The major source of heat loss in a coal fired thermal power plant is through flue gas losses in the boiler. True or false
Ans	**False**

………… End of Section - I …………

Section - II: SHORT NUMERICAL QUESTIONS

<table>
<tr><td>L-1</td><td>The following sketch shows the details of an installed pumping system. The rated parameters of the pump are:

Flow (Q) : 30 lps
Head (H) : 20 m
Power (P) : 10 kW
Efficiency (η_P) : 65%



Under normal operating conditions,
1. What will be the total head delivered by the pump if pressure drop across the NRV is 0.2 kg/cm^2
2. What will be the impact on flow rate and power consumption of this pump due to above operation condition?</td></tr>
<tr><td>Ans</td><td>1. Operating head = Discharge head (6 m) - Suction head (- 4 m) + Head loss in NRV (2m)
= 12 m.</td></tr>
</table>

	1. Actual flow rate from the pump will be higher than the rated flow rate due to lower operating head. 2. Actual power consumption will increase due to higher flow rate 3. Pump operating efficiency will be less than the design efficiency under actual conditions.
L-2	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 / 100^{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 – 100) / GCV Effy$_{H.P}$ η_2 / Effy$_{L.P}$ η_1 = (732 – 100)0.8 / (665 – 80) = 0. 8643 =86.43% **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 – 100) / GCV = 14 x(732 – 100) / 10237.5 = 0.8643 = 86.43%

…………. End of Section - II ………….

Section - III: LONG NUMERICAL QUESTIONS

N - 1 An old stoker fired boiler of 24 Tonne/hr delivering 20 tonne/hr of steam on a continuous basis was converted to atmospheric fluidised boiler (AFBC) to improve the efficiency. The existing stoker fired boiler was operating with the following data and parameters:

The ultimate analysis of coal (fuel):

Carbon	Hydrogen	Sulphur	Oxygen	Nitrogen	Moisture	Ash	G.C.V
40%	4%	0.6%	7%	1%	4.4%	43%	4000kCal /kg

Operating Parameters (in both the cases):

Parameter	**Unit**	**value**
Steam Pressure	Kg./cm^{2}a	20
Enthalpy of Steam	kCal/Kg	690

Steam temp	^oC	250
Feed water enthalpy	kCal/kg	95
Heat loss due to presence of H_2 & Moisture	%	6.5
Flue gas temperature	^oC	165
Ambient temperature	^oC	30
Specific heat of fluegases	kCal/kg^oC	0.27
Radiation and other unaccounted losses	%	2.0
CO2 actual in dry flue gas	%	11

Operating parameters (that have changed):

Parameter	CO in flue gas	GCV of Bottom Ash	GCV of fly Ash	Ratio of bottom ash to fly ash
units	PPM	kCal/kg	kCal/kg	
Before conversion	700	950	500	90:10
After conversion	nil	800	400	20:80

Find out the daily reduction in coal consumption after converting to AFBC boiler.

Carbon = 40%; H_2 = 4%; S = 0.6%; Ash = 43%; O_2 = 7%; N_2 = 1%; Moisture = 4.4%

Theoretical air reqd. = [11.6 C + 34.8 (H – O/8) + 4.35 S]

Where C, H, O, S are percentages by weight per Kg of coal.

= [11.6x 40 + {34.8 (4 – 7/8)} + 4.35 x 0.6] x 1/100

= 5.754 Kg. air / Kg. coal

$$\% CO_2 (_{th}) = \frac{\text{Mole C}}{\text{Mole } N_2 + \text{Mole C} + \text{Mole S}}$$

$$\text{Mole } N_2 = \frac{\text{Wt. of } N_2 \text{ in theoretical air}}{\text{Mol Wt. of N2}} + \frac{\text{Wt. } N_2 \text{ in Fuel}}{\text{Mol Wt. of N2}}$$

$$= \frac{5.754 \text{ X } 0.77}{28} + \frac{0.01}{28} = 0.1586$$

Mole C = 0.4 / 12 = 0.033

Mole S = 0.006 / 32 = 0.0001875

$$\therefore CO_2 (_{th}) = \frac{0.033}{}$$

0.033 + 0.1586 + 0.0001875

= 0.033 / 0.1916 = 17.2 %

Actual CO_2 measured = 11%

$$\% EA = \frac{7900 \times [(CO_2\ \%)t - (CO_2\ \%)_a]}{(CO_2\ \%)_a \times (100 - (CO_2\ \%)_{th})}$$

$$= \frac{7900 \times (17.2 - 11)}{11 \times (100 - 17.20)} = \frac{49.138}{11 \times 82.78} = 53.8 = \text{say } 54\%$$

Actual Air Supplied (AAS) = 5.754 x (1.54) = 8.86 Kg. air / Kg. coal

Mass of Dry flue gas = Mass of combustion gases due to C, H, O & S + Mass of N_2 in fuel + Mass of N_2 in AAS + Mass of oxygen in flue gas due to excess air supplied

= 0.4 X 44/12 + 0.01 + 8.86 X 0.77 + (8.86 – 5.754) 0.23 + .006 X 64/32

= 1.46 + 0.01 + 6.822 + 0.7144 + 0.012 = 9.02 Kg / Kg. coal

$T_{fg} = 165^oC$

$$\text{*Heat loss due to dry flue gas} = \frac{9.02 \times 0.27 \times (165 - 30)}{4000} \times 100 = 8.2\ \%$$

*Heat loss due to H_2 & moisture in fuel = 6.5 % given
Ratio of bottom to fly ash = 90 : 10
GCV fly ash = 450 Kcal
Fly ash in Coal = 0.1 X .43 = 0.043 Kg/Kg. Coal
Heat loss due to fly ash = 0.043 X (500 / 4000) X 100
*Heat loss due to fly ash = 0.54%

Bottom ash qty. = 0.9 X 0.43 = 0.387 Kg. / Kg. Cal
*Heat loss in bottom ash = 0.387 X(950 / 4000)x100 = 9.19 %

$$CO_{loss} = \frac{\%\ CO \times C}{\%\ CO \times \%\ CO_{2a}} \times \frac{5654}{\text{GCV of fuel}} \times 100$$

CO = 700 p.p.m
= 0.07 %

$$= \frac{0.07 \times 0.4}{0.07 + 11} \times \frac{5654}{4000} \times 100$$

*Heat loss due to partial combustion of carbon to CO = 0.357 % = 0.36%

*Heat loss in dfg = 8.2%
* Heat loss due to presence of H_2 & M = 6.5%
* Heat loss in fly ash = 0.54%
* Heat loss in bottom ash = 9.19%
*Heat loss due to CO = 0.36%
* Radiation & other unaccounted losses = 2.00 %

Effy η = 100 – % total losses
η = 100 – [8.2 + 6.5 + 0.36 + 0.54 + 9.19 + 2.00] = 73.21%

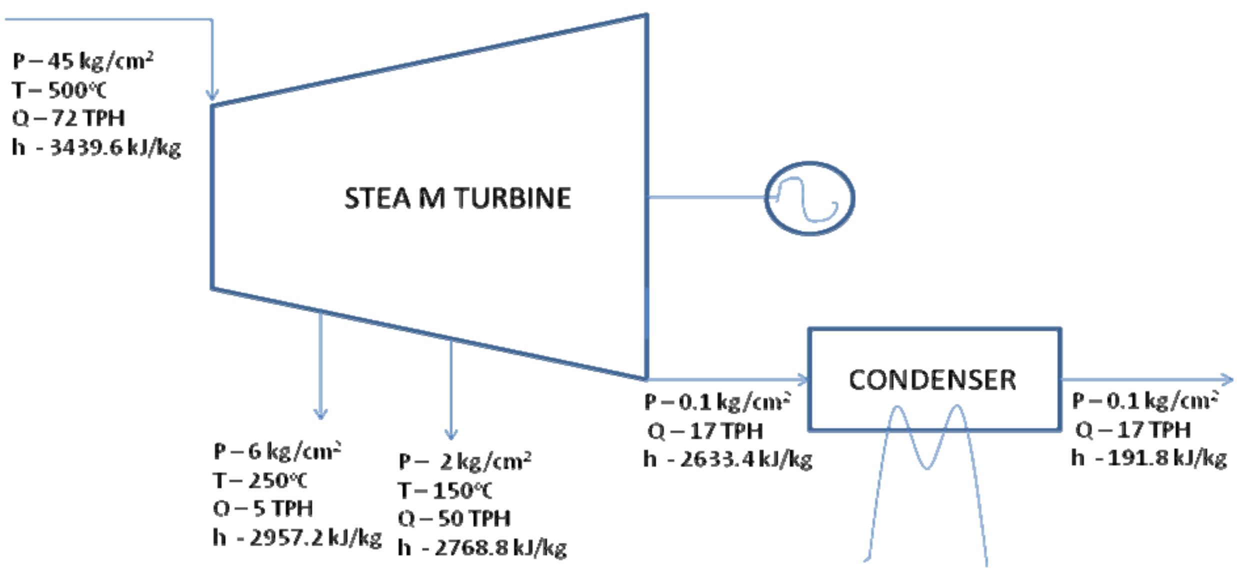
In case of FBC boiler bottom to fly ash is 20 : 80
GCV of fly ash = 400 Kcal/Kg; GCV of bottom ash = 800 Kcal/Kg.
*Heat loss in fly ash = 0.8 X 0.43 = 0.344 Kg. fly ash / Kcal.
*Heat loss due to fly ash = 0.344 X(400 / 4000)X100
= 3.44%

Bottom ash = 0.2 X 0.43 = .086 Kg/Kg. Cal
*Heat loss in bottom ash = 0.086 X(800 / 4000)X100 = 1.72%

Heat loss =
*Heat loss due to dfg = 8.2 %
*Heat loss due to H2 & M = 6.5 %
*Heat loss due to fly ash = 3.44 %
*Heat loss due to bottom ash = 1.72 %
*Radiation other losses = 2.0 %
Total Loss = 21.86 %

Effy η = 100 – 21.73
Efficiency of boiler after conclusion to FBC = 78.14 %

$$\text{Effy } \eta = \frac{m_s (h_g - h_f)}{M_f \times GCV}$$

	$$mf = \frac{20000\ (690 - 95)}{0.7321 \times 4000}$$ Coal consumption with stoker fired system = 4063.6 Kgs/hr = 4.06 Tonnes/hr. $$\text{With AFBC conversion, } mf = \frac{20000\ (690 - 95)}{0.7814 \times 4000}$$ Coal consumption = 3807.3 Kg./hr = say 3.8 Tonnes / hr. Saving in daily coal consumption = (4.06-3.8) X 24 = 6.24 Tonnes / day
N-2	For a double extraction cum condensing turbine with data as given in the following diagram, evaluate a. Power generated if the efficiency of the turbine is 90 % b. Cooling water flow rate circulation in the condenser if the range is 7°C 

a. Power generated if the efficiency of the turbine is 90 %

Input heat to turbine = 72000 x 3439.6
= 2.477×10^8 kJ/hr
= 2.477×10^8 / 3600
= 68792 kW

Output heat of different streams

1st extraction = 5000 x 2957.2
= 0.148×10^8 kJ/hr
= 4107 kW

2nd t extraction = 50,000 x 2768.8
= 1.38×10^8 kJ/hr
= 38456 kW

Condenser input heat load
= 17,000 x 2633.4
= 0.448×10^8 kJ/hr
= 12436 kW

Total heat leaving the turbine = 4107 + 38456 + 12436
= 54999 kW

Heat available for power generation = 68792 – 54999

= 13793 kW

Power generation at 0.9 turbine efficiency = 13793 x 0.9
= 12414 kW

b. cooling water flow rate circulation in the condenser if the range is 7^{o}C
Condenser load = 17,000 x (2633.4 – 191.8)
= 415072000kJ/hr
= 415072000 /4.18 = 9929952.15kCal/hr

At a range of 7^{o}C cooling water flow rate = 9929952.15 / 7
= 1418.56m^3/hr

N-3 In a plant, a single cell 3000 million cal/hr, cooling tower with one CW pump is operated for cooling water system. The operating parameters are tabulated as 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/cm2	4kg/cm2
6	Efficiency CW Pump CW Pump motor CT fan CT fan motor	 54% 89% 60% 90%	 53% 89% 64% 90%
7	Pressure developed by CT fan	20mmwc	20mmwc
8	Approach	4°C	3°C
9	L/G ratio	1.5	1.5
10	Density of air	1.29kg/m^3	1.29kg/m^3

The cooling tower is refurbished as a result of which the effectiveness has increased to 70 %. Also with improved water treatment the COC is 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

Parameter	Equation / formulae	Before refurbishment	After refurbishment	
approach	= T_{CW0}-WbT Twco = approach+ Wbt	=4+25 =29°C	=3+25 =28°C	
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***	***= 103.4/0.9 =116.2 kW***	***=90.4/0.9 = 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 xMotor Eff)*	***=14.07/(0.60*0.9) = 26.05kW***	***=12.058/(0.64*0.9) = 20.93 kW***	

(1) Reduction in power of pump and motor = (116.2+26.05) - (101.6+20.93)= 19.72 kW

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

N-4 **Answer ANY ONE OF THE FOLLOWING among A, B, C and D**

A) A utility type captive thermal power plant of 65 MW is generating an output of 60 MW at the generator . Steam generated in the boiler at 105 kg/cm^{2}a and 510^{o}C is expanded in the steam turbine exhausting to condenser maintained at 0.1 kg/cm^{2}a and 45.5^{o}C. The cooling water flow rate through the condenser is 166m^3 per min. The other operating data and particulars are,

Enthalpy of steam at 105 kg/cm^{2}a & 510^{o}C = 805 Kcal/kg.
Enthalpy of steam at turbine outlet = 565 Kcal/Kg.
Enthalpy of water at condenser pressure 0.1 kg/cm^{2}a &at 45.5^{o}C = 45.5 Kcal/Kg.
Inlet/outlet temperature of cooling water at the condenser =26^{o}C/38^{o}C
The efficiency of the generator = 95%
Enthalpy of saturated steam at 10kg/cm^{2}a = 665 Kcal/Kg.

Based on the above, find out,
a. Heat load on the condenser in million kcal/hr
b. Output of the steam turbine in KW
c. Loss in the gear box in KW
d. Condenser effectiveness
e. DM water at 135^{o}C to be sprayed for desuperheating of boiler steam after pressure reduction to 10 kg/cm^{2}a required for auxiliary service in kgs/tonne steam

Ans

	a.	Heat load on the condenser	= 166 x 60 x 1000(38-26)/1000000 **= 119.52 million kcal/hr**
	b.	Inlet enthalpy of steam to condenser Steam flowrate through the turbine	= outlet enthalpy of steam from turbine = 119.52x 1000000/(565-45.5) = 230000 kg/hr = 230.0 tonne/hr
		Inlet enthalpy to turbine **Steam turbine out put**	= 805 kcal/kg =230000 x (805-565) **= 64186.00 KW**
	c.	Generator out put Generator efficiency Generator input	= 60000.0 KW =95% =60000.00 / 0.95 = 63157.9 KW
		Loss in gear box	= 64186 .00 – 63157.9 **= 1028.1 kw**
	d.	Cooling water inlet temperature Cooling water outlet temperature Inlet steam temperature to condenser	= $26^{o}C$ = $38^{o}C$ = $45.5^{o}C$
		∴ Condenser effectiveness i.e. € =	= (Cooling water temp. rise) / (Inlet steam temp. to condenser – inlet cooling water temp.) = (38 – 26) / (45.5 – 26) = 0.615
	e.	Quantity of DM water to be sprayed for desuperheating ms= mass ofhigh pressure superheated steam mw= mass of DM water to be sprayed ms x 805 + mw x 135 = (ms + mw) x 665 Enthalpy of 105 kg/cm^2a, $510^{o}C$ superheated steam 805 kcal/kg Enthalpy of saturated steam at 10 kg/cm^2a 665 kcal/kg Enthalpy of DM water at $135^{o}C$ = 135 kcal/kg assumed ms (805 – 665) = mw (665 – 135) mw / ms = (805 – 665) /(665 – 135) = 0.264 kg water / kg steam	

	= 264 kg water/ tonne steam
	or
B)	The preheater exhaust gas from a cement kiln has the following composition on dry basis : CO_2 – 23.9%, O_2 – 5.9%, CO – 0.2%, remaining is N_2. The static pressure and temperature measured in the duct are -730 mmWC and 350^0C 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 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 plant has decided to install a waste heat recovery power plant with the heat rate of 5200 kcals/kWh. The temperature drop across the waste heat boiler of the power plant is 100^0C. calculate the maximum possible power generation from this system?
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 x(2.8/2) ^{2}= 6.15 m^2 Volume flow rate =A Cp $(2 \text{ x g x } \Delta P / \gamma)^{1/2}$ = 6.15 x 0.89 $(2 \text{ x } 9.81 \text{x } 19/0.0.584)^{1/2}$ = 138.4 m^3/s Volume flow rate = 498194 m^3/ h Fan efficiency = $\frac{\text{volumetric flow rate x pressure developed}}{\text{(102 x power drawn x motor eff)}}$ = $\frac{138.4 \text{ x } 630}{(102 \text{x} 1582 \text{x} 0.92)}$ x100 = 59% Mass flow rate of preheater exhaust gas = Volume flow rate x density = 498194*0.584 = 2,90,945 kg/hr Heat given up to power plant by exhaust gas = 290945 x0.25 x100

	= 7273625 kcals/hr Maximum possible power generation from the WHR power plant =7273625/5200 = 1399kW
	or
C)	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°C and wet cloth inlet is at 25°C . The stenter is heated by steam at 8 Kg./cm²a and the daily steam consumption for the stenter is 16.5 tonnes. The efficiency of the stenter dryer is 53%. 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 0.53 = 233928.75 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°C

	T_{in} = wet cloth inlet temperature = 25°C 338.4 x (m_i – 0.0638) X [(75 – 25) + 540] = 233928.75 Kcal/hr m_i = 1.235 Kg./Kg. bone dry cloth(1.235) / (1.235+1)x100 % inlet moisture in wet cloth = 55.25 % total moisture in inlet cloth = 1.235x338.4= 417.924 kg/hr feed rate(inlet cloth rate), = total inlet moisture/hr +bone dry cloth/hr = 417.92+338.4 = 756.32 Kg./hr.
	or
D)	The following data are given for a commercial building. Outdoor conditions : DBT = 37°C, WBT = 26.5°C, Humidity = 17.5 g of water / kg of dry air Desired indoor conditions : DBT = 24°C, RH = 55 %, Humidity = 10.2 g of water / kg of dry air Total area of wall = 320 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 aluminum frames and a thermal break] = 3.56 W/m^2K Other data: • 15 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 25 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 = 4 m • Supply air dry bulb temperature is 17^0C (i) Determine the building cooling load in TR (ii) Calculate the supply air quantity to the cooling space m^3/s
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 (160) x 12] = 633.6 W (ii) Conduction heat gain through the roof= U – factor x net area of roof x CLTD = 0.323 x (15 x 25) x 44 = 5329.5 W (iii) Conduction heat gain through the windows = U – factor x net area of windows x CLTD = (3.56 x 160 x 7) = 3987.2 W (iv) Solar radiation through glass = Surface area x Shading coefficient x SCL = (160 x 0.74 x 605) = 71632 W **II. Internal Heat Gain** (i) Heat gain from people =Sensible heat gain + Latent heat gain Sensible heat gain = (No. of people x Sensible heat gain / person x CLF) =(25 x 75 x 0.9) = 1687.5 W Latent heat gain = No. of people x Latent heat gain / person = (25 x 55) = 1375 W Therefore, Heat gain from people = (1687.5 + 1375) = 3062.5 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 (15 x 25) = 8062.5 W Therefore, heat gain from lighting = (8062.5 x 1.2 x 0.9) =8707.5 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 375 = 2025 W
Therefore, Heat generated by equipment = 3525 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
= { (15 x 25 x 4) x 0.3 } / 3600
= 0.125 m^3 / s

Therefore, sensible heat gain =1210 x 0.125 x (37 – 24) =1966.25 W

Latent heat gain =3010 x 0.125 x (17.5 – 10.2) =2746.6 W

No.	Space Load Components	Sensible Heat Load (W)	Latent Heat Load (W)
1.	Conduction through exterior wall	633.6	---
2.	Conduction through roof	5329.5	---
3.	Conduction through windows	3987	---
4.	Solar radiation through windows	71632	---
5.	Heat gained from people	1687.5	1375
6.	Heat gained from lighting	8707.5	---
7.	Heat gained from equipment	3075	450
8.	Heat gained by air infiltration	1966.25	2746.6
	Total space cooling load	**97018.35**	**4571.6**
Total Cooling Load = 101589.4 W/ 3516 = 29TR			

(ii) Supply Air Quantity Calculation:

Supply air flow = Sensible heat gain / {1210 * (Room dry bulb temperature – Supply dry bulb temperature)}
= 97018.35 W / {1210 J/m^3K*(24 – 17) ^{0}C}
= 11.45 m^3/s

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